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TEACHER PEDAGOGICAL CONTENT KNOWLEDGE FOR THE TOPIC, BIODIVERSITY: A CASE OF SELECTED MIDLANDS URBAN HIGH SCHOOL TEACHERS

BY

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A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS OF THE BINDURA UNIVERSITY OF SCIENCE EDUCATION, FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN BIOLOGY EDUCATION, FACULTY OF SCIENCE EDUCATION

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ABSTRACT

This study investigated teacher pedagogical content knowledge for the topic, Biodiversity and examined why the teachers exhibit the observed level of pedagogical content knowledge. The introduction of the competency-based curriculum by the Ministry of Primary and Secondary Education in Zimbabwe in 2016 came as a tactical approach to solving an array of both social and economic problems bedevilling the country. Learning should be aimed at acquiring 21st century skills such as critical thinking, creativity, problem solving and innovation among others. Teacher pedagogical content knowledge becomes critical when it comes to the implementation of such a curriculum. This study is located within a framework of teacher pedagogical content knowledge. The hexagonal conceptual framework used in the study draws elements from existing pedagogical content knowledge frameworks. Six key constructs in this model were considered in the study. A qualitative research approach was chosen for this study in which a case study research design was employed. The unit of analysis was the biology teacher's pedagogical content knowledge. Four teacher participants were purposively selected as information rich sources for the phenomenon under study. Data was collected using lesson observations, teacher interviews and learner questionnaires. Content analysis on the topic Biodiversity in the 'A' level Biology competence-based curriculum was used to ascertain the demands of the curriculum. An analytical framework consisting of six constructs from the hexagonal conceptual framework was used to analyse teacher pedagogical content knowledge. The study revealed that the 'A' level Biology curriculum demands context-based teaching of biodiversity and emphasise on the use of constructivist methodologies packaged with learner centred strategies aimed at bringing awareness to the practical application of skills and knowledge in solving societal challenges. The study also revealed that teachers' pedagogical content knowledge varies depending on a consortium of factors. Two of the teacher participants had adequate pedagogical content knowledge whilst the other two had inadequate pedagogical content knowledge. Inadequate pedagogical content knowledge was attributed to a poor teacher identity, non-exposure to workshops, lack of orientation on the demands of the competence-based curriculum, lack of planning, deficiency of motivation and inadequate supervision. The study also revealed the significance of content knowledge in the development of teacher pedagogical content knowledge. The two teachers with inadequate pedagogical content knowledge had inadequate content knowledge. The inadequate pedagogical content knowledge in some teachers was coined as one of the causes of a divide between the intended goals of the competence-based curriculum and what is being implemented in schools. This research led to the design of a model for improving teacher pedagogical content knowledge on Biodiversity. This study recommends the use of the model by 'A' Level Biology teachers. Furthermore, the study recommends education authorities to organise workshops on the demands of the competence-based curriculum, positive teacher identity, content knowledge and pedagogical content knowledge development. There is a need for teachers to shift from traditional instruction to process oriented instruction if skills such as creativity, critical thinking and problem solving are to be imparted to learners. Further research on pedagogical content knowledge of Biology teachers in other topics is strongly recommended.

KEY WORDS

Biodiversity; Pedagogical Content Knowledge; Teacher knowledge: Teaching; Learning

DECLARATION

This is to testify that this thesis is my original work and has been passed through anti-plagiarism systems and was found to be compliant. It has never been submitted to any academic award or qualification.

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CEIT……………………..Nziramasanga Commission of Inquiry into Education and Training

CK……………….……....Content Knowledge

cPCK…………………....Collective PCK

ePCK…………….. …….Enacted PCK

NoS……………….……Nature of Science

PCK……………………Pedagogical Content Knowledge

pPCK………………..….Personal PCK

rPCK……………………Reported PCK.

ZIMASSET……………..Zimbabwe Agenda for Sustainable Socio-economic Transformation

CHAPTER ONE:

SETTING OF THE SCENE

1.0 Introduction

This chapter presents the background of study, statement of the problem, research objectives, and research questions, significance of study, contribution, delimitations, as well as definition of key terms.

1.1 Setting of the scene

In the year 2016, Zimbabwe introduced a competence-based curriculum. This was in response to the clarion call for an improved approach to the country's economic problems. Of significance was the Nziramasanga Commission which advocated for the development of 21st century skills which include problem solving, critical thinking and innovation among others (CIET Report, 1999; Hooker, 2017). The introduction of Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZIMASSET) by Zimbabwe government in the year 2013 further buttressed the need to introduce a competence-based curriculum as it advocated for the development of skills to solve deficiencies of the curriculum (Chitate, 2016). These competences, which align themselves to Zimbabwe's existing national development strategy NDS1, aiming at achieving an upper middle-income society by 2030, were included in the new curriculum of competencies to solve a plethora of developmental challenges.

The competence-based curriculum contains various learning areas which are concerned with the development of a conglomerate of skills. Among these learning areas is Biodiversity, the subject under study. Inclusion of this topic in the curriculum helps solve the current environmental issues faced by Zimbabwe. To this extent, curriculum change was therefore a response to the dynamic needs of society through knowledge advancement (Muzira & Muzira, 2020).

However, the competence-based curriculum requires a high level of teacher Pedagogical Content Knowledge (PCK). PCK is a unique combination of content and pedagogy that enables teachers to capture, portray and share knowledge in ways that are understandable by learners (Shulman, 1986). It comprises integrated knowledge representing teachers' accumulated wisdom with respect to their teaching practice, that is, pedagogy, learners, subject matter, and the curriculum (Chopoo, *et al*., 2014). Such a knowledge domain allows teachers to impart the required skills to learners.

1.2 Background of study

Curriculum implementation is one of the key concerns in the education system (Guerriero, 2014). Educators are concerned with choices made on teaching content and methods. This has seen Zimbabwe introducing a competence-based curriculum in 2016. The competence-based curriculum aims to instil 21st Century skills in learners. These include problem solving, innovation, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity among other skills. Such skills place learners in the job-creator mode and may reduce the unemployment rate in the country. Equipping learners with 21st Century skills also ensure sustainable use and value addition. However, educational reforms typically impose new demands on the already complex and overloaded work of teachers (Ni Shuilleabhain, 2015). Literature suggests that teachers respond to imposed curriculum change by either embracing change, resisting, ignoring the change, or modifying the curriculum, with the latter two often being the norm (Christou *et al*., 2004). Curriculum implementation may be fraught with problems as it may not be done as intended. Often, loopholes are observed which create a gap between the expectations of the designers of the curriculum and what really takes place within the classroom. Confirming this, Mukaro and Stears (2017) observed a non-alignment between the intended 2016 Competency based curriculum and the one being implemented. The scholars cite teachers' misinterpretation of the intended curriculum as one of the causes for lack of alignment. Mavhunga and van der Merwe (2020) noted the divide between theory and practice as an enduring challenge attributed to the disconnection between teacher knowledge and enacting in class. A lot of other criticisms have been made which include inadequate consultations, resource unavailability and lack of textbooks in line with the curriculum, inadequate teacher orientation and capacitation. Teachers' attitudes towards curriculum reform are often negative since teachers can feel that their content knowledge is inadequate, and their teaching experience does not qualify them for this reform.

In the process of developing competent citizens in society, teachers have been seen to play an active role in educational reform (Chopoo, *et al.*, 2013). Azad and Kalam (2013) posited that teachers can create an enlightened human being through building capacities to enquire, innovate, and develop the social value system. The teaching profession has been conceptualised as a clinical practice profession which can be compared to the medical profession (Guerriero, 2014). This implies that decision making is a basic teaching skill, where decisions are regularly made by the teacher while processing cognitive complex information about the learner to decide on alternatives for increasing understanding. The role played by teachers in implementing the curriculum and in facilitating the development of students is considered an indicator for success of the economy, society, politics, science and technology development (Nind, 2020). Hence, success of the competence-based curriculum is dependent on the quality of teachers and their co-operation.

Chang *et al*. (2020) posited that without PCK teachers may face challenges in teaching the subject effectively and may teach wrong concepts. According to Shulman (1987), the most useful forms of representation of ideas, most powerful analogue, illustrations, examples, explanations and demonstrations are essential in presenting and formulating the subject making it comprehensible to others. Shulman concludes that teacher pedagogical content knowledge

(PCK) is made up of attributes that a teacher possesses that guides student towards understanding the specific content. As such, Shulman (1987) proposed PCK to reduce teacher misconceptions.

Chang *et al.* (2020) highlighted that teaching should not only contain the teachers' dexterous demonstration of his knowledge but also the ability to guide the students to understand the content meaningfully. Teachers should be knowledgeable not only about the learners' prior knowledge and use of instructional strategies but also the challenges and needs of the learners in social, emotional, and academic contexts (Aydin, 2012). Issues have been raised on the content and pedagogical content knowledge of teachers. Teacher pedagogical content knowledge (PCK) is a special combination of content and pedagogy that is uniquely constructed by teachers and can be seen as the "special" form of a teacher's professional knowledge and understanding. PCK is intensely rooted in a teacher's everyday work. It encompasses both theories learned during teacher preparation as well as experiences gained from ongoing schooling activities. The development of PCK is influenced by factors related to the teacher's personal background and by the context in which he or she works. When teaching subject matter, teachers' actions are determined to a large extent by the depth of their PCK, making this an essential component in teaching and learning. At the heart of effective content teaching is the teachers' pedagogical content knowledge. If the quality of teaching and learning in Biology is to be improved, teachers' PCK need to be evaluated and improved.

1.3 Statement of the problem

Zimbabwe is faced with high levels of ecosystem depletion. This phenomenon has seriously contributed to biodiversity losses. This relates to loss in the processes which support life on earth, humans included. The lack of variety of animals and plants results in shortage of oxygen, clean water and food. Ecosystem functions are supported by a viable ecosystem that contains a vibrant biodiversity. Depletion of ecosystems has been attributed to clearing of the land for firewood, agriculture, settlement, mining and veld fires among others. In the advent of Zimbabwe's Vision 2030 and the realisation of demands of National Development Strategy Number 1 (NDS1) (which strives to achieve an upper middle-income society by 2030), the implementation of education 5.0 becomes a vital tool in solving this challenge.

The teaching of 'Biodiversity' in the most effective way can be a game changer with respect to biodiversity losses, hence significantly contributing to sustainable development of the country's economy. Whilst the understanding of biodiversity among learners may significantly lead to the necessitated maintenance of biodiversity, there seems to be no evidence of such behavioural changes among the learners currently learning Biology in schools. The introduction of the competence-based curriculum by the Ministry of Primary and Secondary Education in 2016 that aimed to impart 21st century skills to learners should be seen to be a stepping stone towards the critical environmental awareness, especially when it comes to the maintenance of biodiversity. Even though the curriculum has purposely included such an important topic to be taught in schools, teachers seem not to manage the teaching of the topic in order to bring the expected impact on learners. There seems to be a mismatch between teachers' pedagogical content knowledge on the teaching of the topic biodiversity and the current demands of the competence-based curriculum. Literature spells out the critical role of teacher's pedagogical content knowledge in achieving students' behavioural change. Teachers with a high degree of PCK tend to achieve the intended goals of the curriculum. Biology teachers seem to lack this PCK on biodiversity. It is against this background that the research intended to interrogate teachers' levels of PCK on biodiversity to address this acute environmental issue.

1.4 Aim

Evaluate the 'A' Level Midlands urban Biology teachers' PCK in Biodiversity in the competence-based curriculum.

1.6 Significance of study

This study may encourage the teaching of the topic ‘Biodiversity’ in the best comprehensible manner that promotes learner understanding. Effective teachers have the capacity to help students construct knowledge through tactful blending of content and pedagogy. Such teachers may effectively engage students in a way that prepares the students to apply scientific principles and processes in decision making and in understanding the nature of the world. Hence, learners may venture into various professions that require the knowledge of biodiversity and use knowledge of biodiversity in sustainable use, conservation, and value addition.

Lifelong learning about biodiversity may promotes sustainable use, conservation of ecosystems and, consequently, poverty eradication. This may improve the quality of life in communities. At present, biodiversity is declining rapidly due to human activities, and the loss of biodiversity and deteriorating ecosystem services contribute to worsening human health, higher food insecurity, increasing ecosystems’ vulnerability to natural disasters, and lower material wealth. Hence, this study may help in producing problem solving and innovative citizens that may help restore our ecosystems and consequently improve food security and reduce vulnerability to natural disasters.

Effective teaching of the topic, ‘Biodiversity’ may lead to conservation and sustainable use. This may improve the quality of ecosystems and promote tourism. An increase in tourism may contribute to the national purse and accelerate achievement of the country’s vision of attaining a middle-income economy by 2030.

This study seeks to guide stakeholders on measures that may be put in place to improve teacher PCK, improve understanding of biology learners, and achieve the goals of the competence-based curriculum.

1.5 Research Questions

The study sought to answer the following research questions:

1. What does the ‘A’ level Biology Curriculum demand of the topic biodiversity?
2. How do ‘A’ Level Biology teachers teach the topic, ‘Biodiversity’?
3. Why do ‘A’ Level Biology teachers teach the topic, ‘Biodiversity’ in the way they do?
4. What instructional model can be used to improve teacher PCK in Biodiversity?

1.7 Contribution

The outcome of this research led to the design of a PCK model encompassing critical issues in the teaching of Biodiversity. Fig 6.1 shows the designed model for PCK for the topic, ‘Biodiversity’.

1.8 Delimitations

This study was focussed on studying teacher pedagogical content knowledge in only one topic in the Advanced level Biology curriculum. The selected topic of study was Biodiversity. The study was confined to Midlands Urban High schools only. Selected students for the study where A-Level Biology Students.

1.9 Limitations

The study could have involved an analysis of all ‘A’ Level biology teachers’ PCK in the whole curriculum but the researcher chose to confine the study to teachers chosen from the Midlands urban of Zimbabwe. This was due to the limited time and resources available to the researcher. However, an in-depth qualitative study of teacher PCK guaranteed the trustworthiness of the research. The use of various triangulation methods ensured that the results of the study remained credible.

1.10 Definition of Terms

This section defines terms or concepts used throughout the study and gives contextual information on how these concepts were used in this study.

Pedagogical content knowledge (PCK) is a unique fusion of content and pedagogy to teach different topics in a graspable manner to learners.

Twenty-first century skills are a broad set of knowledge, skills, work habits, and character traits that are critically important to success in today's world (Windschitl, 2009). The twelve 21st century skills are critical thinking, creativity, collaboration, communication, information literacy, media literacy, technology literacy, flexibility, leadership, initiative, productivity, and social skills. These skills are intended to help students keep up with the fast-changing nature of today's society and modern markets.

Biodiversity refers to the variety of life forms on earth. It is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

1.11 Chapter Summary

This chapter has underscored the need for research on Biology teacher PCK and has outlined the major elements of the research. The research gap has been situated in the background of study, problem statement as well as the significance of the study. The objectives and research questions have been outlined. It cannot escape notice that this study like any other has its delimitations and these have been elucidated in this chapter. The key words were defined so as to lay a concrete basis for this study.

1.12 Organisation of the study

This study consists of the following six chapters:

Chapter 1: Introduction

The introduction presents the background of the study, the problem statement, the significance of study, the objectives, and the research questions. Furthermore, the chapter gives the delimitations and limitations of the study, contribution and the definition of key terms.

Chapter 2: Literature Review

To determine what is known and unknown about the research questions posed, Chapter 2 examines literature. A knowledge gap was determined that the current research filled.

Chapter 3: Theoretical and Conceptual framework

This chapter presents the theoretical and conceptual frameworks. These guided the path of the research and grounded it firmly in theoretical constructs. The theoretical framework guides the study to prevent deviation from the accepted theories. The conceptual framework describes the main concepts of the study and provides a visual display of how ideas relate to one another.

Chapter 4: Methodology

Chapter 4 discusses the research paradigm, research design, population, sample, and sampling techniques. A full discussion of the instruments and data collection procedures is given. The chapter also presents an Analytical framework adopted for the study. Considerations made to ensure credibility, dependability, conformability, and ethical issues are considered and discussed in this chapter.

Chapter 5: Data presentation, analysis, and discussion

Data collected is presented, analysed and discussed in Chapter 5.

Chapter 6: Conclusions and Recommendations

This chapter presents conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This study is on Pedagogical Content Knowledge for ‘A’ level Biology teachers in Zimbabwe and intends to explain how it influences the teaching and learning of the topic, Biodiversity in the ‘A’ level biology competence-based curriculum. For this reason, it is necessary to review both classical and contemporary scholarly and theoretical contributions related to this study. This chapter therefore discusses literature on PCK and the teaching of the topic on Biodiversity in schools; however, to advance understanding of teacher PCK in the teaching of science, various definitions ascribed to curriculum, the science curriculum and the nature of science will be discussed.

2.2 Curriculum

The word curriculum is derived from a Latin word, ‘currere’ which means to run. Thus, curriculum means a course to be ‘run’ by a student for achieving the aims and objectives of education. It can be equated to a tool in the hands of an artist to mould his material according to his studio, where the artist refers to the teacher while the materials are the students (Yang & Li, 2022). Hence, a curriculum is a tool used by teachers to mould desired competences in learners. Young (2018) viewed a curriculum as a structure that contains not only the activities of those involved, primarily teachers and students, but also sets a limit on what is possible to learn in a school or any other educational institution. It is designed for a particular purpose which, in this case is not only transmission of knowledge from generation to generation, but also imparting 21st century skills to learners.

Tirivangana (2019) highlighted that a curriculum is composed of all experiences children have under the guidance of a teacher. These include experiences that students obtain in classes, workshops, playgrounds, and interactions with teachers. In this way, the curriculum focuses on all facets of a learner's life during their school years, resulting in a unified personality or a wholesome being (Silver, 2022). According to Taylor (2018), a curriculum is the collection of learning opportunities that a school plans and directs to achieve its educational objectives. Tirivangana (2019) defined curriculum as a set of skills, concepts, and processes that students are expected to learn from kindergarten to university. As a result, a curriculum is a plan for guiding learning in schools that is described in searchable documents. It entails a pre-planned, standard-based sequence of activities in which students practice and master material and apply learning skills (Guerrero & Torres-Olave, 2022). It serves as a comprehensive guide for all educators on what is required for effective teaching and learning to provide every student with a rigorous academic experience (Yang & Li, 2022).

The curriculum outlines the objectives, strategies, and tests that should be used to best promote teaching and learning (Null, 2023). The standards-based scales or opportunities for teaching and learning are the curriculum's goals. A curriculum's goals must be clear in the form of a sequence of skills to be addressed, as well as the scope and depth of knowledge required of a student (Yang & Li, 2022).

A curriculum consists of suggested strategies and materials that can be used to achieve its goals (Usmanova, 2023). Methods in a curriculum include instructional decisions, techniques, practices, and routines used by teachers to involve all students in meaningful learning (Supriani *et al*., 2022). These options aid in facilitating learning, enhancing the learners' ability to comprehend and apply content and skills. Differentiated methods are used to address the needs and interests of students. Methods may be modified based on assessments of learners' progress against their objectives (Wand *et al*., 2021).

Curriculum materials are chosen instruments for implementing strategies and achieving the curriculum's objectives (Usmanova, 2023). They are carefully selected to aid student learning (Ellahi *et al.*, 2019). Material selection should consider students' interests, cultural diversity, global perspectives, and all types of learners (Ellahi *et al.*, 2019). Finally, evaluation of a curriculum is an on-going method of collecting information from students about their learning success (Yang & Li, 2022). This provides several methods for demonstrating what the student learns, understands, and can do with their experience and abilities. Assessment data is used to make decisions about instructional strategies, teaching resources, and academic support required to improve learning opportunities for students (Campbell-Phillips, 2020).

Muzira and Bondai (2020) noted four forms of the curriculum. These are tested curriculum, taught curriculum, hidden curriculum, and learned curriculum. A tested curriculum is represented in the state test, school system exam, and teacher-made test, according to Riddel in Muzira and Muzira (2020). This curriculum appears to have the biggest influence on the curriculum being offered because so much time is spent training and preparing students to master the art of answering exam questions. However, the competence-based curriculum and Education 5.0 are in opposition to this curriculum since it places more emphasis on grades than on applying what has been learnt.

The taught curriculum is the curriculum that the teacher delivers. It is the curriculum that is operationalized in the classroom as the teacher adjusts according to the actual situation (Muzira & Muzira, 2020). As a result, what is learnt in class is put into practice by the students, fostering critical thinking in them and preventing them from simply becoming reflectors of other people's ideas (Ellahi *et al.*, 2019).

When students interact with their teachers and fellow students, they are also learning a hidden curriculum (Calarco, 2020). Teachers should set a good example for their students because they influence how much of what they learn from what they do. Therefore, a hidden curriculum should be carefully considered because it has the power to either strengthen or weaken students (Hogdal *et al*., 2021).

The learned curriculum is the most important of all (Fensham, 2022) because it is what students learn. Due to their varied experiences and interests, students cannot always learn what is taught, and this can result in a significant mismatch between what is taught and what is learnt. Students will never be able to learn everything there is to know because learning is described as a continual process (Chang & Kidman, 2019).

2.3 Science Curriculum

A science curriculum is designed to assist children in developing fundamental scientific concepts and comprehending biological and physical aspects of the universe. It is also the means through which they acquire knowledge and understanding (Guerrero & Torres-Olave, 2022). Its goal is to instil positive attitudes toward science and to inspire students to investigate and understand how science and technology impact their lives (Yeh *et al.,* 2019). The science curriculum is additionally created to give students the abilities to work scientifically as well as to build and create artefacts (Mork *et al*., 2022). The value of children starting with their own ideas and learning through interactions with things and resources as well as their classmates is emphasised in the science curriculum (constructivist and collaborative approaches). As a result, students may "develop" new knowledge and "invent" new concepts (DeBoer, 2019). Scientific labour entails making observations and formulating hypotheses, making predictions, planning and carrying out experiments with an emphasis on ethical research, documenting and assessing results, sharing and debating observations, and adapting one's perspective to consider new information (Yeh *et al*., 2019). Researching and analysing common artefacts is a necessary step in designing and developing to come up with workable answers to issues. It also necessitates exploration.

2.4 The Nature of Science

The Nature of Science (NoS) is a critical component of scientific literacy that stimulates learner understanding of science concepts and enables them to make informed decisions about scientifically based personal and societal issues. Research indicates that science teachers must understand the nature of science to teach it (Yuenyong & Thao-Do, 2020). It is difficult for experts to define as it is for students to learn. The Nature of Science reflects a wide range of issues relating to an interpretation of the laws of the game of science, as well as its tools as they relate to educational environments, products, and approaches (Oh & Lee, 2023). It entails a comprehension of science as a method of knowing. It is a foundation for learners' understanding of how science is conducted, and Nature of Science components should be included in school science programs. This helps learners develop accurate views of what science is, the types of problems science can provide solutions to, how science differs from other disciplines, and the strengths and limitations of scientific knowledge (Bell, 2008). This encourages learners to participate in experimental activities and move from merely learning about science to practising and knowing it. The Nature of Science is required to make sense of science and technology artefacts and processes in daily life (Ducarme & Couvet, 2020). In the teaching and learning of Biodiversity, this can ensure that teaching and learning activities encourage conservation of biodiversity and natural resources. The Nature of Science stimulates individuals to make informed decisions on socio-economic issues, enables individuals to understand the importance of science as a part of contemporary culture, and aids in the development of an interpretation of scientific community norms that represent moral commitments of societal importance. Scientific learning Nature of Science makes science's subject matter easier to understand.

Elements of the Nature of Science

The Nature of Science is tentative**.** Scientific knowledge is neither static nor conclusive, despite being accurate and enduring. Rather, it is subject to change when new data or interpretations of existing evidence become available (Akerson *et al.*, 2019). Scientific knowledge is neither fixed nor perfect. Rather, it is open to revision in light of new evidence or new interpretations of existing evidence. There is no "absolute truth" in science because of its tentative nature. Since scientific knowledge is inherently uncertain, laws and theories are subject to change. By emphasising the tentative nature of science, teachers inspire learners to approach scientific inquiry with curiosity, open mindedness to revise their understanding based on new evidence and insights.

Science is empirical in nature (Mizrahi, 2021). Science's empirical nature indicates that it is founded on and generated from observations of the world around us, from which interpretations are created. To generate scientific knowledge, scientists rely on empirical evidence. Any scientific explanation must be consistent with empirical evidence, and new evidence allows the revision of scientific knowledge (Gathong & Chamrat, 2019). As such, during the teaching and learning of science, learner activities that promote observations and making inferences are recommended. The empirical nature of science is critical in science teaching and learning as it emphasises the use evidence-based reasoning and experimentation to understand the natural world. Such an approach helps learners develop critical thinking skills, learn how to analyse data and make informed decisions based on evidence. Empirical nature of science helps learners understand that scientific knowledge is constantly evolving and subject to change as new evidence is discovered. Emphasising empirical nature of science in teaching and learning promotes scientific literacy and encourages students to become informed and engaged citizens.

Studying science requires a high sense of imagination and creativity (Tome *et al*., 2019). Observations describe what is seen while inferences are statements made about observed phenomena from conjecture (Mizrahi, 2021). This challenges the misconception that there is one universal way to do science, commonly referred to as 'the scientific method' (Ducarme & Couvet, 2020). All observations require interpretation and inference by scientists. To do this, scientists require imagination and creativity to make inferential statements about what they see. In fact, imagination and creativity are needed in every aspect of a scientist's work to making sense of observations, making the creative leap from data to possible explanation, coming up with new ideas, designing investigations and looking at old data in a new light (Tome *et al*., 2019). In the teaching and learning of science activities that stimulate high sense of imagination and creativity are commended. Teaching for understanding is critical as it prepares learners for further learning and make them more imaginative, creative, effective, useful and relevant in their communities.

Science is theory and subjective-laden. This describes the numerous ways in which different scientists view the same data sets. Without the observer's prejudice, it is impossible to make fully objective assumptions and interpretations (Mizrahi, 2021). Individual scientists have their prior knowledge, theoretical beliefs, experiences, cultural background, training, expectations and biases, each of which will affect their observations and conclusions (Ducarme & Couvet, 2020). All observation is preceded by theory and conceptual knowledge. Science tries to overcome this lack of pure objectivity through the scientific community, which scrutinises scientific work and helps balance individual scientists' leanings (Bell & Ladderman, 2003).

Scientific awareness is created as part of a broader social and cultural context (Toma *et al*., 2019). Politics, economy, power structures, religion, and philosophy are all social and cultural elements that influence the knowledge generated (Mizrahi, 2021). Social constructivist view science knowledge as a personal and social construction that takes place within a social and cultural environment. (Stears, 2009). Teacher knowledge and understanding of the culturally conditioned knowledge learners bring to class can facilitate effective learning (Mavuru, 2016). It has also been noted that failure can be attributed to discontinuities between culture and school (Heath, 1983). Therefore, both the context in which learning occurs and the learning experiences that learners bring to their learning environment are crucial.

2.5 Curriculum Change and Impact on Teaching and Learning

Human life is subject to transition (Mondal & Das, 2021). Awareness is expanding and culture is evolving because of scientific and technological advancements. As a result, the curriculum should be adjusted accordingly. One of the most significant characteristics of a curriculum is that it is flexible (Law, 2022). For teachers and their classes, curriculum reform is a learning experience. For better implementation of the competence-based curriculum, a clear understanding of change and a clear conception of the curriculum are needed (Hicks *et al*., 2022). Policymakers, educators, and teachers; all need to understand the factors that influence effective curriculum change in schools (Anuradha & Techer, 2023).

Curriculum change refers to altering the curriculum in some way to give it a new position or direction (Mondal & Das, 2021). This usually entails changing its ideology, such as its goals and priorities, updating the material, revising its processes, and rethinking its evaluation procedures. Curriculum change was described by Hancock *et al*. (2012) as the transformation of curriculum schemes, such as their design, objectives, and content. Curriculum reform, according to Dziwa *et al*. (2013) entails shifting attitudes, beliefs, skills, and relationships rather than simply providing relevant technical knowledge. As a result, curriculum change can be described as the creation, refinement, and renewal of a curriculum to meet the needs of a changing society, as well as changing awareness of learners.

Curriculum reform implementers must contribute to the changes in the curriculum (Muzira & Muzira, 2020). Teachers, as curriculum implementers and evaluators, must have a meaningful role in decisions during curriculum change. One of the keys to a successful curriculum shift is teacher involvement. This can be done through workshops on curriculum changes to help them understand the new curriculum, as well as discussions on the conditions that must be met to adopt and maintain the curriculum (Hancock *et al*., 2012). Hence, certain conditions must be met if implementers are to support and effectively implement change. Ornstin &Hunkins (2010) highlighted that the educators' attitudes to the change initiative could yield positive or negative results. Implementers should see the need for change, understand the purpose for change and what change involves for them to support it.

Many countries are undergoing curriculum reform because of their education systems which are failing to meet the demands of their economies (Muzira & Muzira, 2020). The competency-based curriculum was implemented in the United States of America, and it was thought that the technique would increase the efficacy of classrooms, students, and educators, as well as resolve society's concern about unsatisfactory results in the creation of teacher education programs (Leeds, 2017). In 1998, South Africa implemented a competency-based curriculum in response to a severe shortage of engineers, technicians, and artisans in industry and trade (Leeds, 2017). South Africa embraced the competency-based program, in an effort to transform people's perceptions and provide them with employable skills to deal with the challenges of the twenty-first century. The competency-based curriculum was introduced in Rwanda in April 2015 (REB, 2015). Less academic, more realistic, more skills-based, and more orientation to a working environment and everyday life were needed by the updated Rwanda curriculum. The competence-based curriculum was implemented in Zimbabwe in 2016 in response to the difficulties that the education system was facing as a result of technological advancements, and the material in the curriculum which was no longer sufficient to accommodate the changes that had occurred in society (Ministry of Primary and Secondary Education [MOPSE], 2016)

For several teachers, implementing innovations necessitates familiarity with modern curriculum topics as well as the ability to teach in novel ways. Many seasoned teachers, on the other hand, are resistant to the changes (De Jong, 2016). This emphasises the importance of designing new in-service courses that concentrate on ensuring that teachers' PCK is appropriately changed (De Jong, 2016). Such workshops would try to close the distance between theory and reality. Following the workshops, teacher networks must be developed in order to expand opportunities for teachers to share new teaching experiences and boost their confidence (De Jong, 2016). To encourage teachers to become co-owners, there is a growing need to recognize them as professionals with unique expertise (Bentrovato & Dzikanyanga, 2022. Teachers must be recognized as practitioners with specialised experience for them to be encouraged to become co-owners of inventions (De Jong, 2016). Teacher PCK can be improved through PCK courses, interaction with collaborating teachers, teaching experience, and reflection, as Evens *et al*. (2015) noted. Gonzalez-Gomez (2020) found that after an intervention training program, awareness of the curriculum and teaching methods increased, highlighting the importance of PCK courses.

Teachers in Mathura (2019) are enthusiastic about curriculum reform and see it as an on-going phase aimed at enhancing the curriculum and improving student learning. However, a variety of factors, such as a lack of professional development and funding limit their efforts. Teachers are expected to introduce curriculum reform and innovation crafted by external agents who may or may not be familiar with the teachers' experiences and views, or even the classroom context in which the innovation is to be applied, (Mathura, 2019). Not taking teachers' experiences and viewpoints into account could further complicate the often-complicated nature of implementation of something new.

According to Mathura (2019), the aims are commendable, and the curricula are generally well-established, but policymakers' attention and efforts are primarily directed toward the "what" rather than the "how" of the desired educational development. Several other scholars have established their own findings (Ngwenya, 2019; Madondo, 2020; Gory *et al*., 2021). For example, Madondo (2020) observed that teachers in Zimbabwe lack adequate support in terms of proper infrastructure, and schools lack human, financial, and material resources for effective curriculum implementation. Gory *et al*. (2021) identified infrastructure, implementation, teacher capability, and economic challenges as major obstacles to Zimbabwean educational reform. Madondo (2020) suggested that teachers, parents, and students' interests be included in instructional preparation and implementation. According to Ngwenya (2019), attempts to improve teachers have been made through numerous capacity building workshops whose facilitators were not proactive. It is worth noting that, despite the difficulties, the teachers in Zimbabwe have adopted the competence-based curriculum. Teachers regard it as competency-based and self-empowering because students gain entrepreneurial skills.

To ensure the effectiveness of the implementation of the competence-based curriculum, Ngwenya (2019) proposed a collaborative approach to resource mobilisation. Tshiredo (2013) observed that teachers, especially those who did not receive training on the competence-based curriculum changes during their tertiary education, believe it is unnecessary for them to change the way they teach (Jenkins, 2020). Ngwenga (2019) noted that in Zimbabwe, most schools are under-resourced and shortage of funding has a detrimental effect on the implementation of curriculum change in science teaching and learning. Inadequate resources and a lack of human capital make it difficult for subject advisors to provide relevant support. According to the findings of Thiredo (2013), insufficient resources, lack of expertise and awareness, as well as a lack of preparation for new curriculum growth, have a negative impact on science teaching and learning in schools. As a result, Tshiredo (2013) suggested that the proposed curriculum creation and improvement be piloted before being adopted as proposed in the model for successful science curriculum changes and development. At the school, circuit, and district levels, it is also critical to have functional curriculum support forums (Ngwenya, 2019). Science centres with well-equipped laboratories would play a bigger role in successful science teaching and learning in schools if they are built in every circuit (Ramani *et al*., 2019). During a program transition, teachers' self-efficacy levels usually tumble (Jenkins, 2020). The lack of teacher participation in the process, the hurried nature of the transition, the lack of aligned textbooks to support the new curriculum, and the perceived lack of opportunities to improve student mastery of the standards given the compressed instructional timelines; all contribute to the decrease in teacher efficacy level (Jenkins, 2020).

One of the most significant roadblocks to introducing the new curriculum is a lack of sufficient infrastructure (Jenkins, 2020). In the implementation of any curriculum, infrastructure is critical. It is not possible to undertake an ICT curriculum, for example, if there is no ICT infrastructure. Secondly, teachers oversee the implementation of the program (Ramani *et al*., 2019). They must be prepared to incorporate new material into the curriculum. Now, not much was done to in-service teachers. As a result, teacher preparation for the new program becomes a challenge. The third challenge in implementing curriculum change concerns attitudinal issues (Akala, 2021). Negative attitudes toward curriculum reform are a major issue. People tend to be attached to old ways and find it difficult to transition. Finally, the primary impediment to curriculum reform is a financial one (Akala, 2021). Money is needed at any stage of the new curriculum's implementation.

2.6 The Zimbabwe Competence Based Curriculum

A competency-based curriculum is one that focuses on what learners are expected to perform rather than just what they are expected to know (MOPSE, 2016). It can be seen as a system of instruction, assessment, feedback, self-reflection and academic reporting that is based on learners demonstrating that they have learnt the knowledge, attitudes, motivations, self-perceptions and skills expected of them (Ali *et al*., 2023). Such a curriculum is learner-centred and adaptable to learners', educators', and society's evolving needs. The curriculum stresses the multifaceted results of a learning process (i.e., learner-applicable knowledge, abilities, and attitudes) rather than focusing just on what learners are supposed to acquire in terms of traditionally defined topic content (Jan, 2022). It indicates that learning activities and surroundings are chosen so that learners may acquire and apply knowledge, skills, and attitudes to real-life circumstances (Jan, 2022).

The previous curriculum in Zimbabwe was developed during the colonial era and was primarily intellectual in character with little practical application. It was exam-focused and encouraged rote learning and cramming. The outdated curriculum limited students' options in terms of career pathways, and most students who were deemed failures at the "O" Level would depart the educational system without displaying any distinguishable ability or competency (MOPSE, 2016). It also did not address the needs of business or larger socioeconomic change.

Zimbabwe then developed a competency-based curriculum in which learning is focused on application. Emphasis is placed on the learners' ability to apply knowledge, skills, and attitudes that will enable them to be productive community members. The competence-based curriculum lay the groundwork for a human capital that will boost national productivity and innovation across the board, particularly in agriculture and mining, resulting in increased growth in associated industries and manufacturing. It places strong emphasis on STEM, information technology, innovation, financial literacy, and entrepreneurship, as well as patriotism and pride in one's country (MOPSE, 2016). The skills enforced by the competence-based curriculum include problem solving, critical thinking, leadership skills, communication skills, technological skills, enterprise skills, self-management skills, innovation, and lifelong and continuous learning (MOPSE, 2018).

The competence-based curriculum promotes a learner-centred approach to teaching and learning, in which learning revolves around learners as they search for and find new information (Jan, 2022). In the process of knowledge discovery, the teacher functions as a co-explorer and facilitator. The learner must demonstrate not only content understanding, but also skills and competences. Schools must evolve from simple structures to nerve centres that connect teachers, learners, and communities (MOPSE, 2018)

2.7 Education 5.0

Zimbabwe's higher education system has been overhauled to align with the country's urgent goal of achieving an upper middle-income society by 2030. This has seen the introduction of Education 5.0 in 2018 (Togo & Gandidzanwa, 2021). Education 5.0 is a student centric approach to learning that emphasises critical thinking, problem solving and collaboration skills (Muzira & Bondai, 2020). The goal of education 5.0 is to create a learning environment that prepares students for the rapidly changing demands of the global economy and challenges of the modern world. The pillars for Education 5.0 are teaching, community service, research, innovation, and industrialization. The focus is on problem solving to add value. According to Tagwira (2018), Zimbabwe relies on its intelligentsia, which includes scholars, innovators, scientists, and the rest of academia to provide solutions to the multifaceted problems that society faces and to enhance citizens' quality of life (Chirume, 2020). Education 5.0 involves providing students with the skills they need to become more creative in their approach to social growth through the application of transformative science and technology to deliver goods and services. According to Muzira and Bondai (2020), such a curriculum reform transfers students' focus from white- and blue-collar jobs to engaging themselves as job creators, which would help to alleviate the country's unemployment issue. With education 5.0, the educational system must engage and cultivate job creators and providers of industrial solutions (Chirume, 2020). Critical thinking, imaginative thinking, innovativeness, an entrepreneurial mentality, and technical know-how are some of the skills needed to provide national economy-impacting industrial solutions (Jayanthi *et al*., 2020). Nurturing a job creator mentality necessitates close collaboration with the community to recognize economic opportunities, not just to educate, but also to leverage those opportunities for small businesses and eventually companies that contribute to the national purse and the lowering of the unemployment rate (Ministry of Higher and Tertiary Education, Science and Technology Development [MHTESTD], 2018). The industrial solutions provider mode enables the educational system to reach out to businesses in their neighbourhood, hear about their challenges, and seek out solutions for them (Ministry of Higher and Tertiary Education, Science and Technology Development, 2018). By combining the two forms, the unemployment rate and societal problems may be reduced while industry efficiency is increased.

Learners' desired competencies are developed through a competency-based curriculum and Education 5.0 encourages learners to apply their gained competences to solve social challenges and contribute to the nation's economic growth (Muzira & Bondai, 2020). The competence-based curriculum's tasks and projects are designed to help students improve their study skills, creativity, and critical thinking (Jayanthi *et al*., 2020). It is without doubt that with proper implementation of the competence-based curriculum and Education 5.0, the country will attain a middle-income economy by 2030.

2.8 Importance of Curriculum Change

The competence-based curriculum and education 5.0 programs aspire to generate citizens who are both educated for life and responsible enough to contribute to societal harmony and higher living standards (Muzira & Muzira, 2020). Curriculum change is therefore responding to the dynamic needs of society and allows for knowledge advancement (Muleya, 2020). The state of knowledge is continually evolving (Patekur *et al*., 2022). A lot of theories are being found now that have not been recognized previously. This new knowledge should be made familiar to the students. As a result of this increase in knowledge, a shift in the curriculum is needed (Muleya, 2020).

Technology is developing in tandem with expertise (Erstad *et al*., 2021). The use of different methods in teaching and learning have changed the field of education, for example use of ICT. As a result, the curriculum should be adjusted accordingly. Learners' needs, desires, and abilities are also evolving. (Patekur *et al*., 2022). There is a significant contrast between the needs of students in the twenty-first century and those of previous generations. Likewise, their interests and abilities have evolved. It is now mandatory to have a working knowledge of computers. As a result, knowledge of ICT has become a requirement in the curriculum, which was not so important before.

Curriculum change allows for the reconstruction of the program considering current teaching methods (Jenkins, 2020). Now, the teaching approach is focused on the learner. Collaborative learning, spaced learning, flipped classroom, self-learning and other innovative teaching approaches are currently being used. The curriculum is being adjusted to accommodate these teaching approaches. Globalisation is the interaction and convergence between individuals, businesses, and governments all over the world (Ramsey, 2012). This provides an opportunity to observe how the program is taught in various countries (Muleya, 2020). Then, one can compare them based on what they are looking for. These comparisons allow for more efficiency. The curriculum can always be modified in this way since curriculum research is on-going. Curriculum research is conducted to develop the curriculum. Many new outcomes are being discovered because of research. These study findings result in a re-designing of the curriculum.

2.9 The Role of Teachers in Curriculum Implementation

Teachers are social reformers. They play a critical role in society's progression and take on the task of adapting the curriculum to the evolving needs of the society in various ways (Suncar *et al*., 2021). A teacher ensures that the subject is included in the curriculum considering societal needs and requirements. It is the role of the teacher to understand their students as they are guardians of their students. They are aware of the desires, skills, and attitudes of their students. Students engage directly with the teacher during the teaching-learning period. Teachers communicate with the students via the curriculum. Consequently, teachers play a critical role in developing the curriculum to meet the needs of the students (Tondeur *et al*., 2019).

Teachers are the curriculum implementers (Herodotou *et al*., 2019). The curriculum should be applied after its revision. It is pointless to change the curriculum if it is not to be enforced. The teacher oversees implementation of the program. In this way, he contributes to curriculum reform. Teachers play a critical role in curriculum evaluation. The curriculum is assessed to determine if there are any existing mistakes or gaps. This is how it is determined whether the program should be altered or not. The teacher oversees curriculum evaluation (Tondeur *et al*., 2019).

2.10 Teacher Identity

Miller (2009) viewed teacher identity as influencing teachers regarding how individuals see themselves, and how they enact their profession in their settings. Miller highlighted that identity is continuously co-constructed in situ, using resources, interactional skills, knowledge, attitudes, and social capital. Teachers use a variety of resources to negotiate and build their professional identities in social and institutional contexts (Noonan, 2019). Negotiation of teacher professional identity is influenced by contextual factors outside of the teachers themselves and their pre-service education courses. These include workplace conditions, curriculum policy, social demographics of school and students, institutional practices, curriculum, teaching resources, and access to professional development (Izadinia, 2013). Teacher identity refers to beliefs, values, and commitments an individual teacher holds towards being a teacher. Teacher identity can be seen as what teachers know and do which is continuously transformed through interaction in the classroom. Beauchamp and Thomas (2009) pointed out that student teachers undergo a shift in identity as they move through programs of teacher education and assume positions as teachers in todays' challenging school contexts. A further identity shift may occur throughout a teacher's career as a result of interactions within schools and the broader community.

Supporting science teacher identity is one way to deal with issues like low self-efficacy, self-confidence, and pedagogical material awareness (Izadinia, 2013). Teachers build their identities as science teachers and deepen their understanding of social justice problems in science through meaningful teaching experiences in teaching placements. Learning to teach takes place in the context of social interaction in a teaching culture, where meaning-making and teacher roles are negotiated in and through practice (Carpenter *et al*., 2019). When a teacher engages in teaching activities, his or her modes of engagement, ways of seeing teaching, ways of seeing himself or herself, and ways of being seen in the teaching group alter and turn, resulting in a shift in identity. As a result, teaching entails a process of personal transformation, or identity change into a specific type of teacher.

While scholars identify and quantify teacher identities in a variety of ways (Izadinia, 2013), a growing body of evidence indicates there are at least three key characteristics. First, identities are complex mechanisms involving experience, perception and reinterpretation. That is, identity is not about who someone is, but rather who they are becoming. Second, it entails a negotiation between the person and a comprehension of the contexts in which he or she works. Lastly, it needs human decision-making. Embracing a professional identity, such as that of a teacher, necessitates experiences in which one has some control and discretion over one's professional activities.

2.11 Twenty First Century Teacher Attributes

Individuals are expected to update and adjust their competencies and keep their expertise current because of the globalisation and 21st century developments such as personalisation and commoditization of technology (Gosper & Ifenthaler, 2014). The evolving world and learners' complex learning needs necessitate a shift in education's current paradigm. A more versatile, learner-centred model is needed, one that, among other things, instils the habit of becoming self-directed lifelong learners. Other fundamental concepts include concentrating on competency-based learning rather than one-size-fits-all content delivery, shifting the position of teachers to learning orchestrators and learners to active learners, as well as shifting the emphasis from lower cognitive levels to higher cognitive levels that encourage creativity and independent problem solving. Fisher *et al*. (2011, p.35) described innovation as "a novel idea put into practice that adds value to customers and society." Teachers are expected to be innovative and to instil innovative skills in learners.

The 21st century teachers can adjust to any situation. In today's world, becoming a teacher requires one to adapt to the ever-changing tools and improvements introduced in schools (Astuti *et al*., 2019). Smart boards are taking the place of chalkboards, and tablets are taking the place of textbooks, and a 21st-century teacher must be able to manipulate and use these during teaching and learning. These teachers not only expect their students to be lifelong learners, but they also expect it of themselves (Austini *et al*., 2019). They keep up with new educational trends and technology, and they know how to modernise their old lesson plans from previous years. A good teacher understands that learning about the latest gadget will completely change their students' education, so they are not only up to date on the latest trends, but also know how to master them (Fisher *et al*., 2011). A successful 21st-century educator must be able to communicate and work well in a group setting. When you can share your ideas and knowledge with others, learning is thought to be more successful. The learning and teaching process requires teachers to share knowledge and experience, as well as communicate with and learn from others. A successful 21st-century educator considers their learners' futures and the job prospects that will emerge because of their studies. Teachers make every effort to ensure that no child is left behind, so they concentrate on educating today's children for the future. They are not only advocates for their learners, but also for their practice.

A 21st-century educator stands up for themselves and their career (Sulaiman & Ismail, 2020). They keep a close eye on what is going on in the classroom and discuss these problems head-on. They also speak out on behalf of their learners. Today's classrooms are brimming with learners who need someone to watch out for them, provide guidance, support, and a sympathetic ear. Effective teachers share their experience and expertise with their students and serve as role models for them (Fisher *et al*., 2011). Teaching in the twenty-first century means using today's resources and technologies to do what teachers have always done. It entails leveraging everything important in today's world for learners to survive and succeed in today's economy, as well as the opportunity to direct and prepare students for the future. In the teaching of Biodiversity, a 21st century teacher is expected to focus on practical work and engage learners so that they can apply the gained competences in their day to day lives (Astuti *et al*., 2019).

Traditional teaching methods are still used in most schools (Zafari & Kamal, 2019). The traditional teacher uses chalk and a chalkboard to demonstrate the subject to students in the traditional teaching style. Every crucial detail about the subject is put on the whiteboard, and students take notes from it. Students go over their notes again after the class and try to memorise them. The primary goal of traditional education is to pass the examination (Astuti *et al*., 2019). However, there is a one-way flow of information; teachers frequently talk incessantly without understanding the pupils' reactions or replies. The information supplied is based only on notes and textbooks. The emphasis in teaching and learning is on the plug-and-play method rather than practical components. There is a lack of interaction between the teacher and the pupils, and greater emphasis on theory rather than practice and real-life situations ((Fisher *et al*., 2011).

Lessons in traditional teaching are teacher-centred, there is mass education (one size fits all), everyone learns at the same rate, and learning takes place only in a classroom setting. However, lessons are student-centred, with mass customisation of instruction to meet individual requirements, flexible pacing based on student capacities, and learning is not constrained to the four walls of the classroom with 21st-century innovative teaching approaches. Whereas in traditional education, students apply a known solution to a problem, in a twenty-first-century lesson students come up with new solutions. Traditional education has little connection between theory and practice, but 21st-century teaching emphasises the integration of theory and practice, critical thinking, and real-world situations (Zafari & Kamal, 2019).

2.12 Constructivist Orientation to Science Teaching

Constructivist perceptions of teaching and learning have had a strong influence on science education during recent years (Fernando & Marikar, 2017). The constructivist perception emphasises on teaching through engaging learners as active participants in learning and supporting them as they make sense of new ideas by reflecting upon their experiences with the phenomenon. Cakir (2008) highlighted that those teachers who aim to model scientific reasoning in an effective fashion need to research and be informed about the constructive nature of students' learning processes, models, and misconceptions. The constructivist view of learning recognizes that learners bring their knowledge of the world and how the world works into the classroom. For learners to make sense of new ideas, they use prior knowledge and experiences as well as first-hand knowledge gained from explorations of phenomena.

Teachers holding a constructivist orientation perceive learners as active participants in learning and teachers as facilitators of learning (Fernando & Marikar, 2017). Through a constructivist lens, learning opportunities are designed to engage learners first in explorations and, second, to construct knowledge from their experiences. The constructivist orientation to science teaching and learning is an active interaction between teachers and learners (Singh & Yadavanshi, 2015). It is through this interaction that learners begin to make sense of their experiences with phenomena. Teachers with a constructivist orientation engage learners in explorations of phenomena prior to introducing and explaining the phenomena to learners. Adak (2017) observed that the constructivist strategy can improve students' mastery of content to higher levels of cognition in his study on the effectiveness of the constructivist approach on academic achievement in science at secondary level. Therefore, application of constructivism in teaching and learning entails active engagement of learners by facilitators (teachers). Learners are not tabula rasa (empty vessels); hence their prior knowledge is of significance for building up new knowledge. A constructivist facilitator creates a learning environment that promotes exploration and discoveries by learners.

2.12.1 Constructivist Instructional Model

Effective learning takes place when learners are active participants in learning, challenged to make and test predictions, and support explanations with evidence (Singh & Yadavansh, 2015). Ideas are best introduced when students see a necessity or a reason for their use and this enables them to see relevant uses of the knowledge to make sense of what they are learning. Science educators have explained learning within the context of three categories: transmission, maturation, and construction (Bybee *et al.*, 2006). The constructivist perspective assumes students to be active participants in learning. In contrast, the transmission perspective assumes students to be empty vessels with the teacher as teller, while the maturation perspective assumes students will open to new knowledge as they mature (Bybee *et al.*, 2006). Effective instructional sequence follows the scientific process and provides students with an opportunity to formulate and test hypotheses (Rodriguez & Harron, 2019). Rodriguez and Harron (2019) presented a learning cycle that incorporated a student-centred theme of exploration prior to the introduction of the concept. The 5E instructional model has constructivism as the theoretical foundation and assumes that learners bring their own ideas, experiences, and prior knowledge into the classroom and learn as active participants. The 5E instructional model consists of five phases: Engage, Explore, Explain, Elaborate, and Evaluate.

Nawastheen *et al.* (2014) described the 5Es model as an innovative approach for constructive classroom instruction. If learners are actively engaged in learning science, they redefine, replace, and reorganise their initial explanations, attitudes, and skills (Bybee *et al.*, 2006). Teachers facilitate learning through explorations of phenomena while students formulate and test predictions, reflect upon observations and experiments with the phenomena to develop explanations and apply new knowledge to novel situations (Bybee *et al.*, 2006). The 5Es model was remodelled by Rodriguez & Harron (2019) to a maker centred 5E learning cycle. Maker centred learning was defined as a process of inquiry that draws on social constructivism and involves social meaning-making rooted in the interaction between learners, their experiences, and their collaboration with peers (Rodriguez & Harron, 2019). In maker centred learning, understanding is made more visible through the creation and sharing of tangible artefacts. Engaging learners in maker centred lessons instils valuable habits such as resilience, collaboration and reflection referred to as a maker mind-set (Martin, 2015) and these valuable habits are the competences that must be imparted to learners in competence-based curriculum. The five phases of the maker centred 5E instructional model are described in the following sections.

Engagement

The teacher engages learners through brief activities that focus learners' attention on the phenomenon, stimulate curiosity, and reveal prior knowledge. This phase creates connections between the previous and present learning experiences. The teacher makes connections between a new concept and learners' prior knowledge and experience, making the concept relevant to learners (Singh & Yaduvansh, 2015). Students become mentally engaged in the concepts, processes, and skills to be learned and the role of the teacher is to present the situation and identify the instructional task. By focusing learners' attention and making relevant connections, the teacher initiates the learning task (Adak, 2017). Activities in this phase include posing a question, defining a problem, demonstrating a discrepant event and small group discussions to stimulate and share ideas. Qarareh (2012) highlighted that historical events can also be used, such as natural disasters. This stimulates late curiosity and motivates learners. Rodriguez and Harron (2019) emphasised the importance of engaging students in a maker centred lesson. This is done through focusing on student identities as an important first step to help learners build something that is personally meaningful.

Exploration

Before introducing the concept, the teacher challenges learners to explore, formulate, test predictions, make observations, record data, and collaborate with peers to develop and test alternative solutions. The teacher designs activities so that learners have a common concrete experience upon which they continue building concepts, processes, and skills. To Singh and Yaduvansh (2015), this phase aims to establish experiences that teachers and students can use later for introduction and discussion of concepts, processes, and skills. This engages learners in a common experience, emphasising scientific knowledge, processes, and skills (Adak, 2017). Probing questions have been seen to help learners clarify their understanding of major concepts and redirect their investigation when necessary (Quarareh, 2012). Rodriguez and Harron (2019) emphasised that during this stage in a maker centred lesson, the teacher supports learners' iterative designs and fabrication, creates a non-judgmental space for trial and error, facilitates learner collaborations and sharing of ideas, asks questions on what learners are creating as well as actively listening to the learners' ideas. The teacher monitors safe tool and material use and provides feedback, encouraging learners to reflect and redesign.

Explanation

After the exploration, learners review, analyse, and interpret their observations and data. The teacher focuses learners' attention on precise aspects of their engagement and exploration experiences and affords opportunities to demonstrate their understanding of concepts, process skills, or behaviours. Hence, learners may realise their prior ideas, provide explanations at best and seek new ways to explain their observations. The teacher uses representations (e.g. models, analogies, simulations) to enhance learners' conceptual understanding. New scientific vocabulary, unique to the concept, is introduced at this time to expand learners' knowledge (Singh & Yaduvansh, 2015). The teacher facilitates class discussions and encourages learners to share their ideas, experiences and observations developing explanations supported with evidence (Lankford, 2010). More abstract concepts not easily explored in earlier activities are introduced and explained (Quarareh, 2012). Rodriguez and Harron (2019) pinpointed the role of the teacher during this phase in encouraging learners to explain concepts and designs in their own words, highlighting important ideas provided by learners, asking questions that help learners be specific in their explanations and providing opportunities for learners to showcase their creations publicly both inside and outside the classroom.

Elaboration

Learners are challenged to apply their knowledge of the concept to novel situations. Rodriguez and Harron (2019) described the elaboration phase as a stage for development, expansion, and progress. Through new experiences with the concept, learners draw upon knowledge collected as they engage, explore, and explain phases to deepen their conceptual understanding, improve their skills, and expand their understanding of science. This phase extends students' conceptual understanding and allows them to practise skills and behaviours (Singh & Yaduvansh, 2015). The role of the teacher is to challenge learners to extend their knowledge, provide learners with new experiences, expand their limits, and deepen understanding.

Evaluation

This phase encourages learners to reflect upon their knowledge and assess their own learning. It provides opportunities for teachers to assess learning and the effectiveness of their instruction. Evaluation of learners' conceptual understanding of phenomena through formative assessment has the potential to inform instructional decisions throughout the phases of the instructional model. Singh & Yaduvansh (2015) noted that this phase encourages learners to assess their understanding of key concepts and skills development. This is an important phase as it provides closure and verifies learner understanding. It measures the effectiveness of teaching methods, teachers and teaching aids. There is also feedback, gratification and motivation to learners (Rodriguez & Harron, 2019).

2.12.2 Constructivist Prediction, Observation and Explanation (Poe) Inquiry-Based Learning Model

POE inquiry-based learning model was developed to improve students' scientific learning performance (Hwang *et al.*, 2017). The model concerns the importance of helping students to resolve questions, guiding them to become aware of problem solving and leading them to critical thinking. Inquiry is a process of self-correction and self-adjustment and has been noted by Hwang *et al.* (2017) as a powerful way for learners to develop strategic thinking and to master scientific content. In inquiry-based learning, students combine scientific processes with scientific knowledge. They think critically about evidence and explanations to develop their understanding of science. In the POE model, students predict the outcome of an event or situation and provide a justification for their prediction, this provides opportunities for them to clarify and justify their own perception (Costu *et al.,* 2012). After making predictions, students must then observe the action taking place. This can be through field work, simulations, experiments or other hands-on activities. They then describe the possible divergences or congruencies between their prediction and their observation (Erriska, 2019). If their predictions are not correct, the learners are assisted by the teacher in changing their prediction. The teacher explains why the assumption is false. Thus, learners experience a change of concept from wrong to correct. POE helps students with self-correction and self-adjustment and improves their performance. It helps with gradual elimination of scientific misconceptions. Then lastly, there is the explanation phase where the teacher gives feedback to help the learners make self-corrections (Erriska, 2019). Learners learn from their mistakes and concepts learnt this way will not be easily forgotten. Hong *et al.* (2014) developed a POE strategy to facilitate preschoolers' acquisition of scientific concepts regarding light and shadow, and students taught using POE model significantly outperformed their counterparts. Costu *et al*. (2012) also found out that POE inquiry-based learning helped students eliminate scientific misconceptions and improved their scientific learning performance. Prabawati *et al.* (2020) observed that learners taught using POE had better cognitive, affective, and psychomotor skills. Students' science process skills are improved using the POE model in teaching and learning. Process skills give students the opportunity to live the process of finding a concept and excess process skills makes students become active in thinking and skilled in gaining knowledge. In teaching the topic on

Biodiversity, the use of POE can help improve students' scientific understanding of the topic, improve their scientific knowledge, eliminate misconceptions, and improve their science process skills which can help in sustainable management of biodiversity and conservation. The POE learning model helps students convey their opinions and knowledge, so that they can construct knowledge using prior knowledge and new knowledge gained in the learning process (Prabawati *et al*., 2020).

2.12.3 Constructivist Problem Based learning (PBL)

The Problem Based Learning is a constructivist tool used to advance students' thinking. It develops, improves, and builds creativity (Amalia *et al.*, 2017). PBL provides an opportunity for learners to develop high order thinking through analysis, exploration, and application of the concept. The steps in PBL include identification or defining a problem, generation of alternative solutions to the problem, evaluation and finally implementation and follow up on the solution (Amalia *et al.*, 2017). PBL priorities engaging learners in complex real world problems and making learners understand the issues that need to be solved, engaging learners in learning to apply knowledge and skills in a variety of contexts, providing opportunities for learners to learn and practice skills needed to live and work and providing opportunities for students to learn and practise interpersonal skills in groups. It includes reflection activities that direct learners to think critically about the experience (Fajra *et al.*, 2020).

To Afifi, Hindriana & Soetisna (2016), PBL aims to help learners develop knowledge and technology based environments, prepare students for the challenges of today's world, and solve complex problems. It improves analytical and critical thinking skills, exploration, teamwork and communication skills which are cornerstone skills throughout an individual's lifespan. The advantages of PBL are that it develops a variety of work skills, improves the enthusiasm, creativity, and innovation of learners. It also improves the skills needed for a career in the workplace, the effectiveness in learning, assists students in solving real life problems, honing cognitive, manipulative and designing skills. Further, PBL, evokes curiosity and triggers creative imagination as well as critical thinking (Sunardi & Hasanuddin (2019). Therefore, PBL empowers learners with research skills thereby enabling them to integrate theory and practice as well as to apply knowledge and skills to develop viable solutions to problems. In teaching the topic on Biodiversity this can be a valuable tool to ensure conservation of biodiversity, ecosystem, and sustainable management.

2.13 Weaknesses of Constructivist Teaching Approaches

Constructivism models have generally been successful (Fatimah *et al.*, 2022). However, constructivist-based teaching encourages the introduction of discrepant and novel materials and methods to capture students' attention and to motivate students to engage and, unless the teacher remains disciplined in the use of such materials, the classroom experience may devolve into entertainment. Constructivist models operate based on the principle that students build knowledge based on their prior knowledge. This may lead to confusion and frustrations as some students may not be able to form relationships and abstracts between the knowledge they already have and the knowledge they are learning for themselves. Furthermore, extensive training is needed for constructivism teaching (Fatimah *et al*., 2022) and this may require costly long term professional development. It may actually be expensive for the schools and disruptive to students' learning. In addition, it is also difficult to customise the curriculum to each student's needs in a class with an average number of students as their prior knowledge will vary.

Constructivist teaching approaches require teachers to be experts in child development (Brau, 2020). Teachers must be experts at observing children and be able to understand their students' responses and make changes to the environment whenever students fail to make connections between concepts. Hence, constructivist teaching approaches may be difficult to manage, and need more preparation and time to implement.

2.14 The Nature of Teacher Pedagogical Content Knowledge

Pedagogical Content Knowledge is a unique combination of content and pedagogy that enables teachers to capture, portray and share knowledge in ways that are articulable and meaningful to learners. Pedagogical content knowledge is also known as *craft knowledge* (Chopoo, Thathong & Halim, 2014). It comprises integrated knowledge representing teachers' accumulated wisdom with respect to their teaching practice pedagogy, learners, subject matter, and the curriculum. The term PCK was coined by Shulman (1986) who introduced it as teachers' own special form of professional knowledge. Shulman coined out the constituents of PCK as: Knowledge of instructional strategies that is, knowledge of useful forms of representations of specific topics, powerful analogies, illustrations, examples, explanations, and demonstrations and knowledge of learners' conceptions that is knowledge of learners' misconceptions and their influence on subsequent learning of frequently taught topics.

Magnusson *et al*. (1999) proposed five components to PCK namely: knowledge of aims and objectives for teaching science (at a particular level), knowledge of the science curriculum (goals and specific curricular programs), knowledge of learners' understanding of specific science topics, knowledge of assessment in science (relevant aspects of learners' learning, ways to assess these aspects) and knowledge of strategies for teaching science topics (e.g. use of representations, group work, fieldwork and simulation). Teacher PCK is one of the most important factors contributing to students' learning and achievement (Keller *et al*., 2017). PCK connects subject matter knowledge and teachers' understanding of how to teach content to students. It is therefore a unique province of teachers and a prerequisite to student cognitive activation. High levels of PCK allows teachers to develop learning environments that simultaneously challenge and support students' learning process and allows teachers to anticipate student difficulties and adaptively respond when students encounter problems.

Teachers therefore have a task to pack and present knowledge in such a way that the learners can understand (Chan & Hume, 2019).

Two epistemological views of science PCK have been identified (Gess-Newsome *et al*., 2008). These are integrative and transformative views. The integrative view conceptualises science PCK as a blend of different teacher knowledge domains, for example, content knowledge, knowledge of the curriculum and knowledge of instructional strategies. Hence during teaching, teachers can integrate all their knowledge domains to create learning opportunities. In the transformative view, other teacher knowledge domains are viewed as being transformed and combined through experience into a form of knowledge which is science PCK (Appleton, 2006).

2.15 The Role of Pedagogical Content Knowledge

Well-developed PCK is the science teachers' ability to determine aspects of a particular topic that are most difficult for learners to understand (Shulman, 1986). PCK plays a vital role in the planning of subject matter to be taught and learnt (Smith & Niale, 1999). It is also the teacher in making choices on instructional approaches and strategies and in the process influences the learning processes. PCK is subject and topic specific and teachers develop appropriate knowledge to teach the content in a particular way, hence, PCK enables teachers to understand the alternative ways of representing knowledge so that it becomes comprehensible to learners. Consequently, the teacher would identify analogues for example, demonstration, simulations and manipulations and the most effective communication strategies suitable for the learners of a particular background to understand.

Teachers with well-developed PCK can use suitable language, behaviour and explanations, thereby making appropriate decisions in a particular science classroom setting (Gess-Newsome, 2001). PCK allows effective communication with learners which involve teachers setting up activities and questions that help learners to formulate and express their own ideas as well as listening to what other learners say. In that way teachers motivate learners and lead them towards fruitful ideas.

Furthermore, teachers with well-developed PCK are capable of recognizing learners' misconceptions that can be barriers to learning and use several strategies to correct the misconceptions (Mavuru, 2016). PCK also enables teachers to identify conceptual difficulties that are likely to be experienced by their learners during the teaching of particular concepts and design strategies to tackle the difficult concepts.

Mavuru (2016) noted that PCK is essential for teachers to devise and use the pedagogical resources appropriate to teach a particular topic or concept. Teachers' pedagogy is influenced by the level of his/her PCK. Grossman (1990) asserted that PCK is the most important knowledge domain in classroom teaching. Day (2001) acknowledged the importance of teachers' PCK when he described teachers as the most important assert in learning society, who teach in a changing and unpredictable environment where knowledge is constructed from different sources and viewpoints.

2.16 Teacher Acquisition of Pedagogical Content Knowledge

Shulman (1986, 1987) formulated a model of pedagogical reasoning which is a cycle of comprehension, transformation, instruction, evaluation and reflection. In the cycle, teachers continuously learn and strive to improve the teaching and learning process throughout their professional lives. This is achieved through actively engaging in preparing what they teach, how they teach and why they should teach in a particular way (Mavuru, 2016).

During the comprehension stage, teachers conceptualise what they teach through understanding the purposes, subject matter and ideas within and outside the discipline (Shulman & Richert, 1987). This is followed by the transformation stage, in which teachers prepare, select appropriate instructional strategies, select teaching material and activities and tailor them to suit specific learners in the classroom (Shulman, 1987). During this stage, the teacher chooses teaching material and strategies according to the learners' attributes such as their ability, prior knowledge and culture.

The comprehension stage is followed by the instructional stage in which pedagogical approaches such as classroom management, presentation, class or group interactions and questions occur. At the evaluation phase, teachers determine whether learners understood during the interactive teaching. The process of evaluation is an extension of instructional process and not a way of grading learners (Wilson *et al*., 1987).

The reflection stage is the last stage. During the reflection stage, teachers review, reconstruct, re-enact and analyse their practice in order to become better teachers (De Jong, 2010). The process of reflection is a key component to improving teacher quality. Teachers can either reflect-in-action or reflect-on- action (Schon, 1987). When a teacher reflects-in-action, he/she thinks about their teaching as they teach and this allows the teacher to make decisions during instruction and respond to unexpected events (Schon, 1987). Reflection on action is when the teacher thinks after or before practice (Connelly & Clandinin, 1986). During the process of reflection teachers determine the reasons for success or failure in their teaching. Consequently, there comes the stage of new comprehension, where the teachers start the cycle all over again in a bid to improve practice. Teachers conceptualise new and better ways of presenting their science lessons and a richer understanding of the concept is also gained.

Through such a cycle, teachers build upon their PCK as they develop new ways of understanding and presenting the subject matter knowledge. As such, science teachers possess varying levels of PCK which continuously develop throughout their teaching career. Hence, classroom teaching experience is an important factor in enhancing teachers' PCK. Teachers build up their PCK from several sources which include preservice teacher training, professional development and teaching experience (Hume & Berry, 2010). Teachers also acquire PCK through interactions and imitations of experienced work mates, reflection on one's practice, involvement in professional conferences, teacher networks and research (Kind, 2009)

2.17 Factors that Influence Pedagogical Content Knowledge Change

PCK change is determined by several factors which include the nature of the topic, the context in which the topic is taught, the way a teacher reflects on teaching experiences and educational background among other things. The following sections give details on these factors.

2.17.1 Teacher Content knowledge

Content knowledge is a body of knowledge and information that teachers teach and that learners are expected to learn in each subject or content area (Childs & McNicholl, 2017). This body of knowledge includes facts, theories, and principles which teachers must master for effective teaching. Teachers must therefore have a deep understanding of the subject they teach and the corresponding curriculum. Childs & McNicholl (2017) noted that when teachers' subject content knowledge was insecure, their ability to give appropriate and effective science teaching explanations in the classroom was limited. However, explaining scientific phenomena to students is at the heart of what science teachers do and appropriate measures must be taken to ensure that all science teachers have adequate content knowledge.

Shulman (1986) argued that teaching requires the teacher to be equipped with both content knowledge (CK) and pedagogical content. Studies into science teaching show that when teachers possess subject CK expertise and the ability to represent this to their pupils (sound PCK), they engage classes with activities that enable learning, for example, being able to proficiently lead free-ranging class discussions of content (Garnett &Tobin, 1988; Roth *et al*., 1986; Tobin & Fraser, 1990). Such teachers have ample awareness of common alternative conceptions and scientific models that provide rich opportunities for their learners.

There is a direct correlation between teachers' CK and effectiveness in science teaching (Santau, *et al*., 2014; Fitzgerald *et al*., 2013; Alshehry, 2014). Contrary, poor CK results in low self confidence in teaching science and consequently ineffective lessons (Kind, 2014). CK is an important element of science teacher efficacy because teachers cannot explain what they do not know (Nowicki *et al*., 2013). Scantiness of content knowledge affects the ability of the teacher to teach science effectively (Usak, *et al*., 2011; Oh & Kim, 2013) since teachers cannot teach what they do not know.

Kind (2014) noted that maturity and further education contributes to fewer misconceptions in teachers than students regardless of topic, otherwise the misconceptions are apparent in both groups. Kind (2014) highlighted that poor content knowledge contributes to low self-confidence for teaching science and low-quality lessons; hence teachers need a broad and deep subject specific knowledge to provide their students with rich learning opportunities. Teachers' accurate knowledge is a vital component for good science teaching. Teachers need accurate, deep, and rich science knowledge for effective teaching. This is gained not only from rigorous academic studies but also from experience. Hence, teachers cannot help learners learn things they themselves do not understand.

2.17.2 Teacher knowledge of students

Teacher knowledge of students has been recognised as a noteworthy factor in promoting effective instruction (Hill & Chin, 2018). Such knowledge is thought to enable diverse effective classroom strategies. These include altering the pacing of instruction to suit the students' needs (Clark & Peterson, 1986). Appropriate instructional groups can also be formed based on knowledge of students (Shavelson & Borko, 1979). In the Zone of Proximal Development, Vygotsky (1978) noted that there are things a learner can do without assistance, however, learners may need the assistance of a more knowledgeable person to complete a task they would not do independently. Collaborative work can be effective particularly when learners of mixed abilities are grouped together. This can only be accomplished with adequate teacher knowledge of students. This knowledge of students enables teachers to facilely assess students' understanding and misunderstanding in the moment (Scheiner *et al*., 2019). Hence, the teacher can design instruction to address common misconceptions as well as tasks and questions to further student understanding (An, Kulm & Wu, 2004).

Hill and Chin (2018) viewed teachers' knowledge of students as an important factor in promoting effective instruction and students' learning. Such knowledge enables a variety of effective classroom strategies, including adjusting the pacing of instruction based on student need, forming appropriate instructional groups, facilely assessing students' understanding and misunderstanding in the moment and designing tasks to address common misconceptions and questions to further students' understanding (Scheiner *et al*., 2019). Teacher expertise as a skill in attending to students' strategies, interpreting students' understanding and responding with appropriate instructional moves.

The teaching profession has been conceptualised as a clinical practice profession (Guerriero, 2014). Merriam-Webster (2006) noted that clinical practice involves direct observation and treatment of patients or clients and in this case, the learners. Successful outcomes in clinical practice are dependent not only on the skill, knowledge, and actions of the practitioner (teachers), but also on the commitment and actions of the client (learners) (Cohen, 2005). Alter & Coggshall (2009) further noted that in clinical practice, determining the most appropriate course of treatment requires knowing an individual client (learner). This can be through observation, questioning and other diagnostics or evidence collection techniques, as well as knowing what research has shown to work with learners (clients) in similar situations. Hence, teachers need a deep understanding of their learners and excellent decision making. Decisions are regularly made by the teacher while processing cognitive complex information about the student and where appropriate decide on alternatives for increasing understanding. Darling-Hammond (2006) posited that teachers must understand how children learn and how their learning styles vary. This requires that teachers gather information on the students' background, interests and learning styles and diagnose students' strengths and difficulties. Equipped with this evidence, the teacher uses his/her judgement to engage and motivate learners and strategically build on students' prior knowledge.

Learners have educational experiences and personal stories that shape how they respond to teaching and learning. Mabonga (2021) noted that prior knowledge is the information one has before they acquire new ideas or concepts. This information is gathered over time from individual, societal and cultural influences. It ranges from pre-existing knowledge, belief skills and attitudes which influence how learners attend, interpret, and organise incoming information (Hailikari *et al.,* 2007). The constructivist theory points out that humans construct knowledge and meaning from their experiences, making learners have prior knowledge of significance in teaching and learning. Consequently, it is important for teachers to prompt learners to recall previous learning before presentation of new knowledge. This can be achieved through assessments, active learning and beginning of class activities. Thereafter, the teacher can strategize how this information can inform pedagogy.

Accurate prior knowledge makes learners confident during teaching and learning (Mabonga, 2021). Learners with adequate prior knowledge freely participate since they can construct a relationship between their experiences and new information. Mabonga (2021) further noted that confident learners can manage their problems, fears and maintain a positive attitude. Prior knowledge has also been seen as an important factor in redesigning or modification of teaching instructions to cater for learner needs and this enables learners to construct their own knowledge. Furthermore, prior knowledge makes learning meaningful. Learners have no purpose to remember facts that have little meaning to their personality. Relation of a concept to the real world encourages the learner, hence, the teacher must strive to take note of the learner's personal and social background and organise the learning environment in a way that the learners can make connections (Wilson & Burket, 1989).

Prior knowledge of the learners is essential since it allows the teacher to clear up any misconceptions. Learners may come into the learning environment with ideas that are incorrect. Diaz (2017) stated that inaccurate knowledge could lead to misconceptions which may alter learners' view of current information to be learnt. Therefore, teachers must identify and correct learners' misconceptions before teaching new knowledge. DiPietro *et al*. (2008) pointed out that learners must unlearn misconceptions before learning new accurate knowledge. Teachers must therefore inquire about what learners know in the area concerned and guide them to unlearn the incorrect information as they introduce new concepts.

2.17.3 Orientations toward science teaching

Orientation to teaching science is described by Magnusson *et al*. (1999) as "teachers' awareness and beliefs about the objectives and goals for teaching science at a particular level." The teacher's science teaching orientation is a way of thinking about science teaching and learning. Teacher orientation serves as a "road map" for deciding on learning goals, implementing curricular content, and assessing students' progress (Magnusson *et al*. 1999, p. 97). Kind (2014) presented nine orientations to science teaching as outlined by Magnusson *et al*. (1999). These are academic rigour, didactic, activity driven, conceptual change, discovery, process, inquiry, and guided inquiry. Academic rigour is described by Kind (2014) as an approach to science teaching that includes a variety of activities for verifying concepts, demonstrating connections between concepts, and representing science as a body of knowledge. According to Friedrichsen *et al*. (2010), an analytical rigour approach to science teaching is teacher-centred, with the aim of presenting a specific body of information. To check on the relationship between concepts and phenomena, students are faced with challenging problems and exercises, laboratory work, and presentations.

Didactic orientation is teacher-centred with the aim of transmitting scientific information (Friedrichsen *et al*, 2010). According to Kind (2014), a didactic orientation is one in which the instructor says, demonstrates, describes, and asks students to check their understanding. The instructor introduces the material and focuses on student recall. An activity driven orientation to science teaching offers hands-on activities but may lack conceptual coherence (Kind, 2014). Discovery orientation is student-centred, allowing students to experiment and discover scientific ideas for themselves by pursuing their interests. During their study of the natural world, students find trends in how the world functions (Friedrichsen *et al.*, 2010).

Conceptual change orientation has a goal of facilitating the development of scientific knowledge by confronting students with contexts to explain that change their naïve conceptions. Kind (2014) highlighted that it is a student-centred approach where the teacher asks for children's views and helps establish valid claims, prompts dissatisfaction with initial thinking and or intuitive ideas. Project based orientation involves students investigating solutions to authentic problems. This approach to science education is consistent with the goals of the competence-based curriculum and education 5.0. Science is represented as an investigation in inquiry-based learning, and students are required to examine problems and evaluate their expertise. Finally in guided inquiry, students participate in investigations, scaffolds learning to achieve students' independence, and adapts genuine scientific contexts for investigation environments (Kind, 2014; Friedrichsen *et al.*, 2010). The teacher's orientation to science teaching influences the competences that will be gained by the students. To instil critical thinking, creative thinking, innovativeness and problem solving, innovative teaching methods must be used. Key components determining science teaching orientation include the teacher's beliefs about the purpose of teaching science, beliefs about science teaching and learning as well as beliefs about NoS. These components will be discussed below.

2.17.4 Teacher's beliefs about science teaching and learning

Teachers' beliefs are investigated as part of the process of determining how they conceptualise their work, which is crucial to understanding their actions and decisions in the classroom (Mansour, 2008). Some teachers see teaching as a means of passing on knowledge, while others see it as a means of guiding children's learning or of fostering social ties. Bell and Gilbert (1996) presented two opposing viewpoints on the kind of teaching that can occur in each classroom. According to the first, the common assumption is that a teacher's responsibility as an expert is to deliver that knowledge directly to students in a logical order. The second viewpoint holds that knowledge is created by individuals, and that the teacher's responsibility is to facilitate students' ability to reconstruct, extend, or replace their existing knowledge. As a result, teachers' perspectives on scientific education are quite diverse.

Some teachers believe in teaching pupils by lecturing or giving direct instruction. Others represent constructivist approaches of learning and teaching, through adopting cooperative learning or inquiry. However, according to Mansour (2008), most science teachers are more likely to combine elements of several science teaching techniques. A teacher's view of science education is more likely to include elements of numerous forms of instruction than to fit neatly into a single model description. According to Tsai (2002), many instructors' traditional perspectives of teaching science, learning science, and the nature of science may derive from a difficulty with their own school scientific experience. Science classes, laboratory exercises, and associated activities in teacher education courses may have reinforced these "traditional" attitudes.

In the same way, Trumbull and Slack (1991) felt that teachers fail to acquire constructivist-oriented conceptions about teaching and learning since they have all found success in the present (i.e., traditional-oriented) educational systems. As a result, individuals may miss out on potentially insightful constructivist learning and teaching concepts. Teachers' perceptions of the learning science process, behaviours and mental activities engaged on the learner's behalf, and what constitutes suitable and archetypal learning activities are all part of their views about learning science. The most important question is how and in what manner learners should learn science. A "transmission view" is an underlying element of a certain view of learning that can be observed to be implicit in some science education. When a teacher asks students questions or orders them to write, it is mostly for the purpose of determining if they have received the teacher's information. A teacher who uses the transmission mode sees themselves as subject "authorities," praises learner performances if they meet discipline requirements and regards the teacher's job as evaluating and correcting the learner's performance. An unstated assumption made by the teacher under the "transmission view" is that students do not contribute relevant ideas to lessons and that they merely behave as receivers of knowledge, adding the material to their "memory bank." During teaching, pieces of information are therefore passed from teacher to pupil. This viewpoint is expressed in a multitude of ways, including the way teachers approach the material, the kind of teaching practices they use, and how pupils are evaluated. The curriculum is viewed as a list of items to be taught in the "transmission perspective" of learning.

In contrast to the transmission viewpoint, there is a constructivist perspective on science education and learning. In science education, a constructivist method considers students' active participation in the building of knowledge rather than simply their personal reconstruction of previously constructed knowledge provided by the teacher or the textbook. Students learn more about scientific inquiry and enhance their conceptual understanding through participating in scientific inquiry, if there is ample opportunity and support for reflection. Learning is considered as the active production of knowledge in gradually growing networks of ideas through interaction with others and things in the environment from a constructivist perspective (Marshall, 1992). It is possible that the purpose of science education is to generate individuals who can think for themselves. Such individuals have some control over the meaning they assign to events, as well as the ways in which they construct their lives and ideas.

Constructivism emphasises the autonomy of each individual's interpretation of his or her own experience (Roth, 1994). The use of hands-on investigative laboratory activities, a classroom environment that provides learners with a high level of active cognitive involvement, cooperative learning strategies, and the inclusion of test items that activate a higher level of cognitive processes are all implications of constructivist views for the science classroom. The main pedagogical implication is that teachers who provide stimulating and motivating experiences that challenge students' existing conceptions and engage them actively in the teaching/learning process can facilitate the active learner's construction of his or her own understanding (Gil-Pérez *et al*., 2002). According to Watts (1994), science should be relevant to students' everyday lives since this real-world setting offers the roots from which their studies should be pulled. It must be relevant to their interests and modern lifestyles, current events and television news, as well as individuals and practices around the world.

2.17.5 Teacher's beliefs about Nature of Science

Teachers' ideas on the nature of science can be expressed in the classroom (Brickhouse, 1990). The link between teachers' views on science and how students learn science reflects a larger epistemological question of how scientific knowledge is formed, whether in a community of scientists or in a classroom of students (Brook & Park, 2022).

Science is described as knowledge that is socially produced by a community of scholars rather than a collection of natural-world truths by the socially constructed scientific theories (Kuhn, 1970). Scientific knowledge is created to fulfil the scientific community's goals, according to this viewpoint (Toulmin, 1982). The theories that scientists develop are instruments for organising and interpreting information, solving problems that they deem relevant, and assisting them in seeing new possibilities and challenges. Theories are assessed using widely agreed-upon criteria; the development and evaluation of theories are viewed as complicated social processes rather than as routine, logical historical processes. According to this viewpoint, science is a culture that possesses exceptionally powerful tools for comprehending the natural world, and the purpose of science education is to create bridges between a child's ordinary experience and the culture of science (Hawkins & Pea, 1987).

The relationship between observation and theory highlights that scientists' theoretical commitments influence the observations they make as well as how those findings are interpreted (Brook & Park, 2022). Children's conceptual frameworks and their perception of scientific observation in the classroom have a similar link; that is, when children face evidence that contradicts their hypotheses, they may not notice the disagreement (Kuhn, 2012). They can choose to ignore or manipulate evidence to match their views, or they can change their theories to account for the evidence (Kuhn, 1989). It is critical to explore the relationship between students' explanations and the facts so that students may make informed decisions concerning theory and evidence (Kuhn, 1989). It is also vital to teach learners to be critical of their own views and to create alternative hypotheses. Because observation is theory-driven, children do not always pay attention to what the instructor thinks is significant for them to see in a science exercise. As a result, the teacher may need to emphasise key findings in science experiments (Harlen & Symington, 1985).

According to Kuhn (2012), scientific progress and its nature is best understood as a revisionary rather than a cumulative process. Changes in science's techniques and goals which produce new anomalous data sets commence this revisionary process, in which scientific hypotheses are changed or replaced (Duschl, 1990). Similarly, children bring notions about how the world works to scientific classrooms. In science, learning is more about changing preconceived notions than it is about providing explanations where none previously existed.

2.17.6 Knowledge and beliefs about science curriculum

Patankar and Jadhav (2013) highlighted that a curriculum outlines what the learners will learn, possibly guide on when the learners learn the information from the lesson. It includes the planned interaction of learners with instructional content, materials, resources, and processes for evaluating the attainment of educational goals. Patankar and Jadhav (2013) identified the teacher as the mediator between curriculum and students. Teacher curricular knowledge refers to teacher understanding of the goals and objectives for student learning and the scope and sequence of the scientific concepts to be taught (Gess-Newsome, Taylor, Carlson, Wilson & Stuhlsatz, 2017). It involves the ability to apply theoretical principles and behaviours associated with planning, implementing and evaluating the curriculum (Niemela & Tirri, 2018). Teacher knowledge of curriculum consists of two categories that is, the mandated goals and objectives and the specific curricular programs, resources, and materials (Magnusson *et al.*, 1999). Key components that influence the teacher's knowledge of the curriculum are the teacher's knowledge of goals and objectives, relating concepts to other topics and relating the concepts to other disciplines

2.17.7 Knowledge and beliefs about assessment in science

Kipers *et al*. (2018) described assessment as a process by which knowledge or performance of a learner is appraised and resulting judgments are made based on the consideration of evidence. Education assessment involves teachers applying their understanding of how students develop skills and knowledge, attitudes, and values in a subject domain (Edwards, 2013). This component of PCK consists of knowledge of the dimensions of science learning important to assess and knowledge of assessment strategies and methods through which students' learning can be assessed (Magnusson *et al.,* 1999). Methods of effective assessment include informal, formative, and summative evaluations implemented to reveal student understanding implemented to assess students' understanding of scientific concepts. Edwards (2013) viewed quality assessment as an integral part of good teaching practice and highlights that teachers need to know on what to focus to ensure their assessment of students' learning is meaningful. To teach science well, science teachers need to know what to focus on in order to ensure that their assessment of student learning is meaningful and useful for the students' on-going learning and development. The diversity of content and skills within science calls for assessment capabilities by teachers.

Edwards (2013) proposed a framework for quality assessments in science which focuses on concurrent consideration of five areas, that is, teaching, students, evidence of learning, future decision making and impact. Edwards (2013) highlighted that teachers are better placed to assess well if they consider the assessment components of their teaching during the planning stages and articulate their range of intentions and goals for the lessons so that they can communicate these to their students. Quality assessment focuses on a student, that is it addresses the intended students learning outcomes and is responsive to group or individual feedback needs (Mellati & Khademi, 2018). Teachers must therefore focus on their students' needs and develop the skills to be able to design assessment tasks. Quality assessment gathers evidence of students' progress as a purposeful pursuit (Benzehaf, 2017). The assessment data can be used by teachers to make interpretations and decisions about what an individual knows and able to do. Edwards (2013) further pointed out that quality assessment should focus on impact on the curriculum and classroom culture, and a deep understanding of these impacts is essential for a more accurate appraisal. To Mellati and Khademi (2018) teachers' assessment literacy has a statistically significant impact on learner achievements and teachers' assessment awareness leads teaching into effective and motivated assessment designs.

2.17.8 Knowledge and beliefs about instructional strategies

General teaching strategies such as the learning cycles, which have broad application in teaching within a scientific discipline (e.g. biology, chemistry, physics, etc.) are included in this component of PCK. Topic-specific strategies including ways to represent concepts (models, diagrams, pictures, tables, and/or graphs) and engage students with instructional strategies (investigations, experiments, demonstrations, simulations, problems or examples) to facilitate student learning of specific concepts in science (Magnusson *et al.*, 1999) are also included. Vosniadou (2007) noted that teachers need to develop and utilise instructional strategies to promote students' metaconceptual awareness and engage in learning to promote conceptual change.

2.18 Importance of Inclusion Of The Topic 'Biodiversity' In The Biology Curriculum

The Convention on Biological Diversity (CBD) underlined biodiversity as an indicator for sustainability and recognizes communication, education, and public awareness as essential elements for the effective and successful implementation of the Convention's aims (Rohden & Scholz, 2022). Furthermore, the need for a biodiversity awareness programme is identified as a national responsibility. For the improvement of such a programme, there is a need for cooperation between countries to build bridges and connect experiences and expertise.

Biodiversity is defined as 'the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems' (Rohden & Scholz, 2022). At this moment in time, biodiversity is declining rapidly due to human activities such as harvesting, habitat destruction and modification, pollution, overexploitation, and the introduction of exotic species (Wikstrom, 2016). Concerns have been raised that the loss of biodiversity and deterioration of ecosystem services contribute to worsening human health, higher food insecurity, increasing vulnerability of ecosystems to natural disasters and lower material wealth. It also results in worsening of social relations by damage to ecosystems highly valued for their aesthetic, recreational, or spiritual values, and less freedom for individuals to control what happens and to achieve what they value (Boyle, 2015). The willingness of people to confront the loss of biodiversity depends on the monetary value (e.g., as a source for medicines, ecotourism) and non-market value such as ethical, aesthetic value they attach to biodiversity. These values are not mutually exclusive, but may vary both within and among cultures, which must be considered to achieve conservation (Rohden & Scholz, 2022). Biodiversity is thus viewed as a normative conservation concept which is linked to the idea of biological variation and its ecological, economic, ethical, spiritual, and cultural values (Wikstrom, 2016). Inclusion of the topic on Biodiversity in the curriculum ensures that learners understand and appreciate the dynamic aspect of biodiversity and understand that species, habitats, and ecosystems change naturally over time. Learners get to know factors that influence biodiversity and understand that human activity can damage or enhance biodiversity. Learners become more conscious of the impact of their own and other people's actions on biodiversity and actions that can be taken to preserve and enhance biodiversity.

2.19 Biodiversity Education

Wikstrom (2016) noted that tomorrow's conservation minded citizens are today's students; hence our secondary schools are an important place to enact effective biodiversity education. Biodiversity education requires an innovative teaching and learning approach because the framework of Education for Sustainable Development (ESD), requires the construction and critical use of knowledge, critical analysis of the role of natural science, an awareness of the scientific and non-scientific aspects, i.e., the benefits and values attached to biodiversity and its conservation, as well as appropriate pedagogical settings for in-depth discussion and reflection (Boyle, 2015).

Biodiversity education should enable people to understand what biodiversity means, appreciate the dynamic aspects of biodiversity and understand that species, habitats and ecosystems change naturally over time, become more aware of biodiversity as part of their cultural and spiritual (Peter *et al*., 2019), as well as economic heritage, be more aware of and understand the significance of biodiversity in their own environment and be able to define their own level of interaction with it (Gayford, 2000), recognise the relationship between biodiversity and the maintenance of quality of life (Lindermann-Matthies *et al.*, 2009). Furthermore, biodiversity education should enable one to know what factors influence biodiversity and understand that human activity can both damage and enhance biodiversity, be aware of the impact of one's own and other people's actions (including lifestyle and consumer choices) on biodiversity (Navarro-Perrez & Tidball, 2012), improve their skills in relation to biodiversity, including those skills that enhance understanding and promote appropriate action, be aware of what actions they can take to preserve and enhance biodiversity, and act on that awareness and recognize that our ideas and understanding of biodiversity might also change over time (Gayford, 2000).

Biodiversity education in schools should thus offer possibilities to learn about the different meanings, interpretations, and uses of biodiversity, to observe and monitor biodiversity, to critically investigate its conceptual use in environmental and political discourse, and to discuss the normative character of biodiversity (Lindermann-Matthies *et al.,* 2009). Biodiversity education has been seen to foster a sense of environmental stewardship and responsibility. By learning about the importance of biodiversity, learners become more aware of the impact of their actions on the natural world and be inspired to protect it. In schools, biodiversity education should include a wide range of exploratory learning activities and methods for outdoor nature education. Such an approach is strongly appreciated by both learners and their teachers.

2.20 Teaching of The Topic, Biodiversity

Teachers in different context teach the topic, Biodiversity in various ways, depending on their location, resources and student needs. This has been referred to as place-based education (Sobel, 2004). Place based education is an educational approach that uses the local environment and community as a tool to learn about biodiversity and other subjects (Sobel, 2004). In the context of teaching biodiversity PBE involves using local examples and teaching concepts using local flora and fauna and ecosystems (Muir & Schwartz, 2009). Learning about biodiversity in a local context makes the subject more relevant and engaging (Sobel, 2004). Hands on activities which include field works, outdoor activities and hands on experiment can also be used (Lieberman & Hoody, 1998). Hands-on experiences and local examples enhance students' understanding of biodiversity concepts (Muir & Schwartz, 2009). Community involvement is an important tool to the teaching and learning of the topic, biodiversity (Smith & Sobel, 2010). This fosters partnerships between schools and local communities, promoting community engagement and stewardship (Smith & Sobel, 2010). Teachers can collaborate with local communities, organizations, and stakeholders to learn about biodiversity issues and solutions (Smith & Sobel, 2010). Contextual learning can also be used to teach the topic, Biodiversity as that connects biodiversity concepts to real-world issues and applications in the local context and helps improve learner understanding of the topic Biodiversity (Knapp, 1996). Place based teaching of biodiversity has been seen to improve learner critical thinking skills, problem-solving, and collaboration skills (Lieberman & Hoody, 1998).

In Zimbabwe it has been noted that teachers in rural schools use local flora and fauna to teach biodiversity, incorporating traditional knowledge and practical activities like tree planting and animal observation (Mavhura *et al*., 2017). In urban schools teachers tend to focus on urban biodiversity, exploring topics like urban wildlife, pollution, and conservation efforts in cities (Chirisa *et al*., 2019). Teachers also follow the national curriculum, using textbooks and structured lesson plans to teach biodiversity in schools (ZIMSEC, 2019). Teachers in communities with indigenous knowledge incorporate traditional practices and beliefs about biodiversity, highlighting the cultural significance of conservation (Mupemba *et al*., 2016). Experiential learning is also used by teachers in Zimbabwe where they organize field trips to national parks, game reserves, and botanical gardens, providing hands-on experiences with biodiversity (Mwenye *et al*., 2017). Some teachers use digital resources, online platforms, and mobile apps to teach biodiversity, especially in urban areas (Hove *et al*., 2020).

2.21 Impact of PCK On Teaching And Learning

When teaching subject matter, teachers' actions will be determined to a large extent by the depth of their pedagogical content knowledge, making this an essential component of their ongoing learning. Pedagogical content knowledge research links knowledge on teaching with knowledge about learning.

PCK for Biology teachers was evaluated in Thailand and the study showed that the teachers lacked adequate content knowledge and had difficulties in teaching the subject (Chopoo *et al.*, 2014). They noted an inability to design appropriate instructional and assessment activities and recommended an urgent need to improve the biology teachers' teaching methods to enhance the teaching and learning of Biology. Bravo and Cofre (2016) recommended professional development programs to teachers. They observed a change in teacher PCK, a change in beliefs and knowledge about best approaches and strategies to teach Evolution, and about student learning difficulties and misconceptions on Evolution after a professional development program.

In Swaziland, Mthetwe- Kunene *et al*. (2014) also found inadequate PCK in Biology teachers in the teaching of genetics. Teachers' individual PCK profiles consisted predominantly of declarative and procedural content knowledge. The teachers used topic specific instructional strategies such as context-based teaching, illustrations, peer teaching and analogues in diverse forms but failed to use models and individual or group experiments to assist students internalise concepts. Teachers lacked knowledge of students' genetics-related preconceptions. Mthetwe-Kunene *et al.* (2014) noted that teacher PCK develops through university education, professional development programs and experience in the classroom. This concurs with Hadiyanti *et al.* (2014) who observed that experienced Biology teachers demonstrated more PCK than prospective teachers. This emphasises the importance of experience in the development of PCK. Widodo (2016) studied experienced Biology teachers' PCK in teaching photosynthesis and noted that professional development programs should focus on PCK rather than separate content or pedagogy. Lucenario *et al*. (2016) assessed the impact of a PCK guided lesson study intervention in Chemistry and noted that a PCK guided lesson study intervention program was an effective method to develop the teacher' PCK competencies and students' achievement in terms of conceptual understanding and problem solving and recommended the use of the intervention program to Biology, Chemistry, Physics and Mathematics teachers.

Buma and Nyamupangedengu (2023) noted that the teaching of genetics was not effective in the promotion of scientifically acceptable understanding of genetic concepts. They used the topic specific PCK to bridge the gap. PCK resulted in planning and teaching that was pedagogically reasoned and of high quality and was perceived to enhance learning through proficient sequencing of concepts, well thought out instructional representations and learner prior knowledge. Mukaro and Stears (2017) noticed a misalignment between the intended and the implemented Biology Curriculum in Zimbabwe. This was attributed to teachers' misinterpretation of the intended curriculum. Since the introduction of the updated curriculum in 2016, the biology teachers' PCK has not been assessed. This study, therefore, seeks to evaluate the 'A' Level Midlands urban Biology teachers' PCK in Biodiversity in the updated curriculum as a measure to make curriculum implementation a success.

2.22 Summary

This chapter has explored related literature to the topic of concern. Literature on teacher PCK and justification for inclusion of Biodiversity in the curriculum was discussed. Nevertheless, there is no exclusive work as such that has been reported in the literature to the best of the researcher's knowledge that investigated Biology teacher PCK for the competence-based curriculum in Zimbabwe. Thus, the study fills this gap.

CHAPTER THREE

THEORETICAL AND CONCEPTUAL FRAMEWORK

3.1 Introduction

This Chapter presents the theoretical and conceptual framework adapted for this study. In this chapter, the theoretical and conceptual framework will be defined and explained, followed by a presentation of existing theories on teacher PCK, after which a conceptual framework for this study will be presented. Theoretical and conceptual frameworks guide the path of a research and ground it firmly in theoretical constructs. The two frameworks aim to make research findings more meaningful and acceptable to the theories in the research field of teacher PCK.

3.2 Theoretical Framework

A theoretical framework is a guide for a research based on existing theory in a field of inquiry that is related and/ or mirrors the hypothesis of study (Adom *et al.*, 2018). It is therefore a blueprint borrowed to build one's own research inquiry. Grant and Osanloo (2014) compared it to a map or travel plan to a particular location. A map guides one's path and similarly a theoretical framework guides a researcher to avoid deviation from the limits of the accepted theories and make the final contribution more scholarly and academic. The theoretical framework presents and describes the theory which explains why the research problem under study exists. It guides the choice of research designs and deepens the essence of study.

3.3 Conceptual Framework

A conceptual framework is a structure which the researcher believes can best explain the natural progression of a phenomenon to be studied (Adom *et al.*, 2018). It is therefore the researcher's explanation of how the research problem would be explored. The conceptual framework describes the main concepts of a study in a logical structure and provides a visual display of how ideas in a study relate to one another (Grant & Osanloo, 2014). The conceptual framework shows a series of actions that the researcher intends to carry out in a study. Ravitch and Carl (2016) considered a conceptual framework as a generative framework that reflects the entire research process. It highlights the main variables of a study and explains the relationships between them. A conceptual framework represents the researcher's synthesis of the literature on how to explain a phenomenon. It maps out the actions required in the course of the study, given the previous knowledge of other researchers' point of view and the researcher's observations on the subject of research. The hexagonal conceptual framework was adapted for this study. This conceptual framework takes into cognisance six key constructs that determine teacher PCK.

3.4 Adopted Theoretical Framework

A biology teacher differs from Biologist, not in terms of their content knowledge but by the way in which teachers transform their content knowledge to support their teaching and make complex and abstract concepts understandable to learners. Teachers have the ability to transform their content knowledge through the integration of various components of PCK, generate representations and design instructional strategies to engage students and make concepts understandable. Furthermore, assessment strategies used must effectively evaluate students' understanding, encourage their reflections and inform the next step in teaching. During the teaching of the topic biodiversity, the representations, instructional strategies, and assessments are designed specifically for that content and are topic specific. One cannot underscore the value of learners in teaching and learning; hence teachers must understand students as learners and be aware of students' misconceptions and potential learning difficulties associated with content. Park and Oliver (2008) emphasised the significance of teacher PCK and pointed out that it is a necessary base for effective teaching. Teaching for understanding is enhanced through the teachers' classroom experience and through connections made by the teacher between prior knowledge of learners and lesson content. Thus, PCK was coined out as an internal construct through which teachers codify their knowledge, content, students, instructional strategies, assessments, and curriculum into a retrievable form of knowledge for application to new challenges (Loughran *et al*., 2004). PCK is discussed by looking at models and factors that influence it and consequently influence learner understanding in the following sections.

3.4.1 Knowledge of teaching held by experienced teachers

Specialised knowledge, which teachers acquire through classroom practice has been equated to the unique knowledge acquired in practice driven professions such as medicine and law (Lee & Luft, 2007). A unique knowledge base of teachers is developed through classroom experience and allows teachers to engage in pedagogical reasoning and decision making that promote learning (Lee *et al*., 2007). Loughran *et al.* (2006) pointed out that teacher knowledge is not a solitary construct which resides within the individual but tends to be acquired and developed through professional socialisation. Hence, teachers continue to learn on the job with their knowledge grounded in daily experience. However, subject matter knowledge is critical to good teaching.

Magnusson *et al.* (1999) said teachers must be able to identify learner misconceptions and without a strong knowledge base, identification of learner misconceptions would not be possible. Ziedler (2002) emphasised on the importance of teaching experience and states that subject matter knowledge alone is insufficient for good teaching and that experience in the classroom greatly influences teachers' ability to transform their subject matter knowledge into a form more to be understood by learners. Hence, biology teachers have been differentiated from biologists or educational researchers not necessarily in the quality or quantity of subject matter, but in how that knowledge is organised and used (Cochran *et al*., 1991). Cochran *et al.* (1991) gave an example that experienced science teachers' knowledge of science is structured from a teaching perspective and is used as a basis for helping students to understand scientific concepts while a scientist’s knowledge basis is structured from a research perspective and is used as a basis for construction of new knowledge.

3.4.2 Models of teacher knowledge

Shulman (1986) introduced a model of teacher knowledge which identified a specialised form of knowledge unique to teachers and needed to successfully teach a concept in the most comprehensible manner. This specialised form of teacher knowledge distinguishes teachers from subject specialists and was coined out as PCK. Shulman identified the three domains of teacher knowledge as content knowledge, curriculum knowledge and PCK. He noted that as PCK develops, teachers transform their subject matter knowledge to enhance students’ understanding using the most powerful analogue, accurate representation and effective instructional strategies. In his model, Shulman emphasises the importance of curriculum knowledge i.e., knowledge of programs, resources, and instructional materials. Curriculum knowledge supports the formulation of connections between topics and builds upon students’ prior knowledge and provides necessary scaffolding for future learning. Shulman (1987) posited that the development of teacher knowledge involves a dramatic shifting in teacher thinking from a professional understanding of science content to an awareness of new ways to organise, represent and engage students in science learning. Grossman (1990) expanded on Shulman’s ideas and emphasised four general areas of teacher knowledge i.e., knowledge of subject matter, general pedagogical knowledge, knowledge of context and the centrepiece as PCK. Grossman (1990) further identified three components of PCK as conceptions of purposes for teaching subject matter, knowledge of students, instructional strategies, and curriculum. Magnusson *et al.* (1999) expanded on models by Shulman and Grossman. The trio proposed a PCK model similar to Grossman (1990) with two modifications i.e., the conceptions of purposes were changed to orientation towards science teaching, and they also added knowledge of assessment as a component of PCK. Thus, Magnusson *et al.* (1999) highlighted five components into their PCK model which will form the conceptual framework for this research. These are orientation towards science teaching, knowledge and beliefs about science curriculum, knowledge, and beliefs about assessments in science, knowledge and beliefs about students' understanding of specific science topics and knowledge and beliefs about instructional strategies in teaching science.

3.4.3 Orientation to science teaching

Magnusson *et al.* (1999) coined orientation to science teaching as the lens through which all components of PCK are understood, interpreted, and integrated resulting in the unique form of knowledge held by teachers. It acts as a conceptual map guiding decisions about learning objectives, implementation of curricular materials and evaluation of students' learning.

Magnusson *et al*. (1999) referred to knowledge of the science curricula as the teacher's understanding of the goals and objectives and the scope and sequence of the scientific concepts to be taught. Knowledge of students' understanding of science includes teacher knowledge of the requirements for student learning of specific scientific concepts and potential learning difficulties students may encounter. Knowledge of instructional strategies include topic specific strategies, for example, ways to present concepts (models, diagrams, pictures) and engage students in instructional strategies through investigations, experiments, demonstrations, and simulations to facilitate learning. Knowledge of assessment consists of knowledge of dimensions of science important to assess and knowledge of assessment strategies and methods through which students' learning can be assessed. The five components are influenced by the teacher's content knowledge and the context in which teaching is taking place.

Friedrischen *et al*. (2011) defined science teacher orientation construct as an interrelated set of beliefs consisting of beliefs about the purpose of science teaching, beliefs about science teaching and learning and beliefs about the NOS. Gess-Newsome (2015) identified orientations as one of the amplifiers that enable teachers to pass their topic specific professional knowledge through their lens, in conjunction with their beliefs, prior knowledge and context.

The refined consensus model identified three domains of teacher professional knowledge as collective, personal and enactment (Carson & Daehler, 2019). Collective PCK (cPCK) is a specialised knowledge held and shared by a broader community, in this case, science teachers (Shinana *et al*., 2021). Personal PCK (pPCK) is the cumulative and dynamic PCK and skills of an individual teacher that reflect the teacher's own teaching and learning experiences along with contributions of others. Enacting PCK (ePCK) is the unique knowledge that a teacher draws on during planning and teaching. Mazibe *et al*. (2020) further introduced the idea of reported PCK (rPCK) which is the knowledge that teachers portray in written or spoken format. Carlson and Daehler (2019) highlighted that teachers' pPCK in teaching science is developed, shaped, and refined over time through formal education, teaching experiences and professional sharing. In the current study, enacted PCK was evaluated.

Topic-specific PCK is the understanding that offers the necessary knowledge for subject-matter knowledge (SMK) transformation in a specific topic (Mavhunga & Rollnic, 2011). The concept of topic-specific PCK is based on the understanding that one of the main aspects in the construction of PCK is the transformation of subject-matter knowledge. For teachers with high quality PCK, each topic is transformed as teachers reason about its teaching (Shulman, 1987). When a specific topic is thought through, certain topic specific components of PCK are considered. These are learners' prior knowledge that is the knowledge of conceptions and preconceptions that students bring with them, curriculum saliency (the ability to identify the big ideas of a topic, to sequence them and realise their importance), what makes the topic easy or difficult to understand, representations including powerful examples and analogies and conceptual teaching strategies (knowledge of teaching strategies most likely to be fruitful)

(Rollnic *et al*., 2017; Mavhunga & Rollnic, 2011; Mavhunga, 2018). The knowledge domain in this topic specific PCK model was integrated in the current conceptual framework.

Park & Chen (2012) proposed a pentagonal PCK model in which teacher PCK was evaluated using five components. These are orientations towards science teaching, knowledge of student understanding, knowledge of instructional strategies and representation, knowledge of science curriculum and knowledge of assessment in science learning. The pentagonal model defines PCK as an integration of components that are mutually related to each other. It presents the components in a pentagonal form to emphasise the interrelatedness among them. This research used the hexagonal PCK model, adapted from the pentagonal model and the topic specific PCK model (Mavhunga & Rollnic, 2011). After going through the PCK models from Park and Chen (2012) and the topic specific PCK model by Mavhunga and Rollnic (2011), I developed a hexagonal PCK Model by adding content knowledge as a sixth key construct contributing to teacher PCK.

3.5 PCK Conceptual Model Used In This Study

The hexagonal conceptual framework was used in this study. It considers six aspects as determinants of teacher PCK as shown in Fig 3.1.

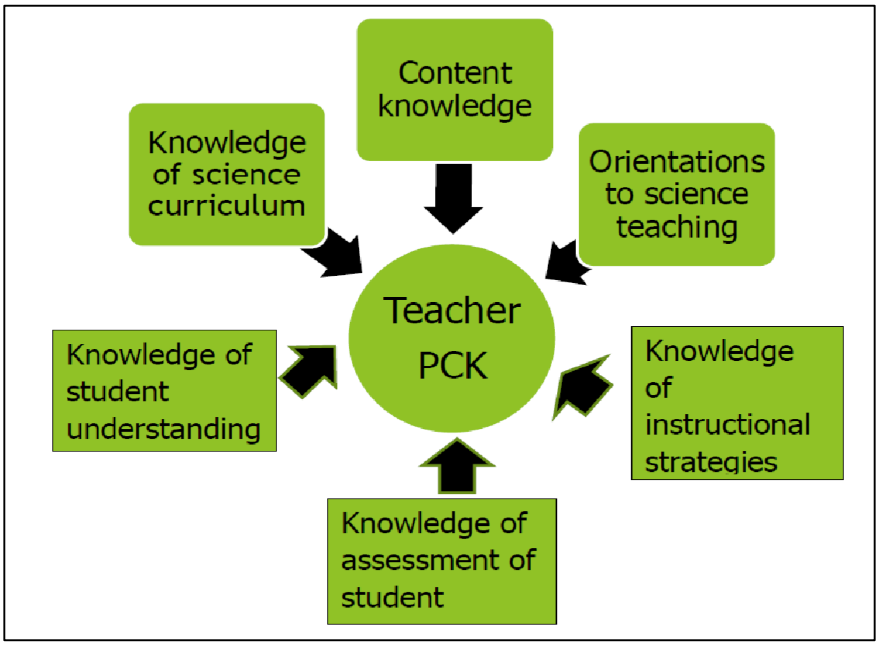

Figure 3.1 Hexagonal PCK model used in this study

PCK is influenced by six factors as illustrated in Fig 3.1. These are content knowledge, orientations to science teaching, knowledge of the curriculum, knowledge of instructional strategies, knowledge of student understanding and knowledge of assessment. These factors are viewed as important in teacher PCK development, however this model emphasised the role of content knowledge in PCK development and in the development of the other concepts.

3.5.1 Key construct 1: Content knowledge

Content knowledge is described by Chang *et al*. (2020) as a body of knowledge and information that teachers teach and that learners are expected to know. Santau *et al*. (2014) noted a direct correlation between teacher CK and effectiveness in teaching science. Insecure CK affects the teacher's ability to give appropriate and effective science teaching explanations. Kaifa et al., (2023) noted that scantiness of CK affects the teacher’s ability to effectively teach science because teachers cannot teach what they do not know. Teacher content knowledge is influenced by the five factors identified in Fig 3.2 as concept coverage, appropriateness of concepts, scientific accuracy of concepts, links with NoS and links with other concepts (Carpendale & Hume, 2019).

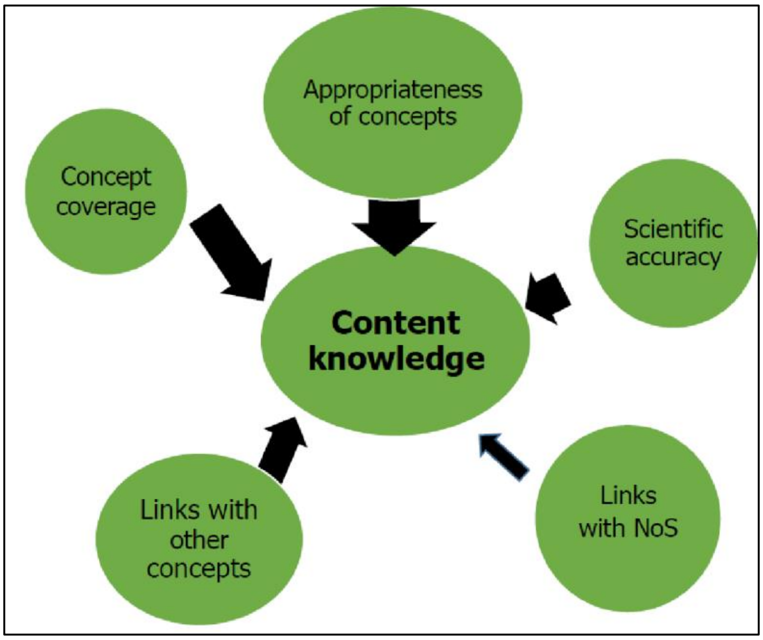

Figure 3.2. Determinants of teacher content knowledge (Carpendale & Hume, 2019)

3.5.2 Key construct 2: Teacher knowledge of the curriculum

This hexagonal conceptual framework underscores the significance of teacher knowledge of the curriculum. Teachers as the mediators between the curriculum and the learners need a deep understanding of the goals and objectives for learning science, the scope and sequence of scientific concepts as well as resources and materials needed for effective science teaching and learning. This saves as a map giving the teacher direction during the teaching and learning of science. Fig 3.3 shows the factors influencing teacher curriculum knowledge, that is, the appropriateness of goals and objectives, interconnections with other topics and with other disciplines (Carpendale & Hume, 2019).

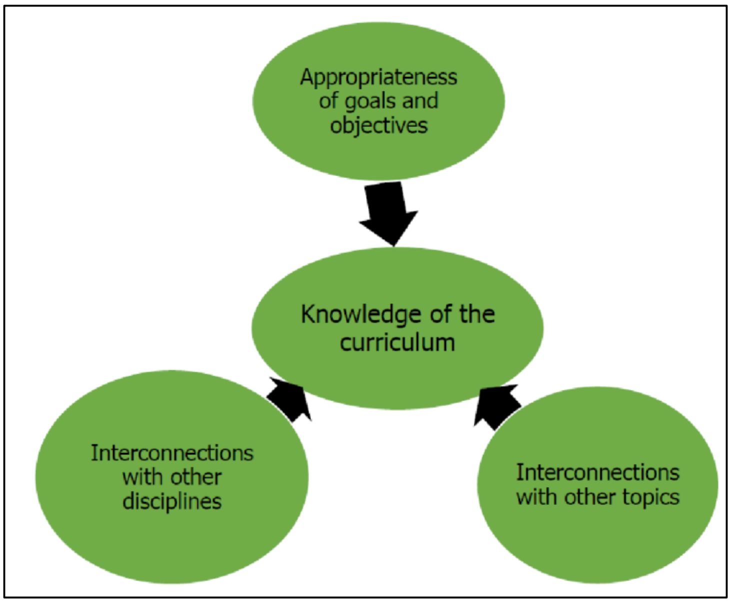

Figure 3.3 Determinants of teacher knowledge of the curriculum adopted (Carpendale & Hume, 2019).

3.5.3 Key construct 3: Science teaching orientations

The hexagonal conceptual framework outlines the need for solid orientations to science teaching for development of high levels of teacher PCK, and the relationship between their knowledge, beliefs and practice (Abell, 2004). Science teaching orientations act as filters and amplifiers in shaping teachers' overall classroom behaviour. The orientation to science teaching was rooted in the constructivist point of view in which learners are active participants in their learning. Teaching and learning must allow learners to make sense of new ideas by reflecting upon their experiences with the phenomenon. During lesson observation, for example, researchers may evaluate the lesson against the 5Es model, i.e., if the teacher managed to engage, explore, explain, elaborate and evaluate, or PBL, or POE inquiry-based learning among other constructivist models. Science teaching orientations are determined by the teacher's beliefs about the purposes of teaching science, beliefs about the NoS and beliefs about science teaching and learning as shown in Fig 3.4 (Carpendale & Hume, 2019).

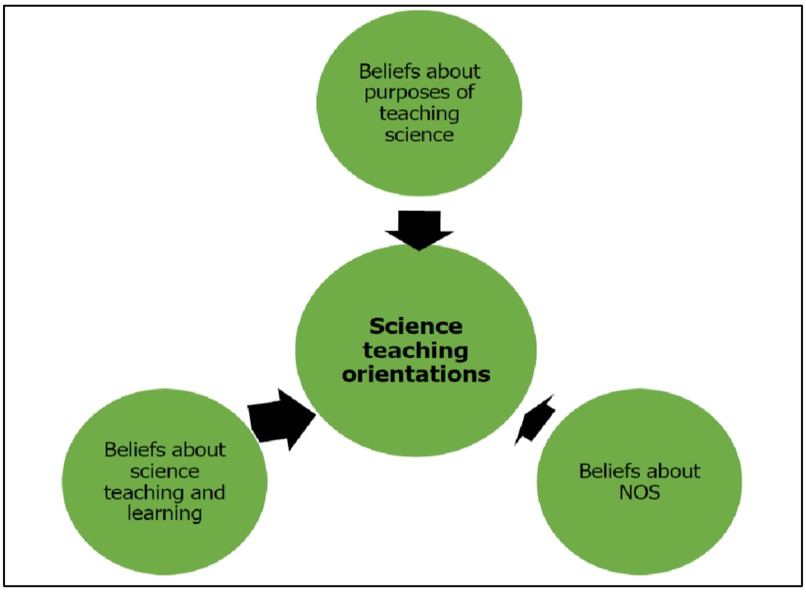

Figure 3.4 Key constructs for science teaching orientations (Carpendale & Hume, 2019)

3.5.4 Key construct 4: teacher knowledge of student understanding

Teacher knowledge of students has been recognised as a noteworthy factor in promoting effective instruction (Hill & Chin, 2018). Such knowledge is thought to enable diverse effective classroom strategies, which include altering the pace of instruction to suit the students' need (Clark & Peterson, 1986) and creation of appropriate instructional groups based on knowledge of students. The teaching profession as a clinical practice profession calls for determination of the most appropriate course of treatment for each learner and requires knowing every individual learner. This can be through observation, questioning and other diagnostics or evidence collection techniques, as well as knowing what research has shown to work with learners in similar situations. Hence, teachers need a deep understanding of their learners and excellent decision making for quality PCK. Teachers must recognize learners' prior knowledge, difficult concepts, and misconceptions. Teachers must be able to ask questions to extend learner understanding, as well as use the variations in students' understanding to guide instruction as shown in Fig.3.5 (Carpendale & Hume, 2019).

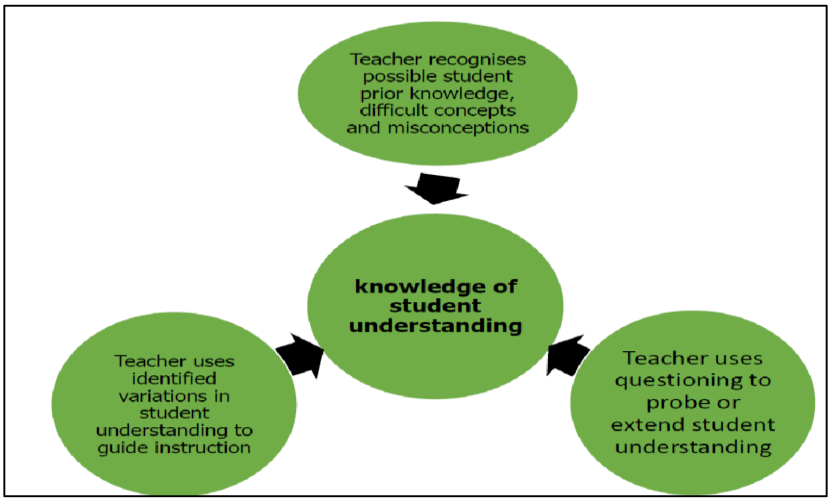

Figure 3.5 Determinants of teacher knowledge of students understanding (Carpendale & Hume, 2019).

3.5.5 Key construct 5: Teacher knowledge of instructional strategies

Teachers need to develop and utilise instructional strategies to promote students' metaconceptual awareness and engage in learning to promote conceptual change. These include any type of learning technique a teacher uses to help students gain a better understanding. Such instructional strategies allow teachers to make the learning experience fun and encourage students to take a more active role in their education and is a determinant of teacher PCK. Fig 3.6 shows that there is a need for appropriate sequencing of concepts, use of strategies that allow learner understanding and use of relevant examples or representations that stimulate student understanding (Carpendale & Hume, 2019).

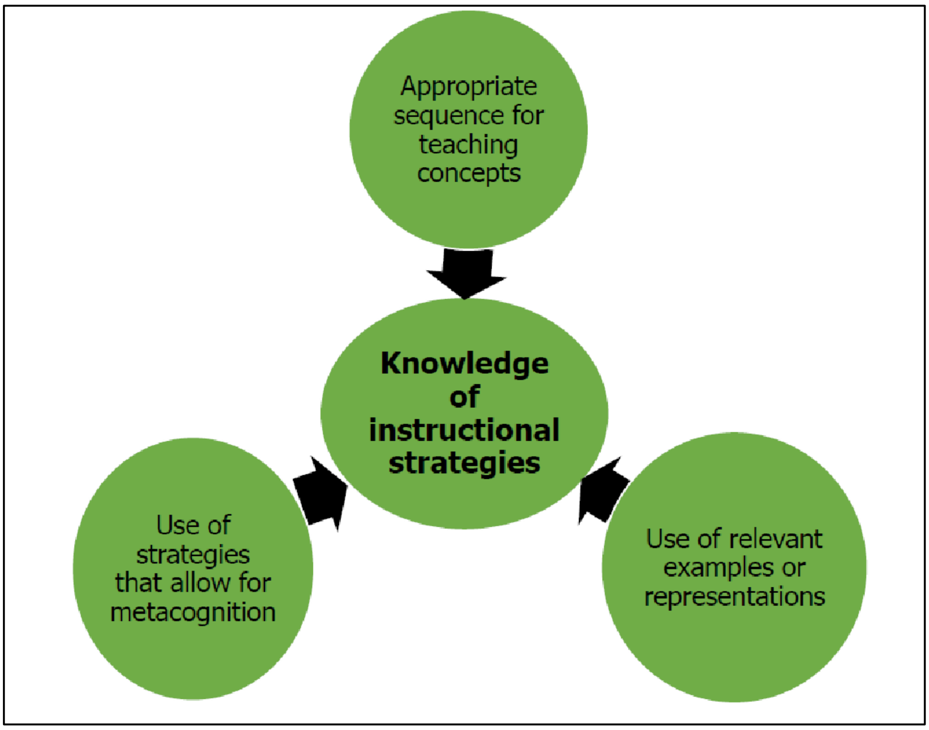

Figure 3.6 Determinants of teacher knowledge of instructional strategies (Carpendale & Hume, 2019).

3.5.6 Key construct 6: Knowledge of assessment

For effective science instruction, science teachers need to know what to focus on to ensure that their assessment of student learning is meaningful and useful for the students' on-going learning and development. Education assessment involves teachers applying their understanding of how students develop skills and knowledge, attitudes, and values in a subject domain (Edwards, 2013). This component of PCK consists of knowledge of the dimensions of science learning important to assess and knowledge of assessment strategies and methods through which students' learning can be assessed (Magnusson *et al.*, 1999) as shown in fig. 3.7.

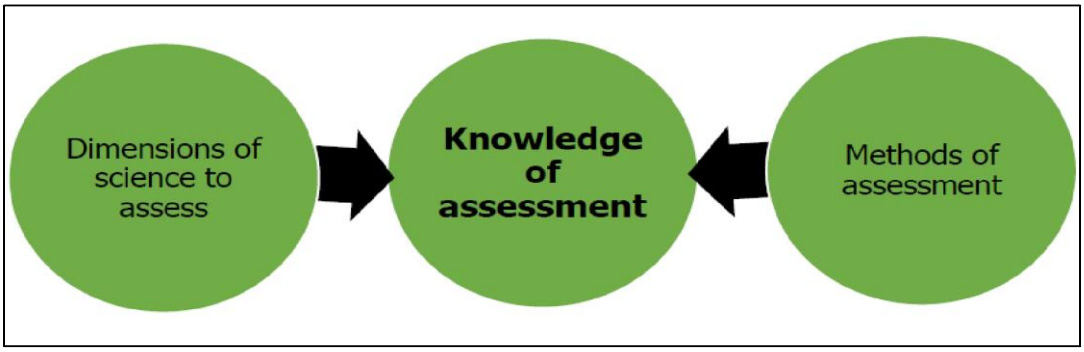

Figure 3.7 Determinants of knowledge of assessment

This research has four objectives, to determine the needs of the ‘A’ level Biology curriculum, to establish the ‘A’ level Biology teachers PCK in teaching Biodiversity, examine why teachers exhibit observed levels of PCK and to design an instructional model for teaching the topic, Biodiversity. To respond to objective 1, an in-depth content analysis of the ‘A ‘Level Biology syllabus was carried out. Having established the demands of the syllabus, lesson observations were used to establish teacher PCK. Questionnaires for teachers and learners, as well as teacher interviews were used to cross validate findings from lesson observations (Carpendale & Hume, 2019) as shown in Fig 3.8.

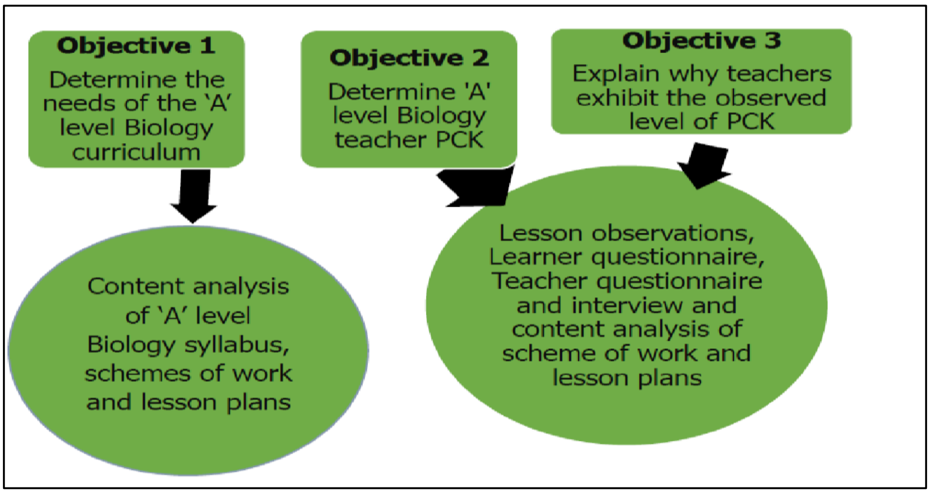

Figure 3. 8 Activities that were carried out to meet research objectives

3.6 Summary

The chapter defined and explained the theoretical and conceptual framework. The theories in teacher PCK were discussed and a conceptual framework for this research was mapped based on the main constructs of the teacher PCK. A series of activities the researcher undertook were also highlighted.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 Introduction

This chapter discusses the research paradigm, research design, population, sample, and sampling techniques. A full discussion of the instruments and data collection procedures is given. The chapter also presented an outline of the data analysis process, limitations, and the ethical considerations.

4.2 Research Paradigm

A research paradigm is described as a collection of shared beliefs and agreements among scientists regarding how problems should be understood and addressed (Kuhn, 2012). The word paradigm is used in educational research to describe a researcher's ‘worldview’ (Mackenzie & Knipe, 2006). This worldview informs the context or perception of research data by providing a viewpoint, reasoning, school of thought or collection of common beliefs. It is made up of abstract beliefs and values that form how a researcher perceives the world, as well as how he or she interprets and behaves in it (Kivunja, 2017). When someone claims that a framework determines the researcher's worldview, they are referring to the abstract values and concepts that form how a researcher sees the world, interprets it, and acts within it. It is the frame of reference from which a researcher examines the universe. It is the conceptual lens through which the researcher explores the methodological aspects of their research project to evaluate the research techniques to be used and the data to be analysed. Paradigms are therefore human constructs that deal with first principles that indicate where the researcher is coming from to create meaning from data. Thus, paradigms are significant because they include beliefs and dictates that influence what should be studied, how it should be studied, and how the study's findings should be interpreted for scholars in a particular discipline. A researcher's philosophical orientation is the paradigm. Epistemology, ontology, methodology, and axiology are the four components of a paradigm (Kivunja, 2017). Ontological questions are ‘What is reality? What is the nature of the “knowable”? Or what is the nature of reality?’ Epistemology is used to describe how we come to know something; how we know the truth or reality (Cooksey & McDonald, 2011). Epistemological questions include ‘How do you know something? What is the nature of the relationship between the knower (inquirer) and known (or knowable)? Methodology is the term used to refer to the research design, methods, approaches and procedures used in an investigation. Methodological questions include, ‘How do you go about finding it out? How should the inquirer go about finding out knowledge? Axiology refers to ethical issues that must be considered when planning a research proposal (Kivunja, 2017). It involves defining, evaluating, and understanding concepts of right and wrong behaviour relating to the research. This research adopts an interpretivist research paradigm. It focuses on interpretation of elements of study (Alharahsheh & Pius, 2020). It is a sociological method of research in which an action or event is analysed based on the beliefs, norms and values of the culture in which it takes place (Kivunja, 2017).

4.3 Qualitative Research

To understand ideas, thoughts, or perceptions, qualitative research includes gathering and evaluating non-numerical data (e.g., text, video, or audio) (Maxwell, 2012). It can be used to gain in-depth understanding of an issue or to generate new research ideas. Qualitative analysis is used to learn about people's perspectives on the environment. Although qualitative analysis has a variety of methods, they all concentrate on maintaining rich meaning when analysing data (Mannay *et al*., 2020). Since all findings, perceptions, and evaluations are filtered through their own personal lens, qualitative researchers often refer to themselves as "instruments" in science. Qualitative research is a form of social inquiry that examines how people perceive and make sense of their lives and the world around them (Cresswell *et al*., 2007). The goal is to investigate people's actions, perceptions, emotions, and experiences, as well as what is at the heart of their lives. The interpretive approach to social reality and the interpretation of human lived experiences form the foundation of qualitative research. Qualitative study is context-dependent, so researchers must be aware of their surroundings. Researchers immerse themselves in the natural environment of those whose thoughts and emotions they want to investigate. Qualitative researchers concentrate on the emic viewpoints, the perspectives of the people participating in the study, and their experiences, definitions, and interpretations (DeJaeghere, 2020). They explain, analyse, and interpret (Cresswell *et al*., 2007). The researcher and the subject of the study have a close friendship that is founded on dignity. Qualitative researchers are interested in learning how people create meaning, or how they make sense of the environment and the interactions they have in it.

PCK is subjective, context specific and not readily communicated other than by demonstration (Nind, 2020). Teachers' PCK is, to a large extent, unarticulated and hidden ('tacit') in nature (De Jong, 2016). While PCK is about translating content knowledge to become knowable to students, researching PCK also involves a process of translation to make it knowable, hence qualitative research methods can unveil the tacit teacher PCK. Lee and Luft (2008) pointed out that a case study approach is appropriate to capture PCK and this enables instructional decision making to be explored in situ (Oleson & Hora, 2014). Hence, the present research adopts the qualitative approach to research as it is appropriate in explaining the teacher's PCK in the topic on Biodiversity. In this qualitative approach, the research used qualitative methods which include interviews, questionnaires and observations. All these are informed by the constructs within the conceptual framework, Fig 3.1, which states that there are six factors influencing teacher PCK that is, content knowledge, knowledge of students, knowledge of the curriculum, orientations to science teaching, knowledge of assessment and knowledge of instructional strategies.

4.4 Case Study Research Design

A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context where boundaries between the phenomenon and context are not clear, and in which multiple sources of evidence are used (Yin, 2012, 2018). A case study is an approach to research that focuses on gaining an in-depth understanding of a particular entity or event at a specific time. A case study is therefore a general term for the exploration of an individual or group or phenomenon. It is a systematic inquiry into an event or a set of related events which aims to describe and explain the phenomenon of interest. It gives a comprehensive description of an individual case and its analysis, that is, the characterization of the case and the event.

Case studies are used to analyse and describe, for example, a person individually. The unit of analysis can vary from an individual to a corporation. The case study is useful to employ when there is a need to obtain an in-depth appreciation of an issue, event, or phenomenon of interest in its natural real-life context (Hollweck & Yin, 2014). It involves determining what the investigated case may be and not about defining populations and selecting appropriate samples (Starman, 2013). Case studies allow for the researcher to closely examine data within the specific context (Zaina, 2007), in most cases a case study selects a small geographical area or a very limited number of individuals as the subjects of study. They are highly useful in exploring and investigating contemporary real-life phenomena through detailed analysis of a limited number of events or conditions and their relationships. It is a unique way of observing any natural phenomenon which exists in a set of data subjects in detail. Zaina (2007) highlighted that a researcher can adopt a single or multiple case study design depending on the issue in question. Yin (2018) noted three categories of case studies namely exploratory, descriptive, and explanatory. An exploratory case study is set to explore any phenomenon in the data which serves as a point of interest to the researcher, while descriptive case studies are set to describe the data as they occur and finally the explanatory case studies examine the data closely both at surface and deep level to explain the phenomenon in the data. This study adopted a single case study in which teachers' PCK on Biodiversity was studied.

4.1.1 Advantages of case study design

Data is examined within the context of its use, within the situation in which the activity takes place (Hollweck & Yin, 2014). For example, in studying teacher PCK in Biodiversity, the researcher will have to observe and record lessons in the environment the teacher deems necessary to teach the topic from. In terms of intrinsic, instrumental, and collective approaches, case studies allow for both quantitative and qualitative analysis. The detailed qualitative analysis accounts produced in case studies not only help to explore or describe the data in a real-life environment, but also help to explain the complexities of real-life situations which may not be captured through experimental or survey research (Yin, 2018).

4.1.2 Disadvantages of case study design

Yin (2012) pointed out that case studies are accused of lack of rigour. The investigator can be sloppy and allow equivocal evidence or biased views to influence the direction of findings and conclusions. Case studies also provide little basis for scientific generalisation since they use a small number of objects (Hollweck & Yin, 2014). The common question asked is how can you generalise from a single case? Another shortcoming of case study design is the fact that they are long, difficult to conduct and produce massive amounts of documentation. The danger comes when the data is not managed and organised systematically. However, case study design allows for the deployment of diverse instruments (Yin, 2018). These include content analysis, observations, questionnaires, and interviews.

4.5 Population

A population is defined as all members of any well-defined class of people, events, or objects. It is a collection of specified groups of human beings or of non-human entities such as objects, educational institutions, time units and geographical areas drawn by individuals. The study population consisted of ‘A’ Level Biology teachers and learners in Midlands urban. The researcher is based in Midlands; hence choice of Midlands urban was a cost cutting measure.

4.6 Sample

The research was a qualitative study focusing on gaining an in-depth understanding of teacher PCK. The sample consisted of four ‘A’ Level Biology teachers and their learners.

4.7 Sample Selection

Sampling is the process of selecting a representative part from the population. This study employed purposive sampling, a non-probability sampling technique, to select participants to select Biology four teachers and their learners. Purposive sampling allowed for intentional selection of ‘A’ level Biology teachers with experience in teaching the topic, Biodiversity and willingness to share their teaching practices and experiences. Kaifa *et al*. (2023) noted that purposive sampling is used to gather information rich sources related to the phenomenon under study, hence the four teachers were selected as information rich sources.

4.8 Pilot Study

The purpose of the pilot study was to test the suitability of instruments and to provide the opportunity to modify the instruments if necessary. The pilot was conducted with participants from a school that did not participate in the research. The purpose was to identify shortcomings of the questionnaires and observation guide before administration to the actual participants of the research. In the initial questionnaire, teachers complained that the questionnaire was too long. Some of the teachers did not find time to complete the whole questionnaire. The researcher with the help of the supervisor had to identify key questions according to the constructs from the conceptual framework and reduce the number of questions.

The interview was not piloted as it was difficult to anticipate how the teachers would respond to the different items of the interview schedule. Some questions arose as a follow up to the questions posed before. However, a thorough discussion of the items included in the interview schedule was done with the assistance of my supervisors and other experienced researchers.

4.9 Methodology

A qualitative research approach was used. The case study research design was adopted, and the unit of analysis was Biology teacher PCK. To ascertain the needs of the 'A' Level Biology syllabus, content analysis was used. Thereafter, five consecutive lesson observations were made for each teacher and relevant data was captured using an observation guide formulated using the six key constructs in the Analytical framework. Lessons were audio recorded to allow for play back and capturing of all data. Teacher interviews and questionnaires as well as learner questionnaires were administered to ensure reliability of data. Interview guides and questionnaires were also constructed using the six constructs in the Analytical framework. Learner questionnaires were administered to authenticate the data collected from lesson observations and teacher interviews. The use of these various data collection instruments was intended to cross validate the findings and improve the trustworthiness of the research.

4.10 Data Collection Procedure

Data collection refers to the systematic gathering and measuring of information of research interest, which enables the researcher to answer stated research questions (Creswell, 2009; Vos *et al*., 2013). To ensure that the research questions are properly answered, emphasis should be placed on ensuring accurate and honest collection of data. The capturing of quality evidence can then translate into rich data analysis which will allow the construction of a convincing and credible answer to the research questions.

The data collection procedure involved several critical stages to ensure conformity to the principles of research. The researcher requested for an ethical clearance from the Bindura University of Science Education ethics committee, and it was granted. The researcher then requested for permission to carry out research from the Ministry of Primary and Secondary Education. After the permission was granted, the researcher went on to request for permission to carry out research from Midlands Education Provincial office and the respective district offices in which the teachers are stationed. After the permission was granted, the researcher requested for permission from the school heads and the teacher participants. The researcher explained to all participants that their participation was voluntary and that they could with draw anytime they felt they could no longer continue. Confidentiality was guaranteed to all participants and the participants signed the consent forms. A pilot study was carried out to test the suitability of the research instruments and the allowed the researcher to modify the instruments. This was done at a school that did not participate in the study.

Following the pilot study, data was gathered using a variety of techniques. In this regard, the researcher's first of data collection instrument was content analysis of the syllabus with regards to the topic, Biodiversity, to ascertain its needs. This was followed by five consecutive lesson observations. After the lesson observations, the researcher interviewed each teacher participant. Teachers and learners were then asked to complete their respective questionnaires. The data collection process considered Creswell's (2009) view that data needed to be collected by the researcher closely linked to the research, hence, instruments were designed with a close introspection of the conceptual framework and the research questions. The data was analysed by a PCK analytical framework formulated from Carpandle & Hume (2019).

Table 4.1 below shows a synopsis of the relationship between the methodology and research questions and the kind of data generated to answer the research questions. An attempt was made to match the respective method of data collection to the data collected.

Table 4.1 A synopsis of the methodology and data collection instruments

	Research question	Method	Instrument	Data
Curriculum demands	What does the 'A' level Biology Curriculum demand of the topic biodiversity?	Content analysis	Content analysis using a rubric	'A' level aims and objectives, aims and objectives of the topic Biodiversity, concepts covered, skills and the emphasis given to the concepts, instructional media and strategies recommended for teaching Biodiversity.
PCK	How do 'A' Level Biology teachers teach the topic Biodiversity?	Lesson observations Questionnaires Interview	Observation guide Teacher questionnaire Learner questionnaire Teacher interview guide	Teachers' content knowledge, knowledge of the curriculum. knowledge of learners, knowledge of instructional strategies, knowledge of assessment and science teaching orientations
PCK	Why do 'A' Level Biology teachers teach the topic, Biodiversity in the way they do?	Lesson observation Teacher workbooks Questionnaire Interview	Observation guide Interview guide Questionnaires	Data collected was used to come up with propositions to explain why teachers teach the topic in the way they do.
PCK	What instructional model can be used to improve teacher PCK in Biodiversity?	Content analysis Lesson observations Interviews Questionnaires	Observation guide Interview guide Questionnaires	Data gathered from all data collection instruments, discussions and conclusions was used to design a model for teaching the topic, Biodiversity.

4.11 Discussion of Techniques And Instruments

4.11.1 Document analysis

A systematic technique for assessing documents in the form of printed or electronic resources is known as document analysis (Corbin & Straus, 2008). Data must be reviewed and evaluated in qualitative research to gain meaning, comprehension, and empirical knowledge**.** To allow for triangulation, document analysis is frequently supplemented with other qualitative research methods such as interviews, observation, and questionnaires. The researcher can corroborate across data sets by reviewing information acquired through several instruments, which reduces the risk of bias on the researcher's part. Triangulation protects a study's conclusions from being dismissed as a result of a single method, single source, or single investigator.

Bowen (2009) pointed out that document analysis is less time demanding because it requires data selection rather than data collection. When compared to other methods of data collection for research, document analysis is more cost effective. Documents encompass a wide range of events and situations. The researcher must skim, read, and interpret the document while using document analysis as a data collection method. It is necessary to use a combination of content and thematic analysis techniques (Mukaro & Stears, 2017). Content analysis entails categorising information in accordance with the research issues to be addressed. Thematic analysis is the process of grouping data into themes to address a specific research topic.

Corbin and Straus (2008) emphasised the relevance of a researcher's ability to distinguish between relevant and irrelevant material. However, certain papers may provide insufficient information because they were not meant for research purposes, and some documents may be classified, resulting in limited access and the lack of linguistic skills of the person who created the document. Despite these flaws, document analysis continues to be significant sources of information that can help researchers solve research problems.

Bowen (2009) emphasised that, though documents can be a valuable source of data, researchers should examine them critically and use caution when using them. Documents should not be regarded as exact, comprehensive, or accurate accounts of events. Bowen cautioned scholars against copying and pasting phrases and portions from texts into their studies, instead they should establish the document's significance and contribution to the topic at hand. The legitimacy, reliability, accuracy, and representativeness of selected documents should be determined by researchers.

4.11.2 Content analysis

Content analysis is a research instrument used to determine the presence of certain words, themes, or concepts within some given qualitative data. By content analysis, researchers can quantify and analyse meanings and relationships of certain words, themes, or concepts (Roller & Lavrakas, 2015). Content analysis rests on the assumption that texts are a rich data source with boundless potential to reveal treasured information about phenomena and can either be manifest content analysis or latent content analysis (Kleinheksel *et al*., 2020). Manifest content analysis is concerned with data that are easily observable both to researchers and the coders who assist in their analyses, without the need to discern intent or identify deeper meaning (Kleinheksel *et al.*, 2020). Latent content analysis on the other hand is most often defined as interpreting what is hidden deep within the text (De Leo *et al*., 2023). In this case, manifest content analysis was applied to analyse the syllabus demands of the topic Biodiversity. To analyse the content for the topic Biodiversity using content analysis, the text was coded, or broken down, into manageable code categories for analysis (i.e., codes or concepts). Hence, themes were used to address the Research Question 1.

4.11.3 Observation

Observation is a method of gathering information through observing people, events, or physical qualities in their natural environment. Direct or indirect observation is possible. Direct observation occurs when the researcher observes processes, interactions, or behaviours as they occur, whereas indirect observation occurs when the researcher observes the outcomes of processes, behaviours, or interactions (Creswell, 2013). Observations can be overt (subjects are aware they are being watched) or covert (subjects are unaware they are being watched) (do not know they are being watched) (Fekete *et al*., 2021). As the name implies, observation is a method of gathering facts through observation**.** Because the researcher must immerse herself in the setting where her respondents are while taking notes and/or recording, observation data collecting is classified as a participatory study. Observation can be structured or unstructured as a data collection approach (Tight, 2022).

Data is collected using certain variables and on a predetermined schedule in structured or systematic observation. Unstructured observation, on the other hand, is carried out in an open and unstructured manner, with no predetermined variables or goals. The advantages of observations include direct access to study phenomena, high levels of application flexibility and creation of a permanent record of events (Tight, 2022). Observation, on the other hand, has the disadvantages of requiring more time, having a high level of observer bias, and having an impact on primary data, in the sense that the presence of an observer may alter the behaviour of sample group elements. It is worth noting that the observation data collection approach may be linked to some ethical concerns. One of the most basic ethical considerations for researchers is to obtain fully informed permission from research participants. At the same time, if sample group members are informed of the observer's presence, their behaviour may change, which could have a detrimental impact on the research validity.

For this research, the researcher carried out five lesson observations for the selected teachers teaching the topic Biodiversity. The position of the researcher was a complete observer who entered the setting but remaining detached from the activities and social interactions of the research participants. A structured observation guide allowed for the researcher to capture all important aspects according to the conceptual framework. This enabled the researcher to respond to research question 2, how do ‘A’ level Biology teachers teach the topic Biodiversity? The lesson observation guide was constructed using the six key constructs of the conceptual framework, Fig 3.1.

4.11.4 Interviews

Interviews are adaptable data collection tools that make use of a variety of sensory inputs, both verbal and nonverbal (Husband, 2020). It is a one-on-one conversation with an individual that uses a series of questions to elicit detailed responses. An interview is a conversation in which one person (the interviewer) elicits information from another person (the subject or interviewee). Interviewer records the respondent's oral responses as the interview progresses. It allows the interviewer to probe for greater depth or explanation (Foley *et al.*, 2021). Interviews provide people the opportunity to express themselves in their own words. Frowns or any other gestures can also be captured as expressed attitudes or opinions by researchers. The information gathered must be transcribed to be analysed (Harrison *et al.*, 2020. Structured, semi-structured, and unstructured research interviews are the three basic categories of interviews (Harrison *et al*., 2020). Interviews provide more in-depth data from the interviewee since they allow the interviewee to be probed about their values, beliefs, attitudes, and preferences through direct interactions with the interviewer (Foley, 2021). The interviewer, on the other hand, must be conscious that interviews take time and require careful preparations. Interviews are also prone to prejudice on the part of the interviewer, and participants may not feel at ease with them in some instances. As a result, to triangulate the data, interviews must be used in conjunction with other types of data gathering tools.

In unstructured interviews open-ended inquiries are asked by the interviewer (Cohen *et al.*, 2011). Both the interviewee and the interviewer must maintain their composure as they freely communicate to generate data for the study. The interviewer asks open-ended questions to which the interviewee has complete freedom to react. The direction of the interview is set by both the interviewer and the interviewee; therefore, it is not predefined. Questions cannot be standardised since they may generate unexpected data that is highly beneficial to the investigation. Although the degree of inquiry can be modified to suit a given environment, unstructured interviews are time intensive and difficult to analyse.

Semi-structured interviews incorporate unstructured and structured interviewing techniques, as well as closed and open-ended questions. Core questions are prepared ahead of time to guide the interview's direction, which is crucial to maintain the interview's focus (Husband, 2020). Participants, on the other hand, are free to elaborate on pertinent facts to the question.

Focus group interviews entail group discussion and hence may be unable to provide structure to the group. Rich data, on the other hand, can come from the interaction of the group's members (Cohen *et al.*, 2007). The benefit of this form of interview is that it can uncover concerns that were missed in individual interviews. Individuals are encouraged to think about things they might not have considered during individual interviews because of the encounter.

Stimulated recall is a study strategy that invites participants to recollect their concurrent thoughts during an event when encouraged by a video sequence or another kind of visual or audio recall. Stimulated recall is a subtype of introspective research methodologies that taps into participants' observations on mental processes and has philosophical and psychological roots (Mackey & Gass, 2005). Benjamin Bloom is credited with the first description of "stimulated recall" in 1953, which he characterised as a way for recalling memories, according to Slough & Chamblee (2007). Stimulated Recall has been utilised in numerous studies to examine classroom practice and interaction (Sime, 2006; Stough, 2001). Stimulated Recall interviews are utilised to get a better understanding of how working memory operates (Beers *et al.*, 2008). One advantage of this method is that participants can justify their decisions. In recall sessions, using multimedia sources provides the advantage of replaying and reintroducing clues that were present throughout the task (Sime, 2006). Stimulated Recall also allows for the incorporation of real-world context. When used in conjunction with "well developed research designs' (Mackey & Gass, 2005; Sime, 2006) and a recall session held as soon as possible after the incident, it is a helpful tool.

This study used semi structured interviews. Semi structured interviews allow for open ended responses from participants for in depth information. The interview guide was constructed using the key constructs in the conceptual framework.

4.11.5 Questionnaire

A questionnaire is a tool for gathering and recording information on a topic of interest. According to Anderson (2004), questionnaires are one of the most extensively used data collection instruments in research, and they can be used to examine behaviour, attitude, beliefs, traits, and a variety of other variables. A questionnaire is a set of written, logical questions that are provided to respondents (Sharma, 2022). Respondents write what they believe is the most appropriate response to the question on a piece of paper. Self-distribution and self-collection of surveys is recommended to achieve a high return rate. Low response rates are common with posted questionnaires. Questionnaires should always have a specific goal in mind that relates to the research questions. One of the benefits of using questionnaires in research is that most people are familiar with them, and only a small percentage of people may require assistance in filling them out (Harrison *et al.*, 2020). In the majority of circumstances, completing the questionnaire is simple and quick. The questionnaire, on the other hand, must be straightforward in order for research participants to find it easy to complete. Questionnaires/surveys also have the advantage of reaching out to many people at once. However, there are certain drawbacks to using surveys. For example some respondents may refuse to take the survey because they do not want to give information that they believe will benefit them. Respondents may provide misleading information in some instances (Sharma, 2022). If the researcher forgets to ask a crucial question, it is impossible to go back and ask it after the questionnaire has been sent out to the respondents. The main flaw is that respondents can interpret questions in ways that differ from what the researcher expects.

In the present study, questionnaires were designed for the teachers and students that helped the researcher to respond to research questions 2 and 3. Data collected was triangulated with data from observations and interviews.

4.12 Data Presentation

Data was presented using themes derived from the key constructs in the conceptual framework. Tables with narrations and verbatim were used to present data.

4.13 Data Analysis

Six key constructs were identified as teacher content knowledge, knowledge of students, knowledge of assessment, science teaching orientations, knowledge of the curriculum and knowledge of instructional strategies. These formed the basis for data analysis. The Analytical framework was adopted from Carpandle & Hume (2019). However, for all the key constructs, sub-constructs have been identified that are a prerequisite to the development and analysis of each key construct. These were used to evaluate the teacher level of each key construct. Analysis of individual key constructs were done separately and used in the evaluation of teacher PCK.

Teachers' levels of each of the sub- constructs were categorised as limited, basic, proficient, and advanced according to the teacher's ability to exhibit certain attributes indicated in the analytical table for the key construct. The teacher's levels of knowledge for each key construct were categorised as inadequate, adequate, and advanced, based on the observed levels of the sub-constructs as shown in the evaluation tables for each key construct.

4.13.1 Analysis of content knowledge

Table 4.2 Analytical framework for teacher content knowledge

Content knowledge				
Constructs	**Limited**	**Basic**	**Proficient**	**Advanced**
Concepts coverage	Misses any concepts stipulated by the syllabus	Covers just the content stipulated by the syllabus. Identifying organisms using diagnostic features of the five kingdoms. Use diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy Binomial nomenclature Socio-economic importance of the five kingdoms	Covers just the content with slight application to day to day lives. Identifying organisms using diagnostic features of the five kingdoms. Use diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy Binomial nomenclature Socio-economic importance of the five kingdoms Conservation	Covers the content and applies the concepts to day to day lives. Identifying organisms using diagnostic features of the five kingdoms. Use diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy Binomial nomenclature Socio-economic importance of the five kingdoms Conservation Restoration
Appropriateness of concepts	No alignment of concepts in lesson	Little alignment of concepts in lesson	Adequate alignment of concepts in lesson	Close alignment of concepts in lesson
Scientific accuracy of the explanation of the concepts	Explanations were mostly inaccurate but did not address the concepts	Explanations were Somewhat inaccurate, which loosely addresses the concepts	Explanations were mostly accurate with only small inaccuracies seen, or they were too brief	Explanations were accurate, which addresses the concept with no inaccuracies
Links and/or connections made to other concepts	No possible links and/or connections are made	Few of the possible links are made, but not connected with explanations	Some of the possible links and connections are made	Many of the possible links And connections are made
Links made to the nature of science (NoS) and/or scientific inquiry (SI)	No links made to NoS and/or SI	Few of the possible links to NoS and/or SI are made	Some of the possible links to NoS and/or SI are made	Many of the possible links to NoS and/or SI are made

Adapted from (Carpendale & Hume, 2019)

Table 4.3 Criteria for evaluation of content knowledge (Based on the conceptual framework*)*

Level of Content knowledge	Advanced	Adequate	Inadequate
Concept coverage	Advanced	Proficient, Basic	Limited
Appropriateness of concepts	Advanced	Proficient, Basic,	Limited
Scientific accuracy	Advanced	Proficient, Basic	Limited
Links made with other concepts	Advanced	Proficient, Basic	Limited
Links made with NOS	Advanced	Proficient, Basic	Limited

4.13.2 Analysis of teacher knowledge of students' understanding

Table 4.4 Analytical framework for evaluating teacher knowledge of students' understanding

PCK indicator:	**Knowledge of student understanding**			
	Limited	Basic	Proficient	Advanced
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	No facilitation of discussions that expose learner' misconceptions Learners are spoon-fed with the necessary prior knowledge.	Facilitates discussions that expose Learners' misconceptions. Confronts some of them by providing standardised definitions.	Facilitates discussions that expose learners' misconceptions. Confronts most of them by expanding and rephrasing further	Exposed learners' misconceptions through discussions Confronts all of them by expanding and rephrasing further. Confirms learners' understanding
Teacher uses identified variations in student understanding and learning to guide instruction	No acknowledgement and/or use of variations in student understanding and learning to guide instruction	Acknowledgement of variations in student understanding or learning, but not used to guide instruction	Some acknowledgment of variations in student understanding or learning are used to guide instruction	Many instances where teacher acknowledged variations in student understanding or learning and used these to guide instruction
Teacher uses questioning to probe or extend student understanding	No questions are used to probe or extend student understanding	A few questions are used to probe or extend student understanding	An adequate range of questions are used to probe or extend student understanding	Many and varied questions are used to probe or extend student understanding

(Carpandle & Hume, 2019)

The teacher's levels of knowledge of students' understanding were categorised as inadequate, adequate, and advanced basing on combined evaluations of the teacher's level of the five sub-constructs as summarised in table 4.4.

Table 4.5 Criteria for evaluation of teacher knowledge of students (Based on the conceptual framework)

Level of Teacher knowledge of students	Inadequate	Adequate	Advanced
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	Limited	Proficient, Basic	Advanced
Teacher uses identified variations in student understanding and learning to guide instruction	Limited	Proficient, Basic	Advanced
Teacher uses questioning to probe or extend student understanding	Limited	Proficient, Basic	Advanced

4.13.3 Analysis of teacher knowledge of the curriculum

Table 4.6 Analytical framework for teacher knowledge of the curriculum

PCK indicator:	**knowledge of curriculum**			
Construct	Limited	Basic	Proficient	Advanced
Knowledge of goals and objectives	No overall knowledge of goals and objectives Explains irrelevant concepts. Leaves out important concepts in the topic.	Limited knowledge of goal and objectives	Adequate knowledge of goals and objectives	Highly knowledgeable
Interconnection of concepts with other topics	Sequencing of all key ideas is Illogical. The interconnections between concepts are not explained. No connections made with other topics.	Relevant key ideas are discussed but not given attention equally. Sequencing has illogical placing of most of the key ideas. Limited connections made to other topics	Relevant concepts are explained and given enough attention. Most of the key ideas are sequenced logically. The interconnection between most concepts was also logical. Adequate interconnections made with other topics	Explains concepts giving them the attention they deserve. All concepts are sequenced logically, in the order of importance. Also explains the interconnections between all concepts. Much use of interconnections with other topics
Interconnection with other disciplines	No connections made to other disciplines	Limited interconnections made with other disciplines	Adequate interconnections made to other disciplines	Much use of interconnections with other disciplines

Adapted from (Carpendale & Hume, 2019)

Table 4.7 Criteria for Evaluation of teacher knowledge of the curriculum (Based on the conceptual framework)

Level of Teacher knowledge of the curriculum	Inadequate	Adequate	Advanced
Knowledge of goals and objectives	Limited	Proficient, Basic	Advanced
Interconnection of concepts and of concepts with other topics	Limited	Proficient, Basic	Advanced
Interconnection with other disciplines	Limited	Proficient, Basic	Advanced

4.13.4 Analysis of teacher knowledge of assessment

Table 4.8 Analytical framework for teacher knowledge of assessment

❖ **PCK indicator**: **Knowledge of assessment**				
	Limited	Basic	Proficient	Advanced
Appropriate dimensions of science to assess	Inappropriate dimensions assessed	Limited /few dimensions of science assessed	Adequate dimensions assessed	Highly appropriate dimensions assessed
Appropriate methods of assessment	Inappropriate methods of assessment	Limited/few	adequate	Highly appropriate

Table 4.9 Criteria for evaluation of teacher knowledge of assessment (Based on the conceptual framework)

Level of Teacher knowledge of assessment	Inadequate	Adequate	Advanced
Appropriate dimensions of science to assess	Limited	Proficient, Basic	Advanced
Appropriate methods of assessment	Limited	Proficient, Basic	Advanced

4.13.5 Analysis of teacher knowledge of instructional strategies

Table 4.10 Analytical framework for teacher knowledge of instructional strategies

PCK indicator:	**Knowledge of instructional strategies**			
	Limited	Basic	Proficient	Advanced
Appropriate sequence for teaching concepts	Explains new concepts without exploring and developing prior knowledge Concepts are sequenced illogically, and interconnections are not explained.	Teachers ask closed ended questions. Confronts misconceptions but does not expand explanations. Key ideas are explained in isolation as well as their interrelatedness.	Teacher asks few higher order questions Expands confrontation of misconceptions but does not confirm understanding. Most key ideas are almost sequenced logically with links.	Teacher asks higher order questions. Expands confrontation of misconceptions and confirms understanding. All key ideas are sequenced logically as well as the links between them consecutive concepts.
Relevant examples and/or representations are used in the lessons, which appear to be pedagogically effective at portraying the concept	No examples and/or representations used to engage with concepts Lesson is highly teacher centred.	Examples And representations used that do not appear to be pedagogically effective Limited involvement of learners.	Examples and/or representations used have some relevance but appear pedagogically limited. Evidence of encouraged learner involvement.	Relevant Examples and/or representations used that appear pedagogically effective Generally, learner centred lesson.
Use of strategies that allow for metacognition	No use of strategies that allow for metacognition	Limited use of strategies that allow for metacognition	Adequate use of strategies that allow for metacognition	Much use of strategies that allow for deep levels of metacognition

Adapted from (Carpendale & Hume, 2019)

Table 4.11 Criteria for Evaluation of teacher knowledge of instructional strategies (Based on the conceptual framework)

Level of teacher knowledge of instructional strategies	**Inadequate**	**Adequate**	**Advanced**
Appropriate sequence for teaching concepts	Limited	Proficient, Basic	Advanced
Relevant examples and/or representations are used in the lessons, which appear to be pedagogically effective at portraying the concept	Limited	Proficient, Basic	Advanced
Use of strategies that allow for metacognition	Limited	Proficient, Basic	Advanced

4.13.6 Analysis of science teaching orientations

Table 4.12 Analytical framework for teacher knowledge of science teaching orientations

❖ **PCK indicator**: **Science teaching orientation**				
	Limited	Basic	Proficient	Advanced
Beliefs about purposes of teaching science	No knowledge on purpose of teaching science	Limited knowledge on purpose of teaching science	Adequate	Highly appropriate and illustrated during lesson delivery
Beliefs about science teaching and learning	inappropriate	limited	adequate	Highly appropriate
Beliefs about NOS	inappropriate	limited	adequate	Highly appropriate and illustrated during lesson

Adapted from (Carpendale & Hume, 2019)

Table 4.13 Criteria for Evaluation of teacher knowledge of science teaching orientations (Based on the conceptual framework)

Level of teacher knowledge of science teaching orientations	**Inadequate**	**Adequate**	**Advanced**
Beliefs about purposes of teaching science	Limited	Proficient, Basic	Advanced
Beliefs about science teaching and learning	Limited	Proficient, Basic	Advanced
Beliefs about NoS	Limited	Proficient, Basic	Advanced

Evaluations of the teacher's level of the key constructs were used to evaluate of the teacher level of PCK. The teacher levels of PCK were categorised as Advanced, Adequate and Inadequate. Table 4.14 was designed and used to evaluate teacher PCK for this study.

Table 4.14 Criteria for evaluation of teacher PCK (Based on the conceptual framework)

Teacher's PCK Level	Inadequate	Adequate	Advanced
Content knowledge	Inadequate	Adequate	Advanced
Knowledge of students	Inadequate	Adequate	Advanced
Science teaching orientations	Inadequate	Adequate	Advanced
Knowledge of assessment	Inadequate	Adequate	Advanced
Knowledge of instructional strategies	Inadequate	Adequate	Advanced
Knowledge of the curriculum	Inadequate	Adequate	Advanced

4.15 Rigour of The Study

One of the key strengths of case studies is the richness of the information they provide (Gibbert et al., 2008). Gibbert *et al.* (2008) also observed that both the strengths and weaknesses of case studies lie in the eye of the beholder. Cohen *et al*. (2007) and Ary *et al*. (2006) suggested that rigour is an important requirement in qualitative research, as it gives credibility to the research. Illustrating rigour in quantitative research is easier as there are standardised procedures, whereas rigour in qualitative research has less standardised procedures (Pratt, 2008).

In qualitative research the term trustworthiness is often used as a measure of rigour in place of validity and reliability as is the case with quantitative studies. Researchers such as Silverman, (2010; 2013) have demonstrated how qualitative research can deal with issues relating to rigour. The notion is supported by researchers such as Schwandt *et al.,* (2007); Ary *et al*. (2006) and Cohen *et al*. (2007) who are of the view that rigour in qualitative research can be determined by the credibility, dependability, conformability and transferability of the study.

4.16 Credibility of The Study

The established confidence in the findings of the study about context, research design, participants and the methodology used in the research give credibility to the case study (Ary *et* *al*., 2006; Silverman, 2011, 2013). Mabry (2009) argued that the use of triangulation helps to enhance the credibility of the study. In this study, triangulation was achieved using various data collection methods which included content analysis, lesson observations, teacher interviews, teacher questionnaires, as well as learner questionnaires in order to produce in-depth understanding of the phenomenon under study. The interrogation of the data collected using different techniques helped to build a deeper and broader view of the study. The lesson observations gave an initial insight into the enacted PCK. Triangulation of data from lesson observations, interviews and questionnaires gave an insight into the general teacher topic specific PCK for Biodiversity. Just as Mabry (2009) argued that there is need for a critical review of work on the study. The researcher had all instruments reviewed by experienced researchers and every stage of the study was constantly critically reviewed by supervisors. These reviews helped in providing a continuous focus on the research questions to be answered and the best way to move towards finding answers to the initial questions posed.

4.18 Dependability of The Study

Schwandt *et al.,* (2007) stressed that there is a close link between credibility and dependability and argued that, in practice, a demonstration of the former may imply ensuring the latter. In this research dependability was achieved using overlapping methods in data gathering and analysis. The research design in this study constituted a prototype which could make the reader of the research understand the methods used and their effectiveness. Yin (2008) and Denzin& Lincoln (2005) regarded the use of multiple data collection methods in a case study as paramount since it allows triangulation which in turn gives the required richness, depth, and breadth of the research. In this research emphasis was placed on the triangulation of data to ensure rigour.

4.19 Confirmability of The Study

Denzin and Lincoln (2005) regarded confirmability of a qualitative research study as residing in the effort by the researcher to attain objectivity. The researcher is expected to ensure that the findings depict the experiences and ideas of the participants rather than the interests of the researcher. To ensure this, detailed reasons for the selection of procedures used in every part of the research are given. The researcher also ensured that the procedure and the interpretation of the findings were free from bias as triangulation was used to corroborate the findings, a notion also held by Ary *et al*. (2006). The researcher also ensured that the findings emerged from the data gathered and not from personal opinions. A personal audit trial was done in the form of a table depicting the research questions in relation to the data collection instruments as well as the methods used.

4.20 Ethical Issues

Ethics in research studies entail the need to take into consideration the informed consent of the participants, confidentiality, anonymity as well as privacy of those involved as participants in the research (McMillan & Schumacher, 2010). To ensure that the research conformed to the ethical demands' researcher obtained an ethical clearance from the university Ethics Committee (Appendix 1) to conduct the research before working with the participants. Permission was also granted to carry out research in the Zimbabwean secondary schools from the Ministry of Primary and Secondary Education (Appendix 2), who then informed the headmasters of the schools in which the study was to be carried out about the intentions of the research through a written communication to the schools.

The Provincial Education Director gave permission to the researcher to go to schools and conduct research through an authorization letter (Appendix 3). The researcher made an initial visit to the four schools and further requested permission from the school head after explaining how data was going to be collected without disrupting the schools' programmes and the headmasters filled in a consent form (Appendix 4). The headmasters acted in loco-parentis, hence their permission also served as consent for the learners. Teachers who participated in the research had to give their consent (Appendix 5) before participating through signing consent form. All participants were informed that their participation was voluntary and that they could withdraw any time they felt they could not continue participating in the research. The researcher also guaranteed the confidentiality of the participants in the research.

Before entering the classrooms for observation, the teachers explained my presence and intentions to the learners to create a normal environment for data collection. The researcher only visited the lessons as per timetable of the schools to ensure that the setting remained as normal as possible. The names of the participants were not used in the research report. Instead, pseudonyms of participants were used in the research.

4.21 Summary

This chapter discussed various important issues on data collection. A synopsis of the research methodology was given. This included describing research design and the paradigm followed in the study. The methodological approach used in this study; case study was discussed. The reason for a pilot study was given and explanation on the selection of participants was given. Data collection methods were detailed to show the logical order of how data collection occurred. A plan of how data were to be analysed was designed which guaranteed focus on answering the research question. The issue of trustworthiness of the research was explained to prove authenticity of the qualitative research findings. Chapter five presents the findings and discussion.

CHAPTER 5

DATA PRESENTATION AND ANALYSIS

5.1 Introduction

This chapter presents and analyses data for the four teacher participants. The key constructs from the hexagonal PCK conceptual framework, including subject knowledge, knowledge of students' understanding, knowledge of instructional strategies, knowledge of curriculum, knowledge of assessment, and science teaching orientations, were used to organise the data. Enacted PCK for the Biology teachers was assessed. This is the specific knowledge and skills utilised by an individual teacher in his/her classroom setting, with a particular learner or group of learners with the goal for those learners to learn a particular concept. Enactment is viewed as the knowledge and reasoning behind the act of teaching when interacting directly with the learners and the act of planning instruction and reflection on instruction and learner outcomes. The data from lesson observation was triangulated with data from teacher interviews and learner questionnaires.

5.2 Characterisation of Teacher Participants

5.2.1 Ms Rose

For purposes of anonymity, the first teacher participant was given the pseudonym Ms. Rose. Ms. Rose is a holder of an MSc Food Science and nutrition, BSc Biological Science, and a Diploma in Education. According to the qualifications given, Ms. Rose is qualified to teach Biology up to ‘A’ level. She has taught Biology at ‘A’ level for a period between 5 to 10 years and acknowledges receiving several orientations to teaching the competence-based curriculum which include syllabus interpretation and teaching methods, particularly the learner-centred teaching methods. She recognizes the need for field trips in the teaching of Biodiversity. Ms.

Rose has access to some resources recommended by the syllabus, particularly access to ICT. Ms Rose teaches at a Boarding school in town.

5.2.2 Ms Candy

The second teacher participant's pseudonym is Ms. Candy. Ms. Candy holds a Bachelor of Science Education Honours Degree in Biology. She has experience in teaching Advanced level Biology for over 20 years. Ms. Candy acknowledges that she received several trainings and workshops as orientations to the competence-based curriculum. The orientations covered all learning areas including psychomotor skills, use of practical work in teaching and learning, entrepreneurship, and problem solving. Ms Candy teaching at a day school in town and has access to a laboratory, ICT facilities and artificial ecosystems.

5.2.3 Mr Dee

The pseudonym for the third teacher participant is Mr. Dee. He is a holder of a Bachelor of Science Education Degree in Biology. From the qualifications given, Mr. Dee is qualified to teach Biology up to 'A' Level. He has experience in teaching 'A' Level Biology of above twenty years. Mr. Dee has not received any form of orientation to the competence-based curriculum. Mr Dee teaches at a day school in town and has access to a laboratory, ICT facilities and artificial ecosystems.

5.2.4 Mr Lazz

The fourth teacher participant was given the pseudonym Mr. Lazz. Mr. Lazz is a holder of a Bachelor of Science Honours' Degree in Biological Science and a Post Graduate Diploma in Education. He has   experience in teaching 'A' Level Biology of between 5 to 10 years. Mr Lazz did not receive any form of orientation for the competence-based Biology curriculum. He teaches at a school day school in town that has a laboratory and ICT facilities.

Research question 1: What does the 'A' level Biology Curriculum demand of the topic biodiversity?

5.3 Demands of The Topic On Biodiversity

To answer research question 1, data was collected using content analysis of the 'A' level Biology syllabus section on Biodiversity. A rubric for content analysis was designed and used to illustrate the concepts, frequency of mention of a concept and the expected teaching and learning activities. Table 5.1 shows the rubric on content analysis for the topic on Biodiversity.

Table 5.1 Rubric for content analysis of topic Biodiversity

Objective	Competences	Concepts	Frequency	Activities	Comment
Identify organisms using diagnostic features	Observation Identification Communication Critical thinking	Concept of biodiversity (Definition, species diversity, Genetic diversity, and ecosystem diversity)	3	Identification of organisms. Use variety of organisms to define biodiversity and the different forms of biodiversity	The syllabus requires learners to identify organisms using diagnostic features. No special mention is done to the concept of Biodiversity, though this marks the beginning of the chapter and is of great importance for understanding of all concepts.
	Observation Identification Communication Critical thinking	classification	10	Use of dichotomous key to guide activities in classification	Emphasis is given to classification of organisms. This is of importance as it allows learners to understand diversity better and help in the identification and conservation of living organisms.
Use diagnostic features to divide kingdom into phyla	Observation Identification Communication inference	Diagnostic features	7	Use of dichotomous key to guide activities on classification	Use of diagnostic features is the key to classification of organisms.
	Observation communication	Taxonomic hierarchy	4	Activities to demonstrate taxonomic hierarchy	The syllabus highlights the need to outline the taxonomic hierarchy.

Observe the rules of binomial nomenclature	Observation Communication inference	Binomial nomenclature	4	Activities on naming organisms using binomial nomenclature	Emphasis is placed on discussing the rules of binomial nomenclature.
	Inference Problem solving Critical thinking	Importance of use of binomial nomenclature	2	Illustration or activities to demonstrate importance of binomial nomenclature	This is a silent concept in the syllabus; however, emphasis must be placed on the importance of the use of binomial nomenclature.
Describe the socio-economic importance of the five kingdoms	Problem solving Critical thinking Innovation communication	Socio-economic importance/value addition	24	Use of videos, ppt or any other activities to show the socioeconomic importance of the 5 kingdoms.	More emphasis is given on the socio-economic importance of the five kingdoms.
	Problem solving innovation	conservation	10	Field trips Discussion on measures that can be put in place to conserve. Activities can be carried out in the communities to conserve ecosystems	Conservation is a cross cutting theme that must be emphasised throughout the topic
	Observation Communication Critical thinking Problem solving	Threats to biodiversity	0		The syllabus does not bring out issues of threats to biodiversity.
	Innovation Critical thinking Problem solving	Restoration of biodiversity	0		The syllabus is silent on ways through which biodiversity can be restored.

The ‘A’ Level ZIMSEC syllabus outlines the need to teach the concept of Biodiversity, five kingdom classification system and use of diagnostic features to further classify the kingdoms into phylum. Furthermore, it emphasises the teaching of the taxonomic hierarchy, binomial nomenclature, and the socioeconomic importance of the five kingdoms. Emphasis is placed on value addition and conservation. However, no emphasis is placed on the threats to biodiversity and the restoration of biodiversity.

Table 5.2 Recommended learning activities

Recommended activities	Suggested resources
Observing organisms	Samples of organisms. ICT tools
Classifying organisms into five kingdoms	Samples of organisms. Dichotomous key
Collecting and classifying organisms	Samples of organisms. Dichotomous key
Outlining the taxonomic hierarchy	ICT tools
Discussing the rules of nomenclature	ICT tools
Discussing the socio-economic importance of the five kingdoms	ICT tools

Table 5.2 shows that sample organisms are needed when teaching about Biodiversity, this can be made possible through collection of samples and through field trips to places like botanical gardens. The table also highlights the importance of ICT in the teaching of the topic, and this can be through using videos and images to show organisms. From table 5.2, the syllabus requires the use of constructivist teaching and learning approaches.

Research questions 2 and 3

How do 'A' Level Biology teachers teach the topic Biodiversity?

Why do 'A' Level Biology teachers teach about Biodiversity in the way they do?

To respond to research questions 2 (How do 'A' level Biology teachers teach the topic Biodiversity?) and research question 3 (Why do 'A' Level Biology teachers teach the topic Biodiversity the way they do?). Five consecutive lesson observations were made, data from the lesson observations was triangulated with data from teacher interviews and questionnaires and from learner questionnaires. The analytical framework consisted of 6 key concepts which were assessed individually. A lesson observation guide was constructed using the hexagonal conceptual framework and used during lesson observations. An interview guide and questionnaire were also constructed using the hexagonal conceptual framework.

5.4 Evaluation of Teacher Content Knowledge

Five sub-constructs for teacher content knowledge were identified in the content knowledge Analytical framework, these are concept coverage, appropriateness of concepts, scientific accuracy of explanations, connections made with other concepts, or connections made to the Nature of Science. The teacher's levels for each of the sub-constructs were categorised as limited, basic, proficient, and advanced according to the teacher's ability to exhibit certain attributes indicated in the Analytical framework.

The teacher's levels of content knowledge were categorised as inadequate, adequate, and advanced based on evaluations of the teacher's level of the five sub-constructs for teacher content knowledge. Pseudonyms for the teacher participants are Ms. Rose, Ms. Candy, Mr. Dee, and Mr. Lazz.

5.4.1 Analysis of Ms. Rose's content knowledge

Table 5.3 Analysis of Ms. Rose's Content Knowledge on Biodiversity

Construct	Observed attributes	Level
Concept coverage	Ms Rose covered just the content stipulated by the syllabus She identified organisms using diagnostic features of the five kingdoms. Used diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy. She defined binomial nomenclature, gave examples and the significance of using binomial nomenclature Socio-economic importance of the five kingdoms. Conservation	**Proficient**
Appropriateness of Concepts	Adequate alignment of concepts in lessons.	**Proficient**
Scientific accuracy **of explanations** **of the concepts**	Explanations were mostly accurate with only small inaccuracies seen	**Proficient**
Links made to other concepts	Some of the possible links and connections were made	**Proficien**t
Links made to the nature of science (NoS) and/or scientific inquiry	No links made to NoS and/or SI	**Limited**

Concept coverage

Table 5.3 shows that Ms Rose had proficient knowledge of concept coverage. Only the concepts stipulated by the syllabus were imparted to the learners. From the five consecutive lessons observed, the teacher covered the concept of Biodiversity, defining the concept and describing the different types of biodiversity *i.e.*, genetic diversity, species diversity and ecosystem diversity. The organisms were classified into kingdoms using the diagnostic features and further into phylum. Ms Rose outlined the taxonomic hierarchy, described using examples the binomial nomenclature and its significance. The teacher discussed the socioeconomic importance of the five kingdoms and issues of conservation. However, issues of restoration were not covered. Hence, Ms. Rose's concept coverage was rated proficient since all the concepts stipulated by the syllabus were covered and the teacher further looked at issues of conservation and sustainable use. She outlined the purpose of teaching the topic at the beginning of each lesson. Findings from the lesson observations tally with the findings from the teacher questionnaires and interviews. Ms. Rose highlighted the need to conscientize learners on the importance of all forms of life, placing emphasis on sustainable utilisation and improving livelihoods through sustainable use. Due to these attributes Ms. Rose is at the Proficient level in concept coverage.

Appropriateness of concepts

Table 5.3 shows that Ms Rose taught appropriate concepts in line with the content analysis of the syllabus. Adequate alignment of concepts was noted. Ms Rose introduced the topic by discussing the concept of biodiversity and the forms of biodiversity, this was followed by a lesson on classification of organisms into kingdoms and further classification into phyla was done. Hence, Ms Rose taught the appropriate concepts with adequate alignment. A clear outline of what was going to be taught was given at the beginning of each lesson in the form of lesson objectives. An outline of lesson objectives helps in guiding learners during the lesson and to assess their learning progress. Objectives also help teachers to be cognizant of the goal of their instruction so that the lesson be purposefully designed to achieve the set goals. Consequently, Ms. Rose was at Proficient level regarding appropriateness of concepts covered on Biodiversity.

Scientific accuracy of the explanation of the concepts

Explanations were mostly accurate with only small inaccuracies seen; hence Ms Rose was rated proficient. The concepts were mostly accurate with small inaccuracies seen for example during teaching the kingdom Animalia. She pointed out cephalization as a characteristic of all organisms in kingdom Animalia. However, there are animals, for example in phylum Porifera, that lack cephalization. If teachers believe that they have high self-efficacy, they may not be aware that they must continually improve their science content knowledge. Due to these attributes Ms. Rose was rated Proficient in terms of her scientific accuracy in Biodiversity.

Links made to other concepts

Some links were made with other concepts taught earlier, for example, on kingdom Animalia the teacher made connections with the digestive, circulatory, and skeletal systems, while links were made with transport systems, reproduction in plants and photosynthesis during discussing the plant kingdom. The data tallies with data from learner questionnaires, when asked if the teacher related the content to other topics and discipline, they all responded yes. Ms. Rose was rated Proficient on linking concepts to other concepts.

Links made to the nature of science

No links were made to the nature of science and scientific enquiry. Nature of Science entails a comprehension of science as a method of knowing. Hence, it is a basis for students' understanding of how science is conducted. This encourages students to participate in experimental activities and move from merely learning about science to practising and knowing it. Consequently, Ms. Rose was rated Limited on links made to NoS.

The Analytical framework for content knowledge was used to evaluate Ms Rose's content knowledge. Ms Rose had adequate content knowledge.

5.4.2 Analysis of Ms Candy's content knowledge

Table 5.4 Ms. Candy's Content knowledge on Biodiversity

Sub-construct	Observed attributes	Level
Concept coverage	Covered just the content with slight application to day to day lives Identifying organisms using diagnostic features of the five kingdoms. Use diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy. Binomial nomenclature. Socio-economic importance of the five kingdoms Conservation Restoration Application in day to day lives	**Advanced**
Appropriateness of **Concepts**	Adequate alignment of concepts in lesson	**Advanced**
Scientific accuracy **of the explanation** **of the concepts**	Explanations were mostly accurate with only small inaccuracies seen, or they were too brief	**Proficient**
Links or connections made to other concepts	Many of the possible links and connections are made	**Advanced**
Links made (implicit or explicit) to the nature of science **(NoS) and/or scientific inquiry**	Some of the possible links to NoS and/or SI are made	**Proficient**

Concept coverage

Ms Candy covered just the content with application to day to day lives. The concept Biodiversity was discussed, followed by identification of organisms using diagnostic features of the five kingdoms and use of diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy, binomial nomenclature, socio-economic importance of the five kingdoms and conservation, issues of restoration and application of concepts in day to day life were covered. The concepts taught tallied with all the concepts in the content analysis, hence in terms of concept coverage Ms Candy was rated advanced.

Appropriateness of concepts

The concepts taught were appropriate and adequate alignment of concepts was noted. For example, in the first lesson Ms Candy introduced the concept of biodiversity and discussed the definition and the different types of biodiversity, *i.e.*, genetic diversity, species diversity and ecosystem diversity. She then moved on to discussing why it is important to study Biodiversity. All concepts taught were appropriate and adequately aligned, hence Ms Candy was rated Proficient.

Scientific accuracy of the explanation of the concepts

The explanations were mostly accurate with few inaccuracies seen, for example, the concept of alternation of generations was explained very well in lesson three, but the teacher referred to it as the 'alteration of generations' while the sporophyte generation was referred to as the 'saprophyte'. This can distort learner understanding since a saprophyte is an organism that is fed through secretion of enzymes on the substrate and absorbing the nutrients digested externally. However, all the concepts were explained very well and Ms Candy was rated as Proficient.

Links and/or connections made to other concepts

Many of the possible links and connections are made, for example, the teacher emphasised the need for conservation, restoration of ecosystems and use of knowledge learnt in value addition and entrepreneurship throughout her lessons. Links were also made with other topics learnt throughout her lessons. For example, on Kingdom Animalia, during classification, she referred to reproduction, digestion, and circulatory systems. She then discussed how organisms in Animalia can be conserved, used in value addition and economic recovery of the country. As shown in table 5.4, Ms. Candy was rated Advanced.

Links made to the nature of science

Some of the possible links to the NoS were made. Several organisms were brought to class during the lesson on classification of organisms into the five kingdoms. Through practical activities in pairs, learners were asked to identify the diagnostic features and classify organisms into their kingdoms. Ms Candy demonstrated understanding of the facts and concepts of the topic and the discipline. In Ms Candy's lessons, the processes used to establish knowledge were mainly through the process of scientific inquiry through practical activities and she was rate proficient as shown in table 5.4

The Analytical framework for content knowledge was used to evaluate Ms Candy's content knowledge. From table 5.4 above, it can be noted that Ms Candy ranged from proficient to Advanced, in all her ratings in the sub-constructs, hence Ms Candy had adequate content knowledge.

5.4.3 Analysis of Mr Dee's content knowledge

Table 5.5 Analysis of Mr Dee's content knowledge on Biodiversity

Sub-construct	Observed attributes	Level
Concept coverage	Missed many concepts stipulated by the syllabus	**Limited**
Appropriateness of concepts	Little alignment of concepts in lesson	**Basic**
Scientific accuracy of the explanation of the concepts	Explanations were somewhat inaccurate, which loosely addressed the concept	**Basic**
Links and/or connections made to other concepts	No possible links and/or connections made	**Limited**
Links made (implicit or explicit) to the nature of science (NoS) and/or scientific inquiry	No links made to NoS and/or SI	**Limited**

Concept coverage

All lessons were carried out through learner presentations, during which the teacher prohibited learners from asking questions. This is what Mr Dee said at the beginning of the lessons.

"We expect no interruptions during the presentations in terms of questions or any other interjections, questions will be asked at the end of the lesson."

However, the teacher did not give time for questions at the end of the presentations but instead moved on to the next presenter.

Several concepts were not taught. For example, in the first lesson, the presenter defined the term biodiversity, and no mention was made to the types of biodiversity. The diagnostic features of the five kingdoms were given and classification of organisms into kingdoms was done, however no further classification into phylum was done. Socio-economic importance of the five kingdoms were discussed, however, no mention was made to conservation, restoration and how these organisms can be utilised in communities for value addition and economic recovery of the country. Due to these attributes, Mr. Dee is at a Limited level regarding the concepts of biodiversity.

Appropriateness of concepts

Concepts taught were appropriate, but inadequate as most concepts were not covered. Adequate alignment of concepts was noticed in learner presentations. Consequently, Mr. Dee is at Basic level regarding the appropriateness of concepts in biodiversity.

Scientific accuracy of the explanation of the concepts

The explanations given by the students during presentations were accurate. However, learners were reading prepared notes during the presentations which can negatively impact learner understanding. Accordingly, Mr. Dee is at Basic level regarding the scientific accuracy of biodiversity concepts.

Links and/or connections made to other concepts

Few links were made by the students to other topics during the presentations. For example, on characteristics of kingdom Monera, the presenter mentioned the presence of a plasmid and linked the plasmid to gene technology. Subsequently, Mr. Dee is at Limited level regarding links made with other concepts.

Links made to the nature of science

No links were made to the NoS in all the observed lessons, learners spoon-fed each other using the lecture method. Even though the organisms are present in every ecosystem, no practical activity was done. The teacher showed a lack of knowledge on processes used to establish new knowledge in science. Therefore, Mr. Dee was rated Limited regarding links made with NoS.

Mr Dee did not have either a scheme of work or a lesson plan. There was no evidence of planning. When asked why he was not planning, this is what Mr Dee had to say:

'I just don't have my scheme of work, but planning is necessary and if one does not plan, he is actually planning to fail.'

From this statement, the research deduced that Mr Dee knew the importance and consequences of not planning but still did not plan. Analytical framework for content knowledge was used to identify the content knowledge level of Mr Dee. It was noted that Mr Dee had inadequate content knowledge for teaching on Biodiversity.

5.4.4 Analysis of Mr Lazz's Content knowledge

Table 5. 6 Analysis of Mr Lazz's content knowledge

Sub-construct	Observed attributes	Level
Concept coverage	Missed some concepts stipulated by the syllabus	**Limited**
Appropriateness of concepts	Little alignment of concepts in lesson	**Basic**
Scientific accuracy of the explanation of the concepts	Explanations were somewhat inaccurate, which loosely addressed the concept(s)	**Basic**
Links and/or connections made to other concepts	No possible links and/or connections made	**Limited**
Links made (implicit or explicit) to the nature of science (NoS) and/or scientific inquiry	No links made to NoS and/or SI	**Limited**

Concept coverage

Mr Lazz missed some concepts stipulated by the syllabus. For example, classification of Kingdoms into phylum was not taught. Lessons were done through learner presentations and issues of conservation, restoration, and use of biodiversity in value addition in the local context were not taught. Hence, Mr Lazz's concept coverage was rated as limited. Mr. Lazz had no workbooks *i.e.,* no scheme of work, lesson plans or even a notebook. The lessons observed were mainly presentations by learners with little to no contribution from the teacher. This could have been attributed to lack of planning. When asked during the interview why he was not planning, this is what Mr. Laz had to say,

"*Scheming and planning is laborious, given that the syllabus has the objectives and everything and the teacher is asked to scheme again while the syllabus is there. I think there should be another way which can involve only evaluation than planning".*

When asked how he ensures efficient lesson delivery and concept coverage without planning for the lesson, this is what Mr. Laz had to say,

"*It depends on the experience of the teacher, when someone is well experienced, there is no need for scheming. I think scheming is necessary when on attachment, if it is to be done, maybe it must be done for the first three years after training and thereafter one can just teach."*

From the responses given by Mr. Lazz, the researcher concluded that poor concept coverage was because of lack of planning. The teacher never commented on the presentations. The researcher felt the teacher had limited content knowledge, hence, lacked confidence to comment on student presentations. This could be attributed to not only lack of planning and preparing for the lessons but also to lack of commitment to the profession. Consequently, Mr. Lazz is at a Limited level regarding the concepts of biodiversity.

Appropriateness of concepts

The concepts covered were appropriate, though there was little alignment of the concepts covered. From the student presentations, learners just presented the concepts assigned to them without linking to previous concepts presented by other students. Accordingly, Mr. Lazz is at Basic level regarding the appropriateness of concepts on biodiversity.

Scientific accuracy of the explanation of the concepts

The concepts presented were accurate and alignment of concepts was noted from the student presentations. The presenters showed that they had researched, however, even the presenters had not mastered or understood the concepts as they were reading during the presentation. Consequently, Mr. Lazz is at Basic level regarding the scientific accuracy of concepts on biodiversity.

Links and/or connections made to other concepts

No links were made to other concepts. Thus, Mr. Lazz is at Limited level regarding the links made with other concepts.

Links made to the nature of science

No links were made to the nature of science. Subsequently, Mr. Lazz is at Limited level regarding the links made to the NoS.

An analysis of Mr Lazz's content knowledge was done by comparing the levels of constructs in table 5.7 and the content knowledge Analytical framework, it was noted that Mr Lazz had inadequate content knowledge.

5.4.5 Comparison of teacher participants' content knowledge

Table 5.7 Comparison of teacher participants' performance

Concept	**Ms. Rose**	**Ms. Candy**	**Mr Dee**	**Mr Laz**	**Comment**
Concept coverage	Covered the stipulated content. No applications to day-to-day life were made.	Covered the stipulated content and applications were made to day to day lives.	Did not teach some concepts.	Did not teach some concepts.	Ms. Rose and Ms. Candy covered the stipulated concepts. However, Ms. Candy made applications to the learners' day to day lives. Mr Dee and Mr Lazz skipped some concepts.
Appropriateness of concepts	Adequate alignment of concepts noted.	Adequate alignment of concepts noted.	There was little alignment of concepts.	Little alignment of concepts.	Concept alignment was noted for Ms. Rose and Ms. Candy, however, there was little alignment of concepts for Mr Dee and Mr Lazz.
Scientific accuracy of concepts	Explanations were mostly accurate.	Explanations were mostly accurate.	Some inaccurate explanations noted	Some explanations were inaccurate	Ms. Rose and Ms. Candy gave accurate explanation, while Mr Dee and Mr Lazz gave some inaccurate explanations
Links made to other concepts	A few links were made to other concepts.	Many links were made	No links made with other concepts	No links made with other concepts	Ms. Rose made more links to the other concepts, whilst a few links were made by Ms. Candy, No links were made by Mr Dee and Mr Lazz.
Links made to NoS and scientific enquiry	No links were made to NoS	A few links were made	No links made to NoS	No links made to NoS	A few links were made to the NoS by Ms. Candy, whilst the other 3 teachers made no link to NoS and the scientific enquiry.
Content knowledge	Adequate	Adequate	Inadequate	Inadequate	Ms Candy and Ms. Rose had adequate content knowledge, whilst Mr Dee and Mr Lazz had inadequate content knowledge.

Table 5.7 summarises the level of each teacher in the sub-constructs of content knowledge. Teacher content knowledge ranged from inadequate to adequate. The researcher noted that all the teacher participants were not planning. They all did not have schemes of work and lesson plans. However, Ms. Rose and Ms. Candy had notebooks which they referred to as the lessons progressed. When asked why they were not planning, this is what Ms. Rose had to say,

"I don't have any scheme or lesson plan; I use my notebook. I don't know when I last schemed or wrote a lesson plan. If you really want the scheme for your research, I can just write the section on Biodiversity for you"

When asked how she ensures efficient lesson delivery, this is what Ms. Rose had to say,

"*With experience, I now know how to deliver my lessons effectively without a scheme or lesson plan but using the syllabus and my notes."*

Ms. Candy had no scheme of work or lesson plan. She used the syllabus and her notebook for the lessons. This shows the need for supervision. When asked why she did not plan, this was what Ms. Candy said,

'I use my teaching experience to ensure that the lessons go on very well. I do plan, but just don't write it down. That's why there were several organisms during the lessons collected from the ecosystem and used to guide instruction."

When asked during the interview why he was not planning, this is what Mr. Laz had to say,

"Scheming and planning are laborious, given that the syllabus has the objectives and everything and the teacher is asked to scheme again while the syllabus is there. I think there should be another way which can involve only evaluation than planning".

Upon requesting permission to conduct research from one of the headmasters, this is what the head said,

"Please do not bother my teachers, don't you know that we are incapacitated."

Such a remark from an administrator, who has the ultimate responsibility of supervising the teachers and the school at large was an indicator of a poor working environment where it was possible that minimum teaching and learning activities were taking place.

5.5 Evaluation of Teacher Knowledge of Student Understanding

The teacher's levels of knowledge of students' understanding were categorised as inadequate, adequate, and advanced. The Analytical framework shown in table 4.4 was used and shows that the teacher level of student understanding is determined by the teacher's ability to recognize and acknowledge student prior knowledge, difficult concepts, and misconceptions. The teacher must be able to use the identified variations in students' understanding and learning to guide instruction as well as use questioning to probe or extend student understanding. Comparisons were made between the teacher's level of knowledge in the sub-constructs in the Analytical framework and evaluations of the teacher's level of students' understanding shown in table 4.5. Data for teacher participants was presented independently, though comparisons between the teachers were made.

5.5.1 Analysis Ms Rose's knowledge of students understanding

Table 5.8 Ms Rose' understanding of students' understanding in Biodiversity

Sub-construct	**Observed attributes**	**Level**
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	Facilitates discussions that expose learners' misconceptions. Confronts most of them by expanding and rephrasing further	Proficient
Teacher uses identified variations in student understanding and learning to guide instruction	Acknowledgement of variations in student understanding or learning, but not used to guide instruction	Basic
Teacher uses questioning to probe or extend student understanding	An adequate range of questions are used to probe or extend student understanding	Proficient

Recognition and acknowledgement of possible student prior knowledge, difficult concepts, and misconceptions

Ms. Rose acknowledged possible student prior knowledge. A question-and-answer session was carried out at the beginning of each lesson from which the teacher would build on the lesson from the ideas the students had. This tallied with the data from the learners' questionnaire responses. When the eighteen students were asked if their teacher considered the knowledge they had when teaching, they all responded yes. The data from the lesson observations and learner questionnaire tallied with the data collected from the interview with Ms. Rose and from the teacher questionnaires. When asked if learner prerequisite knowledge affected her lesson planning, Ms. Rose responded,

'Yes, learning and teaching should be organised sequentially, or from known to unknown or from simple to complex, hence, I had to probe for what the learners knew at the beginning of each lesson."

She facilitated discussions and confronted most of the misconceptions by explanations and corrections. For example, when she was teaching about bryophytes, one student pointed out that they lack roots, and she was quick to correct the learner.

'Bryophytes lack true roots; bryophytes have rhizoids for anchorage and absorption of water'.

Ms. Rose identified learner misconceptions through interaction with learners in class as the learners participated. This tallied with the data collected from the questionnaires and interviews. When asked how she identifies learner misconceptions, Ms. Rose responded,

'*Through pupil feedback when I ask questions, during interactions in class discussions and through weekly assessments in class.*'

Ms. Rose corrected the identified misconceptions in class by revisiting the concept and explaining the misconception. This is what Ms Rose said during the interview, when asked how she addresses the identified misconceptions:

'All learner misconceptions are corrected through class discussions, feedback for assessment work, remediation and concept revisiting and explanations.

This tallied with the data from the learner questionnaires, when asked if they had any misconceptions prior to the lessons, they all responded '*yes*'. And when asked how the misconceptions were corrected, all responded, '*from the teacher's explanations during the discussions.* When asked in what ways students influenced her teaching decisions, this was Ms Rose's response;

'At the beginning of the lessons I ask questions to identify learner prior knowledge, during the lessons I continue to use questions to guide learners and to identify areas of difficulty. This guides the class discussions and my explanations during the lessons.'

From her response, one can tell the emphasis she placed in learner prior knowledge and learner understanding throughout the lesson. Consequently, Ms. Rose was rated Proficient on acknowledging possible student prior knowledge, difficult concepts, and misconceptions.

Use of identified variations in student understanding and learning to guide instruction

Ms. Rose acknowledged the variations in student understanding and learning even though this was not used to guide instruction. No variations were made to instruction to suit various levels of learner understanding. Despite the observed variations in students' understanding, Ms. Rose just used PowerPoint presentations to explain concepts, no practical activities, field work or any other teaching method was used. Subsequently, Ms. Rose was rated Basic at the use of identified variations in student understanding and learning to guide instruction.

Use of questioning to probe or extend student understanding

Adequate range of questions were used to probe or extend student understanding in all the observed lessons. This tallied with the teacher responses in the interview quoted above, it is clear that Ms Rose values the role of questioning and probing. Hence, Ms. Rose was rated Proficient at questioning or probing to extend students' understanding.

Ms Rose's level of students' understanding was evaluated using the Analytical framework shown in table 4.4 and table 4.5 and she had adequate knowledge of students' understanding.

5.5.2 Analysis of Ms Candy's knowledge of students' understanding

Table 5.9 Ms Candy' knowledge of students' understanding in Biodiversity

Construct	**Observed attributes**	**Level**
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	Exposed learners' misconceptions through discussions	Advanced
Teacher uses identified variations in student understanding and learning to guide instruction	Some acknowledgment of variations in student understanding or learning are used to guide instruction	Proficient
Teacher uses questioning to probe or extend student understanding	An adequate range of questions are used to probe or extend student understanding	Proficient

Recognition and acknowledgement of possible student prior knowledge, difficult concepts, and misconception

Ms. Candy facilitated discussions that exposed learner misconceptions and confronted all the misconceptions with explanations, probing and paraphrasing. She recognized that the learners had prior knowledge, hence, the introductions included a set of questions used to derive and activate learner prior knowledge from which the lesson was expanded. For example, on introducing the topic, she asked, "what is biodiversity?" The first student's response was, "*variety of plants and animals on earth*".

This was Ms. Candy's response,

"*Yes, it includes the variety of plants and animals, however, let's break down the word, Bio means life and diversity means variety, so what does biodiversity mean?"*

The second student response was, "*biodiversity is the variety of life forms on earth."*

The teacher's response was, "*Yes, that's good. Biodiversity is the variety of life forms on earth, not just plants and animals. It includes other forms of life like fungi, bacteria, and protist"*

Throughout the observed lessons, Ms. Candy identified misconceptions and difficult concepts and confronted all of them by expanding and rephrasing further. This tallied with the data from learner questionnaires. When asked if the teacher considered their prior knowledge, they all responded, *'yes'*. She further confirmed learners' understanding by asking a set of questions at the end of the lesson and through classwork and tests. Accordingly, Ms Candy was rated Advanced at acknowledgement of possible student prior knowledge, difficult concepts, and misconceptions.

Use of identified variations in student understanding and learning to guide instruction

Some acknowledgment of variations in student understanding or learning are used to guide instruction. Learners were given work to research on and present to class. However, as the learners presented the teacher would interject sometimes and explain identified difficult concepts. For example, during classification of plants into phylum, learners were having challenges in understanding the features of bryophytes and Ms. Candy had to interject during the presentation and used pictures to explain features of bryophytes. Likewise, during classification of organisms into kingdoms, Ms. Candy took over after the presenters and used a dichotomous key and sample organisms to explain the classification.

When asked in what ways students influenced her teaching decisions, this is what Ms Candy had to say,

"Whenever I feel learners are not understanding, I change my teaching methods. Sometimes I take over from the presenter and explain the concepts when I notice that students are having

challenges in understanding. I even bring in pictures and other teaching aids to ensure that students understand.'

From her response, Ms Rose valued learner understanding and used varied methods to stimulate learner understanding. Therefore Ms. Candy was rated Proficient in using identified variations in student understanding and learning to guide instruction.

Use of questioning to probe or extend student understanding

An adequate number of questions were asked to probe and extend student understanding. Hence, the teacher was rated Proficient at questioning to extend students' understanding. In view of the levels of the three constructs, Ms. Candy had adequate knowledge of student understanding.

5.4.3 Analysis of Mr Dee's knowledge of students

Table 5.10 Mr Dee's knowledge of student understanding

Construct	**Observed attributes**	**Level**
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	No facilitation of discussions that expose learner" misconceptions Learners are spoon-fed with the necessary prior knowledge	Limited
Teacher uses identified variations in student understanding and learning to guide instruction	No acknowledgement and/or use of variations in student understanding and learning to guide instruction	Limited
Teacher uses questioning to probe or extend student understanding	No questions are used to probe or extend student understanding	Limited

Recognition and acknowledgement of possible student prior knowledge, difficult concepts, and misconceptions

There was no facilitation of discussion to expose learner prior knowledge or misconceptions. At the beginning of the presentations. This is what Mr. Dee said.

"We expect no interruptions during the presentations in terms of questions or any other interjections, questions will be asked at the end of the presentations."

From his statement, the teacher prohibited any form of discussion, and consequently, throughout the lesson, learners made presentations and no questions, or any form of contributions were made by the other learners or the teacher himself. The learners seemed absent-minded as their colleagues were presenting. Hence, there was no way the teacher could identify the learner's prior knowledge, misconceptions, and difficulties. The findings from the observations tallied with the responses from the teacher questionnaires. When asked if the learner's prerequisite knowledge affected his lesson planning, Mr. Dee's response was 'no'. This implies that prior knowledge, areas of difficulties and misconceptions were not identified and made use of during the lessons. The observation tallied with the learners' responses. When asked if the teacher considers their prior knowledge, 80% of them responded, 'no'.

Learners are not tabularas (empty vessels); hence their prior knowledge is of significance for building up new knowledge. A constructivist facilitator creates a learning environment that promotes exploration and discoveries by learners, however, Mr. Dee did not engage learners to expose the prior knowledge. Subsequently, Mr. Dee was rated Limited at recognising and acknowledging possible student prior knowledge, difficult concepts, and misconceptions.

Use of identified variations in student understanding and learning to guide instruction

No acknowledgements were made to the variations in learner understanding and learning to guide instruction. The teacher just gave learners areas to research on and present. This was the mode of instruction, whether learners understood or not, no questions or interjections were allowed. However, when the presentations ended, learners were dismissed and there was no time for them to ask questions. When asked why he prohibited learners from asking questions, this is what Mr Dee had to say.

‘We are behind in terms of syllabus coverage and so we need to ensure that more concepts are covered during the lessons.’

This was an indication that the teacher was just worried about concept coverage and not if the learners understood or not. Consequently, the teacher’s knowledge of the use of identified variations in student understanding and learning to guide instruction was at Limited level.

Use of questioning to probe or extend student understanding

No questions were used by the teacher to probe or extend learner understanding. When asked in what ways students influenced his teaching decisions, this is what Mr Dee said,

‘Presentations are a learner-centred teaching method that encourages learners to research, present and share information.”

This shows that besides giving out objectives to students for learners to present, he does not consider learners during teaching and learning. Hence, the teacher's knowledge of questioning to probe or extend student understanding was rated Limited. Analysis of Mr Dee’s knowledge of student understanding using table 4.4 and table 4.5 of the analytical framework showed that Mr Dee had inadequate knowledge of student understanding

5.4.4 Analysis of Mr Lazz's knowledge of students' understanding

Table 5.11 Mr Lazz knowledge of students' understanding in Biodiversity

Construct	Observed attributes	Level
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	No facilitation of discussions that expose learner‟ misconceptions Learners are spoon-fed with the necessary prior knowledge.	Limited
Teacher uses identified variations in student understanding and learning to guide instruction	No acknowledgement and/or use of variations in student understanding and learning to guide instruction	Limited
Teacher uses questioning to probe or extend student understanding	No questions are used to probe or extend student understanding	Limited

Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions

There was no facilitation of discussions to expose learner misconceptions. Learners spoon-fed each other during the lessons. When asked if learner prerequisite knowledge affected his lesson planning, he responded 'no'. This was very true since he did not even plan for the lessons. When asked how he identified learner misconceptions, this is what Mr. Laz had to say,

"By using questions and letting the learners do the presentations"

From the response above, the researcher deduced that the teacher never identified the learner misconceptions and seemed not interested in the teaching process. The data tallied with the data collected from the learner questionnaires, when asked if the teacher considered their prior knowledge all responded *'no'*. Hence the teacher's level of recognising and acknowledging possible student prior knowledge, difficult concepts, and misconceptions was at Limited.

Teacher uses identified variations in student understanding and learning to guide instruction

There was no acknowledgement of student variations in understanding, hence this did not guide instruction. Consequently, the teacher's level of identifying variations in student understanding and learning and using them to guide instruction was Limited.

Teacher uses questioning to probe or extend student understanding

No questions were asked to probe or extend student understanding. When asked in what ways students influence his teaching decisions, this is what Mr Lazz said,

'I give the learners the objectives to research on and present.'

From his response, Mr Lazz did not consider learners during teaching and learning. He only gave presentations and never considered learner understanding during instruction. Hence, the level of teacher knowledge of questioning to extend students' understanding was Limited.

An analysis of Mr. Lazz's knowledge of students' understanding was evaluated using a comparison of his levels of the three constructs and table 4.5. His level of students' understanding was inadequate.

5.4.5 Comparison of teacher participants' knowledge of student understanding

Table 5.12 Comparison of teacher participants' performance

Sub-construct	Ms Rose	Ms Candy	Mr Dee	Mr Laz	Comment
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	Identified learner prior knowledge, difficult concepts, and misconceptions through question and answer and facilitated discussions to explain difficult concepts and to clear misconceptions.	Exposed learner prior knowledge, difficult concepts and misconceptions through question-and-answer sessions and facilitated discussions or changed teaching methods to enhance learner understanding.	Did not facilitate discussions to expose prior knowledge, difficult concepts, and misconceptions. Instead, he prohibited learners from asking questions.	Did not facilitate discussions to expose prior knowledge, difficult concepts, and misconceptions.	Ms Rose and Ms Candy acknowledges the significance of prior knowledge in student learning, while Mr Dee and Mr Lazz seemed not to worry about the prior knowledge, difficult concepts, and misconceptions
Teacher uses the identified variations in student understanding to guide instruction	Acknowledges the differences in student understanding, however, did not use them to guide instruction	Teacher used the variations in student understanding to guide instruction.	Did not use differences in students' understanding to guide instruction. Mode of instruction was always student presentations.	Did not use differences in students' understanding to guide instruction. Mode of instruction was always student presentations.	Ms Candy used the identified differences to guide instruction, while Ms Candy did not. Mr Lazz and Mr Dee were in the class as spectators as the learners made presentations without them commenting.
Teacher uses questioning to probe and extend student understanding	Used a wide range of questions to probe and extend student understanding	An adequate range of questions were asked to extend students' understanding.	No questions are used to extend student understanding.	No questions are used to extend student understanding	Ms Candy and Ms Rose used a wide range of questions to extend student understanding, however Mr Dee and Mr Lazz did not ask questions during their lessons.
Teacher knowledge of students understanding	**Adequate**	**Adequate**	**Inadequate**	**Inadequate**	**Ms Candy and Ms Rose had adequate knowledge of student understanding, while Mr Dee had inadequate**

Table 5.12 summarises the teachers' levels of student understanding. The table shows that the teacher's level of student understanding ranged from inadequate to adequate. Two teachers, Ms Rose and Ms Candy had adequate knowledge of student understanding, while Mr Dee and Mr Lazz had inadequate knowledge of students understanding.

5.6 Evaluation of Teacher Knowledge of the Curriculum

Teacher knowledge of the curriculum was evaluated using the Analytical framework shown in table 4.6 and table 4.7. Three sub-constructs were noted as contributing to teacher knowledge of the curriculum. These are knowledge of goals and objectives, interconnection of concepts with other topics and interconnection with other disciplines.

5.61 Analysis of Ms Rose knowledge of the curriculum

Table 5.13 Evaluation of Ms Rose's knowledge of the curriculum

Sub-construct	**Observed attributes**	**Level**
Knowledge of goals and objectives	Laid down lesson objectives at the beginning of each lesson and covered all curriculum objectives on biodiversity.	Advanced
interconnection of concepts with other topics	Interconnection of Concepts with other topic	proficient
interconnection with other disciplines	A few connections made with other disciplines	Proficient

Relevant concepts were explained and sequenced logically. Adequate connections were made to other topics such as ecosystems and conservation as shown in table 5.14. However, limitations in the competences that must be imparted to the learners were noted. These include problem solving, critical thinking and innovation. This was due to the methods of teaching used by the teacher. The lessons were mainly exam oriented and at some point, used typical examination questions. Ms. Rose had adequate knowledge of the curriculum.

5.6.2 Analysis of Ms Candy's knowledge of the curriculum

Table 5.14 Ms Candy's knowledge of the curriculum

Sub-construct	**Observed attributes**	**Level**
knowledge of goals and objectives	Demonstrated knowledge of goals and objectives of the curriculum. Shared objectives with the learner and stated the skills expected to develop in the learners.	Advanced
interconnection of concepts with other topics	Adequate connections were made with other topics during learner presentations	Advanced
interconnection with other disciplines	Connections made by learners during presentations to issues of conservation, sustainable use, restoration learnt in other learning areas	Advanced

Ms. Candy was highly knowledgeable of the goals and objectives of the topic as shown in table 5.15. Concepts were logically sequenced and explained very well. Interconnections between concepts, topics and disciplines were made. Teacher was cognisant of the needs of the syllabus and topic during her teaching, several organisms were brought to class during classification, and the teacher had no access to ICT and pointed out that she could have used videos to show some organisms but had no access and instead brought pictures of those organisms that were beyond her reach. Ms. Candy showed awareness of various instructional materials, teaching procedures, and learning objectives necessary for effective teaching of the topic. The data tallies with responses from learner questionnaires, when asked how they were going to use the information learnt during the topic, responses included '*conservation, value addition and sustainable use*'. This is an indicator that problem solving, and critical thinking skills had been imparted to the learners. Ms. Candy had advanced knowledge of the curriculum.

5.6.3 Analysis of Mr Dee's knowledge of the curriculum

Table 5.15 Evaluation of Mr Dee's knowledge of the curriculum

Sub-construct	Observed attributes	Level
knowledge of goals and objectives	Objectives of the curriculum were shared with learners.	Basic
interconnection of concepts with other topics	Few connections were made with other topics during learner presentations	Limited
interconnection with other disciplines	A few links were made to other disciplines.	Limited

Relevant key ideas were discussed but not given enough attention. Key concepts were just given in presentations without use of any resources to facilitate learning. Knowledge of the objectives was demonstrated as shown in table 5.16. However, some goals of the curriculum were not achieved. These include imparting skills such as problem solving and critical thinking. Critical methods that instil such skills were not used. These include field work, practical and other hands-on activities. Links were made to other topics, and a few made to other disciplines. Mr Dee had inadequate knowledge of the curriculum. This tallies with the responses from the learner questionnaire. When asked the skills that they will use in their day to day lives, they all responded, identification and classification of organisms. This illustrated that key skills needed in the learners' day to day lives were not imparted to them.

5.6.4 Analysis of Mr Lazz's knowledge of the curriculum

Table 5.16 Mr Lazz's knowledge of the curriculum

Sub-construct	Observed attributes	Level
Knowledge of goals and objectives	Teacher well knowledgeable on the goals and objectives of the curriculum. Shared objectives with the learners as a guide to learner presentations.	Basic
interconnection of concepts with other topics	Interconnections of concepts were noted during learner presentations.	Limited
interconnection with other disciplines	A few connections made with other disciplines	Limited

Mr. Laz had inadequate knowledge of the curriculum. He had adequate knowledge of goals and objectives. Relevant key ideas were discussed. The students made few interconnections with other topics during their presentations, for example reference was made to issues learnt in ecology and conservation, and however, few connections were made to other disciplines. However, despite having the knowledge of the objectives, limited knowledge of the goals of science were exhibited since all lessons were through learner presentations and no practical activities were done that instil problem-solving and critical thinking skills. Such skills are necessary in the students' day to day lives. Hence, Mr Lazz had inadequate knowledge of the curriculum.

5.6.5 Comparison of teacher knowledge of the curriculum

Table 5.17 Comparison of teacher knowledge of the curriculum

Key construct	**Knowledge of the curriculum**				
Sub-construct	Ms. Rose	Ms Candy	Mr Dee	Mr Lazz	**Comment**
knowledge of goals and objectives	Laid down lesson objectives at the beginning of each lesson and covered all curriculum objectives on biodiversity. However, methods used did not trigger development of critical thinking and problem solving.	Demonstrated knowledge of goals and objectives of the curriculum. Shared objectives with the learner and stated the skills expected to develop in the learners, used teaching methods to stimulate development of critical thinking and problem solving.	Objectives of the curriculum were shared with learners. Methods used did not enhance development of critical thinking and problem solving.	Teacher well knowledgeable on the goals and objectives of the curriculum. Shared objectives with the learners as a guide to learner presentations. Methods used did not enhance development of critical thinking and problem solving	All the teacher participants had knowledge on goals and objectives, however, Ms Candy demonstrated greater understanding of the needs of the curriculum.
interconnection of concepts with other topics	Interconnection of Concepts with other topic	Adequate connections were made with other topics during instruction	inadequate connections were made with other topics during learner presentations	Few interconnections of concepts were noted during learner presentations.	Ms Rose and Ms connected concepts to other topics.
interconnection with other disciplines	A few connections made	Connections made by learners during presentations	A few links were made to	A few connections made with other disciplines	Ms Rose and Ms Candy connected concepts to

	with other disciplines	to issues of conservation, sustainable use, restoration learnt in other learning areas	other disciples.		other disciplines, though Ms Candy demonstrated excellent skills in connecting concepts to other learning areas, which included Geography, Business studies, Accounting.
Teacher knowledge of the curriculum	**Adequate**	**Advanced**	**Inadequate**	**Inadequate**	Ms. Candy had Advanced knowledge of the curriculum

Table 5.18 summarises findings on teacher knowledge of the curriculum. The table shows that teacher knowledge of the curriculum ranged from inadequate to advanced. The teacher participants with inadequate knowledge of the curriculum demonstrated inadequate knowledge of the goals of the competence-based curriculum, while the teacher with advanced knowledge of the curriculum, Ms Candy demonstrated knowledge of the needs of the competence based curriculum, not only in the objective but also in teaching methodologies that stimulate the development of the 21st century skills.

5.7 Evaluation of Teacher Knowledge Of Instructional Strategies

Teacher knowledge of instructional strategies was evaluated using the Analytical framework shown in table 4.10. Teacher knowledge of instructional strategies is influenced by the appropriateness of the sequence of teaching concepts, use of relevant examples or representations which are pedagogically effective at portraying the concept and use of strategies that allow for metacognition.

5.7.1 Analysis of Ms Rose' knowledge of instructional strategies

Table 5.18 Ms Rose knowledge of instructional strategies

Key construct	**Knowledge of instructional strategies**	
Sub-construct	**Observed attributes**	**Level**
Appropriate sequence of concepts	Concepts logically sequenced in such a way that enhanced learner understanding.	Proficient
Relevant examples or representations that are pedagogically effective at portraying the concept	Examples and representations were pedagogically effective	Basic
Use of strategies that allow for metacognition	Few strategies were used that allowed metacognition.	Basic

The teacher used PowerPoint presentations during teaching classification and the five kingdoms. PowerPoint presentations had some pictures of the organisms. Most key ideas were sequenced logically. The examples/ representations used had some relevance but appeared pedagogically limited. There was limited use of strategies that allow for metacognition. Though the PowerPoint presentations were used to engage learners, there was limited use of strategies that guide learners construct their own knowledge. The topic Biodiversity requires field work, project based learning and practical work to help learners construct their own knowledge, however, these methods that stimulate critical thinking and problem-solving skills were not used, and the teacher could have at least brought model organisms to class. When asked to evaluate her teaching methods, this is what Ms. Rose had to say.

"*Biodiversity must be taught through field works and practical, however we do not have adequate resources for practical and field works*".

Findings from the learner questionnaire tallies with the teacher's response. When asked how the understanding of the topic could have been improved, the learners felt that the topic biodiversity could have been taught best using '*videos, practical and field works*.' However, some plants, animals, fungi, monerans and protista are locally available. Such organisms could have been brought to class and enable teachers to facilitate learning.

Most of the organisms are available in our ecosystems and could have been used to guide learners in classification. Ms. Rose had adequate knowledge of instructional strategies.

5.7.2 Analysis of Ms Candy' knowledge of instructional strategies

Table 5. 19 Ms. Candy's knowledge of instructional strategies

Key construct	**Knowledge of instructional strategies**	
Sub-construct	**Observed attributes**	**Level**
Appropriate sequence of concepts	Concepts well sequenced and explained Teacher asked high order questions Addressed misconceptions	**Proficient**
Relevant examples or representations that are pedagogically effective at portraying the concept	Relevant and pedagogically effective examples	**Proficient**
Use of strategies that allow for metacognition	Strategies learner centred Allow metacognition	**Proficient**

A few high order questions were asked by the teacher. Key ideas were logically sequenced, and relevant examples and representations were used that were pedagogically effective. In all the lessons sample organisms were brought to class and used to guide instruction. Where the organisms were not found locally the teacher used pictures in textbooks, for example bryophytes and sponges. Plate 5.1, Plate 5.2 and Plate 5.3 are the pictures of some of the plants used in classification of Kingdom plantae. The teacher gave students an area to research and present. Students used the plants to trigger discussions on the diagnostic features of the several phyla. The lessons were learner-centred and the teacher was also actively involved in guiding learners as the presentations progressed. This is what Ms. Candy said during the presentations to promote discussions.

"*Can I stop you a little bit, remember you are leading a discussion. You are not giving people answers, I want everyone to be involved.*"

This made the presenter change the mode of instruction delivery from spoon feeding to use of questions to guide instruction. There was adequate use of strategies that allow for metacognition. Ms Candy had adequate knowledge of instructional strategies.

Plate 5. 1 Coniferophyta: Sample plant used in classification and identification of diagnostic features by Ms Candy.

Plate 5. 2 Filicinophyta: Sample plant used in classification and identification of diagnostic features by Ms Candy.

Plate 5. 3 Angiospermophyta: Sample plant used in classification and identification of diagnostic features by Ms Candy.

5.7.3 Analysis of Mr Dee's knowledge of instructional strategies

Table 5. 20 Mr Dee's knowledge of instructional strategies

Key construct	**Knowledge of instructional strategies**	
Sub-construct	**Observed attributes**	**Level**
Appropriate sequence of concepts	Concepts logically sequenced No exploration of prior knowledge No identification and clarification of difficult concepts	Limited
Relevant examples or representations that are pedagogically effective at portraying the concept	No examples or representations used to engage learners	Limited
Use of strategies that allow for metacognition	No strategies were used that allow metacognition	Limited

Concepts were logically sequenced; however, the teacher did not explore prior knowledge, no use of examples or representations to engage with concepts. The lessons were student-centred in the sense that students made the presentations, however, as students presented, there was a need to engage with the media to guide each other and discover new knowledge. In the observed lessons, the students took the role of a traditional teacher, to give information. There was no use of strategies that allow for metacognition. Teacher mentioned limited resources during lesson delivery as a limitation. However, most of the sample organisms are found in every community and to worsen the situation, there were specimens of several animals in the laboratory that neither the teacher nor the presenters referred to during the lesson. Attached are photos of preserved samples of animals in the laboratory (Plate 5.4, Plate 5.5, Plate 5.6 and Plate 5.7). This tallies with the questionnaire response from learners, when asked, what methods could have improved their understanding, they all responded, *'field trips, videos, pictures, or model of organisms.'* Teacher demonstrated inadequate knowledge of instructional strategies.

Plate 5. 4 Preserved animals in Mr Dee's laboratory not used during instruction

Plate 5. 5 Preserved animals in Mr Dee's laboratory not used during instruction

Plate 5. 6 Preserved animals in Mr Dee's laboratory not used during instruction

Plate 5. 7 Preserved animals in Mr Dee's laboratory not used during instruction

The researcher felt the teacher could have availed these samples and many more in the environment to guide learners build new knowledge. Teachers should think of resources locally available instead of creating constraints by wanting to visit the botanical garden or national parks when the concepts can be effectively taught away from the suggested sites. However, funds and other conditions permitting a visit to such places can motivate learners and enhance learning. Consequently, Mr Dee had inadequate knowledge of instructional strategies.

5.7.4 Analysis of Mr Lazz's knowledge of instructional strategies

Table 5. 21 Mr Lazz's knowledge of instructional strategies

Key construct	**Knowledge of instructional strategies**	
Sub-construct	**Observed attributes**	**Level**
Appropriate sequence of concepts	Concepts sequenced logically No exploring learner prior knowledge Teacher did not identify, expose, and explore difficult concepts	Basic
Relevant examples or representations that are pedagogically effective at portraying the concept	No use of examples or representations pedagogically effective	Limited
Use of strategies that allow for metacognition	No strategies were used for learner understanding and development.	Limited

Mr. Laz's knowledge of instructional strategies was limited. The mode of instruction was limited to student presentations. The syllabus stipulates that during teaching Biodiversity there is need for use of sample organisms and ICT, however this was not done during the observed lessons. There was limited use of strategies that allow for metacognition. When asked in the questionnaire on methods students felt could have improved their understanding of the topic, the students pointed out; '*field trips, videos, and use of pictures of the organisms'*. Student presentations can facilitate an active learning environment, however, teachers used learners as a mode of delivering traditional instruction.

5.6.5 Comparison of teacher knowledge of instructional strategies

Table 5. 22 Comparison of teacher knowledge of instructional strategies

Key construct	**Knowledge of instructional strategies**				
Sub-construct	Ms. Rose	Ms Candy	Mr Dee	Mr Lazz	**Comment**
Relevant examples or representations that are pedagogically effective at portraying the concept	Concepts logically sequenced in such a way that enhanced learner understanding.	Concepts well sequenced and explained Teacher asked high order questions Addressed misconceptions	Concepts logically sequenced No exploration of prior knowledge No identification and clarification of difficult concepts	Concepts sequenced logically No exploring learner prior knowledge Teacher did not identify, expose, and explore difficult concepts	All teacher participants logically sequenced concepts. However, Ms Candy used high order questions, identified misconceptions, and addressed them.
Relevant examples or representations that are pedagogically effective at portraying the concept	Examples and representations were pedagogically effective	Relevant and pedagogically effective examples	No examples or representations used to engage learners	No use of examples or representations pedagogically effective	Ms Candy and Ms Rose used examples and representations, however, Mr Dee and Mr Lazz did not use any examples to stimulate understanding.
Use of strategies that allow for metacognition	Few strategies were used that allowed metacognition. e.g use of powerpoint presentations with pictures	Strategies learner centred Allow metacognition e.g practical activities, discussions, sample organisms, pictures	No strategies were used that allow metacognition	No strategies were used to learner understanding and development	Ms Candy used a variety of strategies to allow for metacognition, followed by Ms Rose. However, Mr Dee and Mr Lazz did not and seemed not interested in the process of teaching
Teacher knowledge of the instructional strategies	**Adequate**	**Adequate**	**Inadequate**	**Inadequate**	Ms Rose and Ms Candy demonstrated adequate knowledge of instructional strategies whilst Mr Dee and Mr Lazz had inadequate knowledge.

Table 5.22 shows a comparison of teacher participants' levels of knowledge of instructional strategies. The level of teacher knowledge of instruction strategies ranged from inadequate to adequate.

5.8 Evaluation of Science Teaching Orientations

Factors affecting teacher knowledge of science teaching orientations were identified as the beliefs about purposes of teaching science, beliefs about science teaching and learning as well as beliefs about the Nature of Science in the Analytical framework shown in table 4.12 and table 4.13.

5.8.1 Analysis of Ms Rose' orientations to science teaching

Table 5. 23 Ms Rose's orientations to teaching science

Key concept	**Science teaching orientations**	
Sub-construct	**Observed attributes**	**Level**
Beliefs about purposes of teaching science	Demonstrated adequate knowledge of the purpose of teaching science. Referred to problems in society during discussions, though the teaching methods used did not allow imparting of problem solving and innovation	Proficient
Beliefs about science teaching and learning	Adequate knowledge of science teaching and learning. Inco-operated issues of conservation, value addition	Proficient
Beliefs about NoS	Limited knowledge about Nature of Science as illustrated by lack of exposure of learners to the methods of scientific enquiry	Basic

Ms Rose demonstrated adequate knowledge of the purpose of teaching science. During her lessons she referred to current issues in the society, for example land degradation, destruction of habitats, extinction of organisms and climate change. She allowed for discussions on how such problems affect biodiversity and how they can be solved. However, the teaching method used by Ms Rose (powerpoint presentations and discussions) limits the development of problem-solving and critical thinking skills. Learners could have been exposed to practical activities, field work and videos. Ms Rose illustrated her beliefs that science teaching can solve societal problems by laying out solutions to the issues in society during her discussions. However, Ms Rose had limited knowledge of NoS since all the lessons were conducted through presentations and discussion. From the content analysis, the syllabus emphasises the need for practical and field work. Science is founded or derived from observations of the world around us. No practical, field work or project-based learning was done. This shows the teachers limited knowledge of the process of scientific inquiry.

The researcher also noted that Ms Rose had no scheme of work or lesson plan. Teacher used a notebook and downloaded PowerPoint presentations for the lessons. Lack of planning manifested in delay in starting of the lessons due to failure to use the projector. This showed that on an ordinary lesson, without anyone observing the lessons, the teacher did not use the PowerPoint presentations and the projector. When asked about the workbooks, this is what the teacher had to say

"I don't have any scheme or lesson plan; I use my notebook. I don't know when I lastly schemed or wrote a lesson plan. If you really want the scheme for your research, I can just write the section on Biodiversity for you"

When asked how she ensures efficient lesson delivery, this is what Ms Rose had to say.

"*With experience, I now know how to deliver my lessons effectively without a scheme or lesson plan but using the syllabus and my notes."*

Science is a practical subject that requires planning. Lack of planning limited the teacher during lesson delivery. Ms Rose had adequate orientations to science teaching.

5.8.2 Analysis of Ms Candy's orientations to science teaching

Table 5. 24 Ms Candy's orientations to teaching science

Key concept	**Science teaching orientations**	
Sub-construct	**Observed attributes**	**Level**
Beliefs about purposes of teaching science	Illustrated that she believes science teaching should impart critical thinking, problem solving and innovation	Advanced
Beliefs about science teaching and learning	Solving societal issues Hunger, poverty, land degradation, habitat destruction	Advanced
Beliefs about NoS	Illustrated that she believes scientific method requires observation, experimentation, induction, critical analysis	Advanced

Ms. Candy's beliefs about purposes of science teaching were highly appropriate and were illustrated during lesson delivery. She emphasised on the need for conservation and value addition throughout her lessons. This was her introduction to lesson three.

"*I'm sorry on Friday I was not around. I went to my sister's daughter's wedding, and I enjoyed myself. It was a wedding, not muchato. It was well organised, and everything was there. This showed that they had money to plan the wedding. So, I asked the bride where she got the money, since she only graduated last year. She said I started a mushroom project in January. So, she is growing mushrooms and generating a lot of money. So, I said this is awesome, you are using knowledge of biodiversity to get income, I will take photos to show my students. Remember I said we must be able to use knowledge to make money.*"

In her introduction she gave a tangible example of the value that one can get by using the knowledge obtained from Biodiversity. This may also motivate the learners to venture into several income generating projects from the knowledge gained from science.

Ms. Candy focused on issues of conservation throughout her lessons. She believes science is taught so that people can apply the knowledge for betterment of society and ecosystems which is commendable. This is what Ms. Candy said in one of her lessons.

"*Remember I said all the organisms we are using must be released back into the ecosystem, why. Who can give a reason why we released them back into the ecosystem?"*

The response from one of the learners was, "*to maintain the balance of the ecosystem*". Ms. Candy responded by saying "*Yes to conserve them, to prevent them from getting extinct*."

However, the teacher was cognisant of the fact that the learners were to sit for an examination and guided them on how to answer questions. One salient observation was that participant teachers aimed to assess students' understanding to prepare their students for board exams.

This was Ms. Candy's comment on diagnostic features given by the learners during the revision of the practical test.

"Let's *give features that we can observe, on diagnostic features of any given specimen."*

Ms. Candy's beliefs about NoS were highly appropriate and were illustrated during the lessons. All the five observed lessons were learner-centred, and the lessons scaffolded from engaging, exploring, explaining, elaborating and evaluating, 5Es constructivist model. Such a constructivist strategy can improve students' mastery of content to the higher levels of cognition. Ms Candy demonstrated that she was good at initiating discussions, reinforcing important concepts, and navigating through all her lessons.

Ms. Candy had no scheme of work or lesson plan. She used the syllabus and her notebook for the lessons. This shows the need for supervision. When asked why she did not have schemes of work and lesson plans, this was what Ms. Candy said.

'I use my teaching experience to ensure that the lessons go on very well. I do plan, but just don't write it down. That's why there were several organisms during the lessons collected from the ecosystem and used to guide instruction."

The researcher noted that though she did not have lesson plans and the scheme of work, yes there was some form of planning for her lessons. All lessons involved some form of practical activities. Ms Candy was rated Advanced at her orientation to science teaching.

5.8.3 Analysis of Mr Dee's orientations to science teaching

Table 5. 25 Mr Dee's orientations to science teaching

Key concept	**Science teaching orientations**	
Sub-construct	**Observed attributes**	**Level**
Beliefs about purposes of teaching science	No knowledge about the purpose of teaching science. Believes in teaching for the examination	Limited
Beliefs about science teaching and learning	Traditional mode of instruction	Limited
Beliefs about NoS	No knowledge about NoS Only lecture method used Prohibited discussions	Limited

Mr Dee had limited science teaching orientations. He illustrated no knowledge on the purpose of teaching science, has inappropriate beliefs about science teaching and learning and inappropriate beliefs about NoS. The observed lessons were mainly traditional lessons delivered by the students, where one student, the presenter, transferred knowledge to the rest of the class. When asked what the critical science ideas in his lessons were, this is what Mr. Dee had to say.

"Importance of the various kingdoms, there wasn't much to look at."

This statement clearly shows that the teacher doesn't know the purpose of teaching the topic Biodiversity. The teacher's failure to explain concepts and navigate through his lessons was because the teacher did not know. It is true that teachers cannot explain to students what they do not know. Issues of conservation, restoration of ecosystem and value addition were not mentioned. The teacher also used learner centred student presentations, however, there was no active participation or engagement of learners in learning. When asked 'what do you perceive as the significance of teaching the topic, biodiversity?' This was Mr Dee's response.

'so that students develop interest in Biodiversity and global environment issues'

The teacher was not aware of the need for development of critical thinking skills, problem solving skills and innovation for eradication of poverty and sustainable use. When asked what his role was in the lesson, this was Mr Dee's response.

'Facilitator, educator, evaluator and counsellor'

However, Mr Dee seemed to know what his role in a science lesson was but could not execute his role. Mr Dee's science teaching orientations were inadequate.

5.8.4 Analysis of Ms Rose' orientations to science teaching

Table 5. 26 Mr Lazz's orientations to science teaching

Key concept	**Science teaching orientations**	
Sub-construct	**Observed attributes**	**Level**
Beliefs about purposes of teaching science	Exam oriented	Limited
Beliefs about science teaching and learning	No knowledge demonstrated	Limited
Beliefs about NoS	No knowledge on NoS Traditional instruction used	Limited

Mr. Laz was limited in science teaching orientations. He illustrated no knowledge of the purpose of teaching science. He has limited beliefs about science teaching and learning. Inappropriate beliefs about the nature of science were illustrated. Teacher used learner presentations throughout his lessons, but he was not part of the lessons as he never contributed towards learner understanding. When asked what his role was in the lesson, in both the interview and questionnaire, the teacher said his role was to facilitate or guide the learners, while the role of the learners was to research, present and ask questions. Student presentation is a useful and enjoyable mode of learning that exposes the student to the skills of communication, presentation, as well as to content understanding. However, the researcher has attributed the failures by the teacher to keep up with the demands of being a facilitator to the teacher identity that has developed in him based on the personal and professional experiences. Upon requesting permission to conduct research from the head, this is what the head said.

"Please do not bother my teacher, don't you know that we are incapacitated."

Such a remark from an administrator, who has ultimate responsibility of supervising the teachers and school at large was an indicator of a poor working environment where possible minimum teaching and learning activities are taking place.

Mr Lazz had no scheme of work, lesson plan or any evidence of planning. When asked why he was not planning, this was Mr Lazz's response.

"*Scheming and planning is laborious, given that the syllabus has the objectives and everything and the teacher is asked to scheme again while the syllabus is there. I think there should be another way which can involve only evaluation than planning".*

From Mr Lazz's response the researcher noted a negative attitude towards the demands of the profession. Mr Lazz had inadequate orientations to science teaching.

5.8.5 Comparison of teacher orientations to science teaching

Table 5. 27 Comparison of teacher science teaching orientations

Key construct	**Science teaching orientations**				
Sub-constructs	Ms Rose	Ms Candy	Mr Dee	Mr Lazz	Comment
Beliefs about purpose of teaching science	Demonstrated adequate knowledge of the purpose of teaching science. Referred to problems in society during discussions, though the teaching methods used did not allow imparting of problem solving and innovation	Illustrated that she believes science teaching should impart critical thinking, problem solving and innovation	No knowledge about the purpose of teaching science. Believes in teaching for the examination	Exam oriented	Teacher beliefs ranged from exam oriented to imparting critical thinking and problem-solving skills. Ms Candy demonstrated excellent beliefs on the purposes of teaching science.
Beliefs about science teaching and learning	Adequate knowledge of science teaching and learning. Inco-operated issues of conservation, value addition	Solving societal issues Hunger, poverty, land degradation, habitat destruction	Traditional mode of instruction	traditional mode of instruction	Teacher participants' beliefs about science teaching and learning ranged from traditional mode of instruction, where learners are spoon fed to learning for solving societal problems.
Beliefs about NoS	Limited knowledge about NoS as illustrated by lack of exposure of learners to the methods of scientific enquiry	Illustrated that she believes scientific method requires observation, experimentation, induction, critical analysis	No knowledge about NoS Only lecture method used Prohibited discussions	No knowledge on NoS Traditional instruction used	Teacher beliefs ranged from Traditional instruction to the scientific enquiry through observation, experimentation, and critical analysis.

Orientations to science teaching	Adequate	Advanced	Inadequate	Inadequate	Ms Candy had advanced orientations to science teaching, Ms Rose had adequate science teaching orientations and Mr Dee and Mr Lazz had inadequate science teaching orientations.

5.9 Evaluation of Teacher Knowledge of Assessment

5.9.1 Analysis of Ms Rose's knowledge of assessment

Table 5. 28 Ms Rose's knowledge of assessment

Key concept	**Knowledge of assessment**	
Sub-construct	**Observed attributes**	**Level**
Appropriate dimensions of science to assess	Assessment of prior knowledge through question and answer Assessment of learner understanding during lessons through questions and answer Understanding of concepts using homeworks and test project	Basic
Appropriate methods of assessment	Oral assessment Written assessments Project based assessment	Basic

Ms Rose had adequate knowledge of assessment. Ms Rose asked questions at the beginning of each lesson to assess learner prior knowledge. During the lessons, questions were also asked to evaluate learner understanding and probing was done to stimulate learner understanding.

Homework was given as well as a test at the end of the topic. However, the assessments done were mainly on recall of the concepts learnt during the lessons. No practical assessments were done by Ms Rose. However, at the end of the topic, the teacher asked learners to collect two samples of organisms, classify them, and give the economic importance of the organisms and explain how the organisms can be used in value addition. Below are some of the students' work (Plate 5.8 and Plate 5.9).

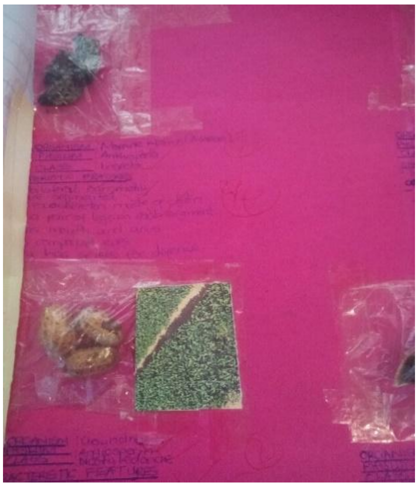

Plate 5. 8 Project based assessments made by Ms Rose

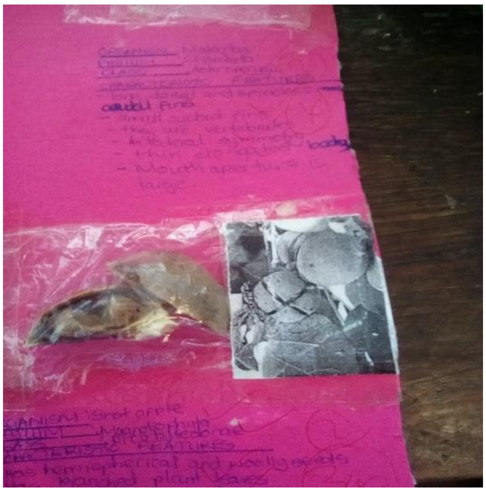

Plate 5. 9 Project based assessments made by Ms Rose

The data collected in observations tallies with the data from the teacher interview. When asked during the interview how she knows if students have learnt, this is what the teacher had to say.

"*I measure learner understanding during the lesson using the responses learners give to the questions. The students also write classwork and tests. Furthermore, the project assigned to them is also used as an assessment tool"*

When asked why there were no practical activities during the lessons and as an assessment tool, this is what Ms Rose had to say.

'Yes, we could have done practicals and field work, however, there are no resources. I would have loved visiting the botanical garden and the national parks, but the funds here do not permit that.'

However, most of the resources required for practical activities on Biodiversity are available in nature and the teacher could have used the locally available materials. Ms Rose had adequate knowledge of assessment.

5.9.2 Analysis of Ms Candy's knowledge of assessment

Table 5. 29 Ms Candy's knowledge of assessment

Key concept	**Knowledge of assessment**	
Sub-construct	**Observed attributes**	**Level**
Appropriate dimensions of science to assess	Assessment of prior knowledge through question and answer Assessment of learner understanding during lessons through questions and answer Understanding of concepts using homework and test Observation, analysis, critical thinking through practical test	Proficient
Appropriate methods of assessment	Oral assessment Written assessments Practical assessment	Proficient

Adequate dimensions of science were assessed. Ms. Candy placed great value on learner prior knowledge and began all lessons with a set of questions to evaluate what the learners knew and used it to build on new knowledge. During lessons, Ms Candy assessed learner understanding by asking a wide range of questions. Classwork exercises were given to learners at the end of the lesson to assess learner understanding of the concepts covered during the lessons. Theory test was given at the end of the topic to evaluate learner understanding on the topic. Teacher also administered a practical test, in which learners were given several specimens and asked to observe and answer questions. Attached are photographs taken during the practical exercise (Plate 5.10, Plate 5.11 and Plate 5.12).

Plate 5. 10 Organisms used by Ms Candy in practical exercise

Plate 5. 11 Organisms used by Ms Candy in practical exercise

Plate 5. 12 Organisms used by Ms Candy in practical exercise.

The data collected tallies with the interview and questionnaire data. When asked on how she evaluated learner understanding, Ms Candy said

'*Through questions asked during the lessons, homework and tests as well as practical tests.'*

Ms Candy demonstrated adequate knowledge of assessment.

5.9.3 Analysis of Mr Dee's knowledge of assessment

Table 5. 30 Mr Dee's knowledge of assessment

Key concept	**Knowledge of assessment**	
Sub-construct	**Observed attributes**	**Level**
Appropriate dimensions of science to assess	Assessed concepts covered No practical skills	Limited
Appropriate methods of assessment	Concepts assessed through h/w and test	Limited

No assessments were made during lesson delivery, since learners were just presenting without meaningful discussions or the teacher asking questions to evaluate learner understanding. The teacher evaluated understanding through written exercises and test, hence assessing only one dimension, theory. There is a need for assessments to be made in practical work, however, this was not done. Practical and project-based assessments could have been used to help instil problem solving skills and innovative skills in learners. Mr Dee had inadequate knowledge of assessment.

5.9.4 Analysis of Ms Lazz's knowledge of assessment

Table 5. 31 Mr Lazz's knowledge of assessment

Key concept	**Knowledge of assessment**	
Sub-construct	**Observed attributes**	**Level**
Appropriate dimensions of science to assess	Concept coverage Practical skills	Basic
Appropriate methods of assessment	Homework and test Practical test	Basic

Adequate dimensions were assessed. He assessed students through homework, tests and a practical exercise in which learners were given specimens to identify, classify and compare. This covered both practical and theory. However, Mr. Laz was limited in assessing students' understanding during lessons as he played a very passive role. A teacher must take the role of an assessor. This helps the teacher to diagnose students' prior knowledge, gauge students' understanding throughout the learning experience and guide instruction, as well as to measure the understanding and knowledge at the completion of the learning experience. Mr. Laz had adequate knowledge of assessment.

5.9.5 Comparison of teacher knowledge of assessment

Table 5. 32 Comparison of teacher knowledge of assessment

Key construct	**Teacher knowledge of assessment**				
Sub-constructs	Ms Rose	Ms Candy	Mr Dee	Mr Lazz	Comment
Appropriate dimensions of science to assess	Assessment of prior knowledge through question and answer Assessment of learner understanding during lessons through questions and answer Understanding of concepts using homeworks and test	Assessment of prior knowledge through question and answer Assessment of learner understanding during lessons through questions and answer Understanding of concepts using homeworks and test Observation, analysis, critical thinking through practical test	Assessed concepts covered No practical skills	Concept coverage Practical skills	All teacher participants assessed theory concepts. This was a simple recall of concepts covered. Ms Rose, Mr Lazz and Ms Candy assessed for observation, critical thinking skills through either project based or practical tests.
Appropriate methods of assessment	Oral assessment Written assessments Project based assessment	Oral assessment Written assessments Practical assessment	Concepts assessed through h/w and test	Homework and test Practical test	Ms Rose and Ms Candy made oral assessments through asking questions during the lessons. All the participants gave written homework and tests. Mr Dee had no form of practical assessment
Knowledge of assessment	**Adequate**	**Adequate**	**Inadequate**	**Adequate**	Except for Mr Dee, all the teacher participant showed adequate knowledge of assessment

Table 5.32 gives a comparison of participant teachers' knowledge of assessment. Teacher knowledge of assessment ranged from inadequate to adequate. Three of the teacher participants had adequate knowledge of assessment while one, Mr Dee had inadequate knowledge of assessment.

5.10 Teacher Pedagogical Content Knowledge

Table 5.33 illustrates each teacher participant's level of the six key constructs in the hexagonal conceptual framework and the subsequent level of teacher PCK. Teacher PCK ranged from inadequate to adequate.

Table 5. 33 Summary of teacher PCK

Key Construct	Ms Rose	Ms Candy	Mr Dee	Mr Lazz	Comment
Content knowledge	Adequate	Adequate	Inadequate	Inadequate	Content knowledge ranged from adequate to inadequate
Knowledge of students	Adequate	Adequate	Inadequate	Inadequate	Knowledge of students understanding ranged from adequate to inadequate
Science teaching orientations	Adequate	Advanced	Inadequate	Inadequate	Science teaching orientations raged from advanced to inadequate
Knowledge of assessment	Adequate	Adequate	Inadequate	Adequate	Knowledge of assessment ranged from adequate to inadequate
Knowledge of instructional strategies	Adequate	Adequate	Inadequate	Inadequate	Knowledge of instructional strategies ranged from adequate to inadequate
Knowledge of the curriculum	Adequate	Adequate	Inadequate	Inadequate	Teacher knowledge of the curriculum ranged from adequate to inadequate
Teacher PCK	Adequate	Adequate	Inadequate	Inadequate	**Teacher PCK ranged from adequate to inadequate**

5.11 Summary Of Findings

Content analysis of the topic of Biodiversity in the 'A' level competence-based curriculum was used to answer **research question1: What does the 'A' level Biology Curriculum demand of the topic biodiversity?** Concepts, objectives, competences, learning material and activities were taken note of. The concepts included the concept of biodiversity, forms of biodiversity, classification, taxonomic hierarchy, binomial nomenclature, socio-economic importance of the five kingdoms and conservation. Competences included observation, identification, communication, critical thinking, problem solving and innovation. The syllabus recommends a wide range of learning materials and activities to ensure the imparting of the skills noted above. These include activities on collecting, observing, and classifying organisms. The syllabus further recommends discussions and activities on binomial nomenclature and socio-economic importance of the five kingdoms. Additionally, discussions and hands-on activities on issues of value addition and conservation are recommended. The syllabus recommends the use of locally available materials such as sample organisms, ICT tools such as videos, PowerPoint presentations, pictures, and simulations. A constructivist approach to teaching and process-oriented instruction is recommended to ensure imparting of the specified skills.

To respond to the second research question: **How do 'A' Level Biology teachers teach the topic Biodiversity?** A topic specific PCK conceptual framework (hexagonal model) was implemented from which an Analytical framework for PCK was crafted. The six constructs used to respond to the research question were content knowledge, orientations to science teaching, knowledge of student understanding, knowledge of assessment, knowledge of the curriculum and knowledge of instructional strategies. Evaluation of the teacher participants revealed the following.

Teacher content knowledge ranged from inadequate to adequate. Ms Rose and Ms Candy had adequate content knowledge for the topic Biodiversity. They taught all the concepts stipulated in the syllabus. Adequate alignment of concepts was noted, and most explanations were accurate. However, Mr Dee and Mr Lazz had inadequate content knowledge. The two teacher participants did not teach some concepts. Little alignment of the concepts was noted, and some inaccurate explanations were given. No links were made to NoS and the scientific enquiry.

Varying levels of teacher knowledge of students' understanding was noted. Two teachers had adequate knowledge of student understanding; Ms Rose and Ms Candy, while the other two teacher participants; Mr Dee and Mr Lazz, had inadequate knowledge of student understanding. Ms Rose and Ms Candy identified learner prior knowledge, difficult concepts, and misconceptions. Lessons were built upon prior knowledge. They facilitated discussions to explain the difficult concepts and misconceptions. Ms Candy further used the variations in student understanding to guide instruction. Ms Candy and Ms Rose used numerous questions to probe learners and extend student understanding. However, the teacher participants with inadequate knowledge of students' understanding, Mr Dee and Mr Lazz, did not expose students' prior knowledge, difficult concepts, or misconceptions. Their modes of instruction were not guided by the students' understanding. The teachers did not use questioning or probing to extend learner understanding. Traditional instruction was noticed in Mr Dee and Mr Lazz's lessons.

Teacher participants ranged from inadequate to advanced knowledge of the curriculum. Ms Candy had advanced knowledge of the curriculum. She demonstrated knowledge of the goals and objectives of the competence-based curriculum. All her lessons were focused on development of skills. Adequate connections were made to other topics, disciplines and placed emphasis on sustainable use, value addition, conservation, and restoration. Ms Rose had adequate knowledge of the curriculum. Objectives were given to the learners for research and presentations though the methods used did not stimulate development of the required skills. Connections were made to other topics and a few to other disciplines. Mr Dee and Mr Lazz had inadequate knowledge of the curriculum. Despite knowing the objectives, the teachers failed to use teaching methods that stimulate development of the 21st century skills in learners.

Ms Rose and Ms Candy had adequate knowledge of instructional strategies, while Mr Dee and Mr Lazz had inadequate knowledge of instructional strategies. The teacher participants with adequate knowledge of instructional strategies (Ms Rose and Ms Candy), logically sequenced concepts during lesson delivery. Examples and representations used were pedagogically effective. These include powerpoint presentations, practical activities and discussions. However, Mr Dee and Mr Lazz had inadequate knowledge of instructional strategies. Though concepts were logically sequenced, no examples or representations were used. The mode of instruction was traditional and did not allow metacognition.

Science teaching orientations ranged from advanced to inadequate. Ms Candy had advanced science teaching orientations. She illustrated the purpose of science teaching, and knowledge of science teaching and learning. Her mode of instruction during all the observed lessons was process oriented. Learners were actively involved in the construction of knowledge. Emphasised on issues of conservation, value addition and on development of the 21st century skills. She illustrated proficient beliefs of NoS. Ms Rose had adequate science teaching orientations while Mr Dee and Mr Lazz had inadequate science teaching orientations.

Ms Rose, Ms Candy, and Mr Lazz had adequate knowledge of assessment. Appropriate dimensions of science were assessed using appropriate methods of assessment. Mr Dee had inadequate knowledge of assessment.

From the assessment of the six constructs and using the PCK Analytical framework (table 4.14), two teacher participants had adequate PCK for the topic Biodiversity, that is Ms Candy and Ms Rose. While the other two teacher participants had inadequate PCK for the topic Biodiversity.

5.12 Discussion

This discussion examines the key findings from the study. Findings are discussed using the key constructs of the conceptual framework. Findings on the demands of the curriculum were also discussed.

5.12.1 Demands of the curriculum

Content analysis shows that most concepts and skills required for conservation, sustainable use and value addition were included in the syllabus. Emphasis is placed on classification and socioeconomic importance of the five kingdoms. Classifying biodiversity helps learners to develop a range of thinking skills and build the foundations for later problem-solving. The visual memory and discernment involved, and the ability to identify patterns, relationships, similarities, and differences, assist in development of problem-solving skills (Reydon, 2021). Reydon (2021) further pointed out that those classifications play an important role in everyday practices and help learners manage the diversity of living organisms, for example, distinguishing between poisonous mushrooms and edible mushrooms, between naturally occurring fauna and invasive species. Hence, classification serves to make diversity manageable, to the extent that without suitable classificatory systems, scientific investigations seem impossible.

The recommended methods are constructivist approaches and ensuring that an active learning environment is maintained during the teaching of the topic, Biodiversity. The constructivist perceptions focused on teaching through engaging learners as active participants in learning and supporting them as they make sense of new ideas by reflecting upon their experiences with the phenomenon (Fernando & Marikar, 2017). The constructivists' view of learning recognizes that learners bring their knowledge of the world and how the world works into the classroom. Learners use their prior knowledge and experiences as well as first-hand knowledge gained from explorations of phenomena. Constructivist teachers perceive learners as active participants in learning and teachers as facilitators of learning (Fernando & Marikar, 2017). Through a constructivist lens, learning opportunities are designed to engage learners first in explorations and, second, to construct knowledge from their experiences (Singh & Yadavanshi, 2015). It is through this interaction that learners begin to make sense of their experiences with phenomena. Teachers with a constructivist orientation engage learners in explorations of phenomena prior to introducing and explaining the phenomena to learners. Adak (2017) observed that the constructivist strategy can improve students' mastery of content to higher levels of cognition in his study on the effectiveness of the constructivist approach on academic achievement in science at secondary level. Therefore, application of constructivism in teaching and learning entails active engagement of learners by facilitators (teachers). Learners are not tabularas (empty vessels); hence their prior knowledge is a prerequisite in building up new knowledge. A constructivist facilitator creates a learning environment that promotes exploration and discoveries by learners.

The syllabus recommends the use of mostly locally available materials for the teaching and learning of the topic, Biodiversity. Lindermann-Matthies *et al.* (2009) noted that every area consists of rich and diverse ecosystems with unique flora and fauna. Bagarinao (1997) pointed out that first hand experiences generate awareness about our ecosystems and heart towards conservation and preservation of our environment. Exposing learners to problem areas will help motivate learners and allow them to appreciate science as a relevant and useful subject. Use of evidence in creating explanations is a learner-centred and inquiry based mode of instruction that help develop 21st century skills in learners (Navarro-Perrez & Tidball, 2012). Localization and contextualization help learners enjoy science. The analysed 'A' Level Biology syllabus is learner centred and placed based and fulfil the demands of a curriculum.

5.12.2 Teacher content knowledge

Ms Candy and Ms Rose had adequate content knowledge. However, when compared to Ms. Rose, though Ms Candy had more content knowledge than Ms Rose. Ms. Candy made more links to other concepts and to the nature of science. Ms Candy also linked the concepts to the day to day lives of the learners, placing more emphasis on conservation, value addition and restoration of Biodiversity and ecosystems. It has also been seen that teachers who are well versed in their subject area, aware of popular opposing viewpoints, and committed to the scientific paradigm offer their students a wealth of opportunities. A noteworthy number of studies have found a connection between teachers' efficacy in teaching science and their mastery of subject matter (Alshehry, 2014; Fitzgerald *et al.*, 2013; Santau *et al*., 2014).

To meet today's standards, teachers must understand the subject matter deeply and flexibly to create useful cognitive maps, relate ideas and address misconceptions. Teachers need to see how ideas connect across fields and to everyday life. To Shulman (1987), this enables teachers to be comprehensible to their learners. Ozden (2008) noted that content knowledge had a positive influence on effective teaching practice. Equally, many researchers such as Halim and Meerah (2002), Ozden (2008) concluded that content knowledge had a positive influence on pedagogical content knowledge. Borko (2004) highlighted that teachers need to understand the facts and concepts of the discipline in addition to having a deep and flexible understanding of the subject they teach. However, poor CK results in low self confidence in scientific teaching and consequently in low quality lessons (Kind, 2014). Content knowledge affects how a teacher interprets the content goals, the way the teacher hears and responds to questions from learners, and the teacher's ability to explain clearly and ask good questions. Hence, teachers with adequate content knowledge interpret the content goals better, respond to questions asked by learners in a more comprehensible manner and ask their learners good questions to enhance learner understanding.

The adequate content knowledge of the two teachers could have been due to the fact that they attended several workshops on the competence-based curriculum. This concurs with Antwi *et al.* (2016) who noted that workshopping increases the teacher's content knowledge. Regular and continual workshops targeting specific sensitive challenging content areas may lead to teachers' developing coping abilities to teach the content area and to meet the specific task needs of pupils. Kind (2014) identified in-service education on science teachers as one of the ingredients needed for building teacher quality and science content knowledge. Though Ms. Rose and Ms. Candy had no schemes of work, some form of planning was observed in the form of prepared notes for the learners. Hence, planning may be conceived of as having contributed to adequate content knowledge. The lesson planning process allows for teachers to evaluate their own knowledge with regards to the content to be taught (Reed & Michaud, 2010). Nyamupangedengu (2015) noted planning as a prerequisite to effective teaching of any course. A teacher with a plan, then, is a more confident teacher. The teacher is clear on what needs to be done, how, and when.

Mr Dee and Mr Lazz had inadequate content knowledge. Similarities noted between the two teachers were that they did not plan and they used student presentations without even commenting on the presentations. The researcher felt the inadequate content knowledge resulted in lack of confidence to comment on student presentations. This could be attributed not only to lack of planning and preparing for the lessons but also to lack of commitment to the profession and lack of motivation. Niemela and Tirri (2017) highlighted that CK is the teacher's understanding of the facts and organisation of the subject. The teacher needs to understand how knowledge is constructed and why certain facts are accepted in that discipline. Niemela and Tirri (2017) further pointed out that the better the CK a teacher has, the better probabilities there are to develop a good level of PCK. It, therefore, follows that the lower the content knowledge the less chances there are to develop a good pedagogical content knowledge.

Teachers must be aware of their lack of content knowledge to remedy their insufficiency and avoid passing misconceptions to their learners (Catalano, Asselta & Durkin, 2019). If teachers believe that they have high self-efficacy, they may not be aware that they must continually improve their science content knowledge. Shulman saw teachers' capability to link concepts to other disciplines as part of CK. Mr. Lazz and Mr. Dee did not relate the subject matter to other concepts and disciplines. However, Niemela and Tirri (2017) pointed out that there is no assurance that the teachers can link concepts to other disciplines. This may be because in teacher training, their lecturers may be specialists in one area, hence teachers lack exposure to other disciplines and thus fail to integrate or link the concepts they teach to other disciplines.

It has been noted that teachers cannot explain what they do not know and the scantiness of CK affects the teachers' ability to deliver science instruction. This is because outstanding science instruction is cultivated from a comprehensive and profound understanding of science CK. Teachers must therefore be aware of their lack of content knowledge to remedy their insufficiency and avoid passing misconceptions to their learners (Catalano *et al*., 2019). It was also noted that the two teachers with inadequate content knowledge never attended any workshops or orientations on the updated curriculum. Workshops are used to explore a specific topic, transfer knowledge, solve identified problems, or create something new (Antwi *et al*., 2016). Teacher Training Workshops help teachers in developing and learning new strategies for teaching, classroom management, technological advancement and improving content knowledge. Hence, workshops provide overall continuous growth opportunities to the teachers to make the best use of their abilities.

The researcher noted that all the teacher participants had no schemes of work and lesson plans. However, Ms. Rose had a notebook, powerpoint presentations and downloaded notes on Biodiversity. The researcher regarded these as some form of planning for the lesson though this does not meet the demands of the Ministry of Primary and Secondary Education. Likewise, Ms Candy had a notebook, downloaded notes and several forms of life brought to class and used for practical activities during the lessons. The researcher also viewed this as some form of planning. Mr Dee and Mr Lazz did not have any form of planning. They both assigned learners to go and research and presented their presentations to class without any input from both teachers. Mr Dee had several forms of Biodiversity preserved in the laboratory which were never used during the lessons but later shown to the researcher after the lessons. However, Mr Dee acknowledges that teachers must plan for effective lesson delivery. This was contradictory to what was on the ground, Mr Dee had nothing planned. Not planning can be attributed not only to lack of supervision in schools but to a new teacher identity developing, one of teachers who do not care about efficacy during instruction. From Mr Dee's response to the issue of planning, it shows he is aware of what must be done but is not willing to do so. Teachers who had some forms of planning for their lessons exhibited adequate content knowledge, while teachers who did not plan at all showed inadequate content knowledge. This shows that planning enhances teacher content knowledge (Rusznyak & Walton, 2011). To Reed and Michaud (2010), lesson planning process allows teachers to evaluate their own knowledge with regards to the content to be taught. If a teacher must teach a particular concept and is not definite of the content, the teacher becomes aware of such an inadequacy during planning and can take the necessary steps to acquire the necessary information (Koberstein-Schwarz & Meisert, 2022). Hence, lesson planning presents an opportunity to evaluate one's own knowledge and acquire any information needed during the lesson, thereby improving teacher content knowledge.

5.12.3 Teacher Knowledge of Students Understanding

Teacher level of students' understanding for the four teacher participants ranged from inadequate to adequate, having two teachers with adequate knowledge of students' understanding and the other two with inadequate knowledge of students' understanding. Ms.

Rose and Ms. Candy had adequate knowledge of students' understanding; however, Ms. Candy exhibited more knowledge of students than Ms. Rose. The knowledge of students is a significant factor in promoting effective instruction (Hill & Chin, 2018). The two teachers probed learners at the beginning of each lesson for prior knowledge. Mabonga (2021) noted that it is important for teachers to probe learners to recall previous learning before presentation of new knowledge. Constructivists point out that humans construct knowledge and meaning from their experiences. Hence, if learning is to take place, a link between the known and the unknown is obligatory. Mabonga (2021) posited that accurate prior knowledge boosts learner confidence during teaching and learning. Learners with adequate prior knowledge freely participate since they can construct a relationship between their experiences and new information. Confident learners manage their problems, fears and maintain a positive attitude necessary for efficacy during learning. Furthermore, prior knowledge makes learning meaningful. As noted by Wilson and Burket (1989), learners have no purpose to remember facts that have little meaning to their personality. Hence, relating a concept to the real world motivates the learners.

Probing for prior knowledge enabled Ms. Candy and Ms. Rose to identify learner misconceptions and correct the inaccurate information through concept revisiting, explanations, and remediation. As Diaz (2017) asserted, prior knowledge of the learners needs to be cleared up of any misconceptions since the inaccurate knowledge could lead to more misconceptions which may alter learners' view of current information to be learnt. DiPietro *et al*. (2008) also pointed out that learners must unlearn misconceptions before learning new accurate knowledge.

Ms Candy used the prior knowledge and identified areas of difficulty to guide instruction, however, Ms. Rose did not. For example, during learners' presentations, Ms. Rose, made a facile assessment of student understanding and noted difficulties in understanding. She interjected several times and explained difficult concepts and at some point, changed mode of instruction to demonstration using pictures and organisms. This is in line with Mabonga's (2021) observations that prior knowledge is an important factor in redesigning or modifying teaching instructions to cater for learner needs thereby enabling learners to construct their own knowledge. This also tallies with Merriam-Webster's (2006) argued that a clinical practice involves direct observation and treatment of patients or clients and in this case, the learners. Hence, Ms Rose observed her learners during instruction and from her diagnosis, modified instruction to improve learner understanding. Both teachers, Ms. Candy and Ms. Rose used a wide range of questions to probe understanding and to extend students' understanding. Probing questions help students acquire new knowledge and make thinking visible paving way for critical thinking (Damayanti, 2022). The critique of each answer makes it easier for the student to correct his/her mistake until they reach the correct generalisation. Damayanti (2022) noted that the question is a stimulus encouraging students to conceive and construct a topic enabling a high level of thinking. Arslan (2006) pointed out that questioning is the strongest tool at the teacher's disposal that teaches students how to think. Hence, critical thinking can be stimulated by asking probing questions to learners.

Mr. Dee and Mr. Lazz had inadequate knowledge of students. There was no facilitation of discussions to expose learner prior knowledge, misconceptions, and difficult concepts. Furthermore, no probing questions were asked to stimulate critical thinking. Ambrose *et al*. (2010) identified circumstances where prior knowledge can inhibit student learning as when it is inactive, insufficient, and inaccurate. They noted that students do not automatically draw on prior knowledge. Despite the student having adequate prior knowledge, if it is ignored or overlooked, this does not help learning of new concepts and the students may struggle learning new concepts despite them having adequate prior knowledge. Hence, the need to activate prior knowledge through questioning or class activities at the beginning of each lesson. Ambrose *et* *al*. (2010) further noted that when inadequate, prior knowledge may hinder student learning, therefore, it is the role of the teacher to design ways to bridge the gap in prior knowledge to facilitate learning of new concepts.

Inaccurate prior knowledge has been seen to impede new learning, resulting in more misconceptions (Ambrose *et al*., 2010). This tallies with DiPietro *et al*.'s (2008) observations that learners must unlearn misconceptions before learning new accurate knowledge. Prior knowledge has also been seen as a crucial factor in redesigning or modification of teaching instructions to cater for learner needs enabling learners to construct their own knowledge (Mabonga, 2021). Consequently, failure by Mr Dee and Mr. Lazz to expose learners' prior knowledge acted as hindrances to learning of new concepts. Additionally, failure by the two teachers to probe learners during the lesson further inhibited critical thinking in learners. Questions are seen as a stimulus, encouraging students to comprehend and construct a concept enabling high level of thinking (Dharmayanti, 2020). Deficiency of critical thinking skills in learners' impact on both the life of the individual and the society. With specific reference to the topic, Biodiversity, this impacts on the individual's ability to make use of biodiversity in value-addition and solving societal problems. One's ability to conserve and restore biodiversity may also be suppressed by poor critical thinking skills leading to biodiversity loss and ecosystem depletion.

Inadequate knowledge of students' understanding can be attributed to lack of orientation of the two teachers to the updated curriculum, lack of planning and inadequate content knowledge, hence the teachers lacked confidence to probe learners in the presence of the researcher. Excellent science instruction is cultivated from a broad and deep understanding of science content knowledge (Heller *et al*., 2012; Tretter *et al*., 2013). Lack of motivation may also result in poor lesson delivery.

5.12.4 Science Teaching Orientations

Ms Rose and Ms Candy demonstrated adequate orientations to science teaching. Magnusson *et al.* (1999) coined orientation to science teaching as the lens through which all components of PCK are understood, interpreted, and integrated resulting in the unique form of knowledge held by teachers. The teacher's beliefs about purposes of teaching science and NoS are guiding tools in instruction delivery. Ms. Rose showed proficient beliefs about NoS and purposes of teaching science. Emphasis was made on value addition and entrepreneurship. Such teacher beliefs influence use of learner-centred teaching strategies. Maker-centred learning is defined as a process of inquiry that draws on social constructivism and involves social meaning-making rooted in the interaction between learners, their experiences, and collaboration with peers (Rodriguez & Harron, 2019). In maker-centred learning, understanding is made more visible through the creation and sharing of tangible artefacts. Engaging learners in maker-centred lessons instils valuable habits such as resilience, collaboration and reflection referred to as a maker mindset (Martin, 2015) and these valuable habits are the competences that must be imparted to learners in the competence-based curriculum.

Ms. Candy's beliefs about NoS were highly appropriate and were illustrated during the lessons. All the five observed lessons were learner-centred, and the lessons scaffolded from engaging, exploring, explaining, elaborating and evaluating, 5Es constructivist model. Nawastheen, Puteh and Meerah (2014) described the 5Es model as an innovative approach for constructive classroom instruction. If learners are actively engaged in learning science, they redefine, replace, and reorganise their initial explanations, attitudes, and skills (Bybee *et al*, 2006). Adak (2017) observed that the constructivist strategy can improve students' mastery of content to higher levels of cognition in his study on the effectiveness of constructivist approach on academic achievement in science at secondary level. The teacher's role is to reinforce, extend, initiate and navigate.

Mr Lazz and Mr Dee demonstrated inadequate orientations to science teaching. Lessons were conducted through student presentations, however, there was no active participation of learners. Hence, the mode of instruction was traditional. Student presentation is a useful and enjoyable mode of learning that exposes the student to the skills of communication, presentation, as well as content understanding (Rodriguez & Harron, 2019). The role of the teacher in a student-centred lesson is to reinforce, extend, initiate and navigate (Puteh & Meerah, 2014). It is through playing these four roles that the teacher becomes a facilitator of a lesson. In the observed lessons, the two teacher participants were not facilitating the lessons but were passive. The facilitator takes the role to maintain the focus of the learning, guides the process, resolves challenges and provides appropriate feedback to each learner and to the group. However, the researcher has attributed the failures by the teachers to keep up with the demands of being facilitators to lack of content knowledge, hence, the teachers were not confident to guide the class in the presence of the researcher.

Science teaching orientations have been seen as filters or amplifiers in shaping the teacher's overall classroom behaviour (Martin, 2015). Episodic memories are the past experiences that affect the teacher's way of lesson delivery. Teachers may replicate the mode of instruction received as a child due to episodic memory. It has also been noted that differences in belief systems may lead to teachers with the same content knowledge teaching a science topic differently (Adak, 2017). Hence, changing from one curriculum to another involves adjusting and accommodating knowledge into a new style of delivery.

5.12.5 Knowledge of Assessment

Deficiency of knowledge of assessment was noted in one of the teacher participants, Mr Dee. Mr Dee assessed through homework and theory tests only. It was noted that some of the tests were simple recall and did not stimulate critical thinking and analytical skills in learners. There is a need for orientations on the dimension of science assessment. If the competence-based curriculum is to evaluate the imparting of problem-solving skills to learners, then methods of assessment must include practical activities and project-based assessments. Edwards (2013) views quality assessment as an integral part of good mode of instruction. Edwards further highlighted that for teachers to teach science well, science teachers need to know what to focus on to ensure that their assessment of student learning is meaningful and useful for the students' on-going learning and development. The diversity of content and skills within science calls for assessment capabilities by teachers. Edwards (2013) proposed a framework for quality assessment in science with focus on concurrent consideration of five areas that is teaching, learners, evidence of learning, future decision making and impact. Edwards (2013) highlighted that teachers are better placed to assess well if they consider the assessment components of their teaching during the planning stages and articulate their range of intentions and goals for the lessons so that they can communicate these to their students. Quality assessment focuses on a student, that is, it addresses the intended student learning outcomes and is responsive to group or individual feedback needs (Mellati & Khademi, 2018). Teachers must therefore focus on their students' needs and develop the skills to be able to design assessment tasks. Quality assessment gathers evidence of students' progress.

5.12.6 Knowledge of Instructional Strategies

Knowledge of instructional strategies include topic specific strategies for example, ways to present concepts (models, diagrams, pictures) and engage students in instructional strategies e.g., through investigations, experiments, demonstrations, simulations, and field work to facilitate learning. Concepts in Biodiversity require learners to actively engage with organisms involved, design activities or projects for value addition using biodiversity, use of videos and pictures where organisms or processes cannot be demonstrated in class. However, Ms. Candy managed to engage her learners in some of the mentioned activities, Ms. Rose used PowerPoint presentations with pictures while Mr. Lazz and Mr. Dee failed to engage their learners in any form of activity. Results tally with Lugosi and Uribe (2022) observation that not all teachers implement active-learning strategies in a way that maximises student outcomes due to variation in the teaching knowledge instructors draw from. However, Freeman *et al.* (2014) revealed that active learning is more effective at promoting the development of conceptual understanding and scientific thinking skills than traditional instruction. Student presentations can facilitate an active learning environment; however, it was noted in this study that teachers are using learners as a mode of delivering traditional instruction. Teachers assign presentations and learners read what they will have researched on to the class without any form of discussion. Active learning often falls short of its potential when it is implemented in ways that do not fully support student learning (Dancy *et al*., 2016). As such, poor implementation of student presentations may act as an impediment to effective teaching and learning.

High school teachers should plan their lessons in a more practical way to enhance not only learners' attitude but also learner achievement (Dagnew & Sitotaw, 2019). Science lessons should extend students' knowledge of the natural world and develop their understanding of ideas, theories and models found by scientists as useful in explaining and predicting it (Abraham, 2009). Hence, teaching science naturally involves showing learners things, or putting them in situations where they can see for themselves. Israel (2014) noted that practical work has significant positive effects on learners' performance and that teaching science without practical activities has a negative effect on learner's interest towards science disciplines.

Humans perceive reality and their surroundings using their senses, with the sense of vision representing the most diverse source of information of the world around us (Amory *et al.*, 1999). This implies that visualisation, and the manipulation of objects have incredible value in teaching and learning. Therefore, hands-on activities as opposed to traditional instruction enhance learners' achievement and attitude towards science. Dagnew and Sitotaw (2019) noted that science teaching cannot be effective without learners being interested in it. Field work and other hands-on activities contribute to the cultivation of this interest. Moreover, the way practical teaching is planned and conducted must be well thought out so that it can boost the learners' attitude. The amount of practical work increases the quality of science subjects, students' view of science and their achievement. It stimulates critical thinking, problem solving and analytical skills among other 21st century skills. If secondary schools must lay down the foundation for future scientists, doctors, engineers, teachers, etc., practical sessions must be conducted as effectively and efficiently as possible.

5.12.7 Knowledge of The Curriculum

Ms Rose and Ms Candy illustrated adequate knowledge of the curriculum. Relevant concepts were explained and sequenced logically. Methods of instruction used by Ms Candy and Ms Rose stimulate the development of 21st century skills. Ms Candy uses the practical activities, while Ms Rose uses pictures on powerpoint presentations to explain concepts. To Mullis *et al* (2016) the goal of the science curriculum is to instil positive attitudes towards science and to inspire students to investigate and understand how science and technology impacts their lives, however this component was deficient in Mr Dee and Mr Lazz's lessons. Curriculum knowledge is of importance to teachers as curriculum implementers. The curriculum identifies the learning outcomes, standards, and competences that students must be able to demonstrate (Charalambous & Hill, 2012). It acts as a map for students and teachers to follow on the path to academic success. Hence, lack of teacher curriculum knowledge misguides learners and leads to the curriculum failing to achieve its goals.

5.12.8 Teacher PCK

Ms. Candy and Ms Rose had adequate PCK on Biodiversity. The two teacher participants illustrated adequate content knowledge for the topic. Shulman (1987) pointed out that teachers need to understand the subject matter deeply and flexibly so that they can help learners create useful cognitive maps, relate ideas to one another, and address misconceptions. Teachers need to see how ideas connect across fields and to everyday life. A noteworthy number of studies also suggested a direct correlation between teachers' science content knowledge and teachers' effectiveness in delivering science instruction (Alshehry, 2014; Fitzgerald *et al*., 2013). Consequently, the two teacher participants managed to use the prior knowledge of learners, teaching aids gathered from the ecosystem, curriculum knowledge, knowledge of instructional strategies, knowledge of assessment and her constructivist teaching orientation to ensure blending of content and pedagogy into a form adapted to diverse interest and abilities of learners.

Mr Lazz and Mr Dee had inadequate PCK for Biodiversity. The low or inadequate PCK can be attributed to not planning and preparing for the lessons. They lacked adequate content knowledge for the topic. Teacher content knowledge is an essential component of teacher effectiveness (Diamond *et al*., 2013; Garrett and Steinberg, 2014; Johnson *et al*., 2012; Nowicki *et al*., 2013). A noteworthy number of studies suggest that there is a direct correlation between teachers' science content knowledge and teachers' effectiveness in delivering science instruction (Alshehry, 2014; Fitzgerald *et al*., 2013; Santau *et al*., 2014). It was also reported that its scantiness affects the eminence of these teachers' ability to deliver science instruction (Usak *et al*., 2011), because teachers cannot teach what they do not know (Nowicki *et al*., 2013). It is accepted that excellent science instruction is cultured from a broad and deep understanding of science content knowledge (Heller *et al*., 2012; Tretter *et al*., 2013).

The two teacher participants with adequate PCK received orientations to the demands of the competence-based curriculum through several workshops. However, the other two with inadequate PCK did not receive any form of orientation to the demands of the competence-based curriculum. Lack of orientation to the demands of the competence-based curriculum renders the teacher incompetent. The competence-based curriculum requires teachers to impart 21^{st} century skills to learners. The belief system of teaching for teachers who were not oriented still resides in the traditional past, yet teachers are expected to impart problem solving skills through interactive, learner centred practical approaches to help learners keep up with the lightning-pace of today's modern society and market. For several teachers, implementing innovations necessitates familiarity with modern curriculum topics as well as the ability to teach in novel ways. De Jong (2016) noted that many seasoned teachers are resistant to the changes. Hence, there is a need for designing new in-service courses that concentrate on ensuring that teachers' PCK is appropriately changed (De Jong, 2016). Such workshops would close the distance between theory and reality.

The research revealed that all the teacher participants had no schemes of work and lesson plans. Ms Rose and Ms Candy had notebooks and PowerPoint presentations, which show a certain level of planning. Inadequate PCK was therefore attributed to lack of planning. There was no form of planning done by the teacher participants with inadequate PCK. This is a manifestation of lack of supervision at all levels ranging from departmental level to national level. Planning entails the process of setting objectives and determining the means to achieving the objectives. It entails deciding in advance what is to be taught and how to teach, when to teach, who is to be taught and the evaluation of learner learning. It has been seen to enhance teaching and learning by establishing set standards to be followed by teachers. Planning provides for effective utilisation of human and material resources used in imparting knowledge in schools as well as direction for teaching and learning. Planning for a lesson makes the teaching-learning encounter valuable and productive, while no planning leads to a wasteful and unproductive lesson. Shulman (1986; 1987) noted that PCK is acquired through a cycle of pedagogic reasoning throughout a teachers' life. The cycle involve comprehension, reflection, transformation, instruction, evaluation and reflection (Mavuru, 2016). However, execution of pedagogical reasoning can only occur as the teacher continuously plans and executes his/her plan in a bid to improve practice. Hence, lack of planning may result in poor or no pedagogical reasoning and consequently in poor or inadequate PCK. De Jong (2010) the reflection stage helps the teacher review, reconstruct, re-enact and analyse their practice to become better teachers. The lesson planning process allows for teachers to evaluate their own knowledge with regards to the content to be taught (Reed and Michaud, 2010). A teacher with a plan, then, is a more confident teacher (Jensen, 2001). The teacher is clear on what needs to be done, how, and when. The study findings tally with Mupa and Chinooneka's (2015) findings that teachers do not employ a variety of teaching methods, they do not prepare a variety of media for use in teaching and learning and their instructional materials are limited to textbooks and syllabi. They recommended school heads to supervise teachers so that proper scheming, planning, and teaching is done.

It was also noted that teacher attitude affected topic specific PCK. Mr. Lazz and Mr Dee showed negative attitudes towards teaching and had inadequate PCK. Romylos (2018) noted that teachers' perceptions of their identities may influence their efficacy, their attitude towards change and the implementation of an innovative teaching practice. He further noted that being an effective and confident teacher is subject to the development of professional identity. Beijaard *et al*. (2007) affirmed that teachers' perception of their professional identities influences their efficacy.

5.13 Summary

Data on teacher participants PCK was presented, analysed and discussed according to the six key constructs. It was noted that two teachers had adequate PCK, whist the other two teachers had inadequate PCK. A discussion of the possible causes of the teacher PCK was given.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter focuses on conclusions made from the findings on teacher PCK in Biodiversity of the selected four teacher participants in Midlands urban. Furthermore, the chapter gives recommendations to stakeholders in an attempt to bridge the gap between the intended goals of the competence-based curriculum and what is being implemented in schools.

6.2 Conclusion

What does the 'A' level Biology Curriculum demand of the topic, biodiversity?

How do 'A' level biology teachers teach the topic on Biodiversity?

The 'A' level biology curriculum demands context-based teaching of biodiversity. It places emphasis on the use of constructivist methodologies which are packaged with learner centred strategies aimed at bringing awareness to the practical application of skills and knowledge in solving societal challenges. The need, therefore, for teacher identity and strong belief systems about teaching cannot be overemphasised. This calls for a well-developed PCK among 'A' Level biology teachers. The PCK entails a context-based assessment that instils strong skills in learners, which in turn results in behavioural changes so that they can participate in the production of goods and services.

Why do 'A' Level Biology teachers teach the topic Biodiversity in the way they do?

My findings which answer the first two research questions were based on interpretation of data. However, a deeper interpretation is required to explain why 'A' level Biology teachers teach the topic in the way they do. I will present my conclusions in the form of propositions. A number of reasons have been seen to explain why teachers teach Biodiversity the way they do. These include lack of content knowledge, teacher identity, inadequate knowledge of NoS, teacher orientations to science teaching, and teacher understanding of the competence-based curriculum.

Proposition 1

Teacher content knowledge influences the way teachers teach the topic, Biodiversity. Teachers with adequate content knowledge interpret the goals better, explain concepts clearly and ask good questions. Such teachers respond to questions asked by the learners in a more understandable manner to enhance learner understanding. However, teachers with inadequate content knowledge, fail to interpret the goals, lack confidence and cannot ask questions to enhance learner understanding. Their belief systems influence the way instruction is delivered.

Proposition 2

Diversity of teacher identities influence the way teachers teach the topic, Biodiversity. Teachers who reside in the traditional modes of instruction fail to use learner-centred teaching methods which instil 21st century skills. However, the 21st century teachers use learner-centred modes of instruction thereby imparting the 21st century skills required by the competence-based curriculum. Teacher belief systems affect their choice of teaching methods.

Proposition 3

Teacher understanding of NoS has an impact on how teachers teach the topic, Biodiversity. Teachers with an in-depth understanding of NoS use the scientific enquiry, through experiments and activities to guide learners to discover new knowledge. Such teachers' belief systems reside in process-oriented instruction. However, the belief system for teachers with inadequate NoS is still in the traditional past. Such teachers use lecture methods and fail to create a conducive environment for learners to share knowledge through discussions, hence, poor acquisition of knowledge and skills.

Proposition 4

Teacher orientations to science teaching guide the teacher's mode of instruction in Biodiversity. Teachers with a constructivist orientation to science teaching, consider learners' prior knowledge and use the identified prior knowledge to develop the lessons. Such teachers identify learner misconceptions and challenging concepts as the lessons progress and address them through explanations or activities that help improve learner understanding. Their teaching methods allow learners to do hands-on activities and to build new knowledge.

Proposition 5

Teacher understanding of the competence-based curriculum impacts on how the topic, Biodiversity is taught. A good understanding of the competence-based curriculum allows the teacher to use teaching methods that enable the imparting of skills to learners. Such teachers use hands-on activities to guide learners during the learning process. Their modes of assessment allow them to assess all skills. However, teachers with a poor understanding of the competence-based curriculum, fail to use teaching methods that allow imparting of 21^{st} century skills.

RQ 4 What instructional model can be used to improve teacher PCK in Biodiversity.

In response to the research question, what instructional model can be used to improve teacher PCK for the topic, Biodiversity, a model was designed (Fig 6.1).

Model for development of teacher PCK for the topic, Biodiversity

Curriculum implementation for the topic on Biodiversity is a function of interpretation. It is the role of the teacher to interpret and implement the curriculum. Findings from this study confirm that inadequate PCK on Biodiversity is an impediment to the attainment of goals for teaching the topic. This thesis therefore proposes a model for enhancing teacher PCK for Biodiversity to map the way for attainment of the goals for the topic.

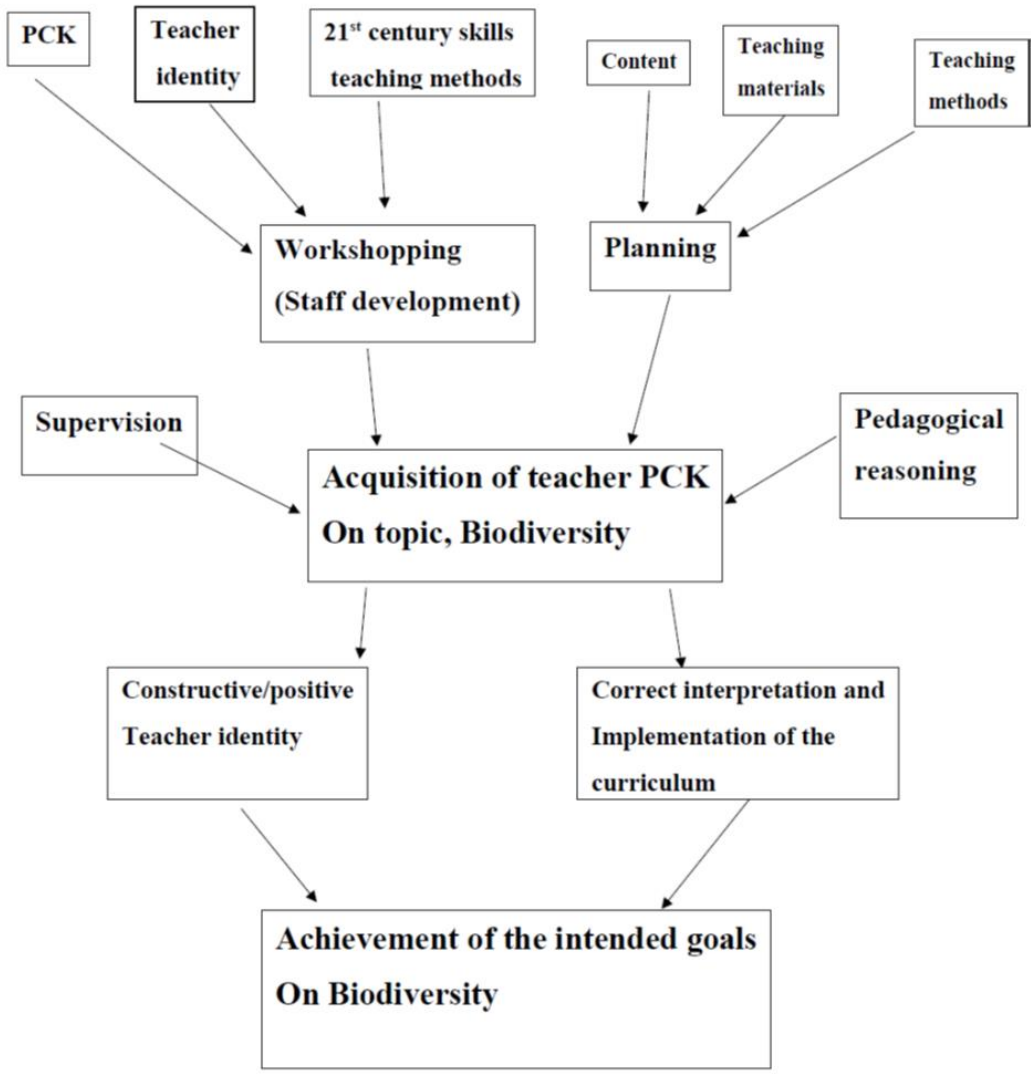

Figure 6.1 Model for teacher PCK for the topic, Biodiversity.

The model identifies a number of factors that stimulate the acquisition of PCK for the topic, Biodiversity. These include planning, staff development, pedagogical reasoning and supervision. Comprehensive planning before instruction is a necessity. Teachers must use the topic objectives to plan for the content, methods and materials. During planning the content to be covered, teachers may notice deficiency in content on their part and research on the concept before instruction. This increases the teacher content knowledge for Biodiversity. There is a need to use the knowledge of learners (for example, their prior knowledge and background) to plan for the teaching methods and materials to be used in the teaching and learning. This improves not only the teacher's knowledge of instructional strategies but also the teacher's knowledge of students' understanding.

Pedagogical reasoning must be applied by teachers during the teaching of the topic on Biodiversity. This improves teacher PCK for the topic, Biodiversity. This model for PCK acquisition considers the Shulman (1986, 1987) model of pedagogical reasoning which is a cycle of comprehension, transformation, instruction, evaluation and reflection. In this newly designed model, teachers are expected to continuously learn and strive to improve the teaching and learning process. This is achieved through actively engaging in preparing what they teach, how they teach and why they should teach in a particular way. Repeated cycles of pedagogical reasoning during teaching the topic, Biodiversity improves the teacher PCK on Biodiversity.

Staff development programmes and workshops on the demands of the topic, Biodiversity in the competence-based curriculum, positive teacher identity, and PCK development are basic needs for teacher acquisition of PCK for the topic, Biodiversity. Furthermore, the model emphasises the need for teacher supervision. This allows teachers to be assisted on areas of weaknesses to ensure quality teaching and learning. Acquisition of teacher PCK leads to correct interpretation of the curriculum on Biodiversity and develops teacher identity. This may consequently result in the achievement of the intended goals for the topic, Biodiversity in the competence-based Biology curriculum.

6.3 Recommendations

This study recommends the use of the designed model for improving teacher PCK for the topic, Biodiversity. The model may also be used in other Biology topics and other science learning areas to improve teaching and learning. Further research is recommended on how the model can be improved and used in other contexts.

This study recommends Staff development programmes and workshops on the demands of the competence-based curriculum, positive teacher identity, and content knowledge and PCK development. The Ministry of Primary and Secondary Education should create a policy which obliges schools, districts, and provinces to ensure that staff development is mandatory for science teachers. It could be ministry policy that promotion to higher grades for teachers should be based on the staff development programmes they would have attended together with the other arms of professional development systems.

Various institutions of higher learning are involved in the training of biology teachers for both O-Level and A-Level curricula. The research recommends that they utilise the outcomes of this research in improving teacher identity as a critical component in PCK. Findings from this research bear testimony to the urgent need to address the current teaching and learning practices in A-level Biology. There is also a need for addressing issues to do with the teacher's mind-set and motivation. This may help develop constructive teacher identity required to instil 21st century skills in learners. It may also help bridge the gap in skill development in learners.

There is a need for a handbook for teaching both O-Level and A-Level Biology topics which outlines which science process skills should be taught and how these should be taught. Instruction should be designed carefully and systematically considering the nature of science (NoS). What should be included in this handbook should promote the teaching of science as a process. The handbook should be systematically reviewed to include any changes that will have occurred. Where possible it is important to contextualise the practical activities in order to boost interest among learners. The practical tasks should involve situations which are relevant or of interest to the learners. Such a handbook may promote a shift from traditional instruction to process oriented instruction and consequently lead to the development of 21st century skills.

This study strongly recommends supervision of teachers at all levels from school, district, provincial and national level. This may help to ensure planning and efficacy during instruction. Subject inspectors must be actively involved in supervision of their specific subjects to ensure that the intended goals of the curriculum are achieved.

6.4 Summary

The chapter presented the conclusions and recommendations in an attempt to improve teacher PCK and bridge the gap between the intended and the implemented competence-based curriculum.

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APPENDIX

Appendix 1: Ethical clearance Certificate

RESEARCH ETHICS COMMITTEE (STAFF)

P. Bag 1020
BINDURA, Zimbabwe
Tel: 263 - 7621-4
Email : rec@buse.ac.zw

BINDURA UNIVERSITY OF SCIENCE EDUCATION

07 July 2021

Dear Jane Kaifa

RE: Title: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools

Thank you for the application for review of Research Activity that you submitted to Bindura University of Science Education Research Ethics Committee (BUSEREC). Please be advised that your protocol has been reviewed and was approved.

This approval is based on the review and approval of the following documents that were submitted to BUSEREC for review:

1. Study protocol
2. Informed Consent for learners and Teachers
3. Data Collection Tools
4. Permission Letter from PED

Approval Number: **0013/2021** should be used on all correspondence, consent forms and documents as appropriate.

Type of Meeting	:	Full Committee Meeting
Approval Date	:	07/07/2021
Expiry date	:	06/07/2022

After the expiry date, the project may only continue after renewal. For purposes of renewal, a progress report should be submitted three months before the expiry date for continuing review.

All serious problems to do with safety of participants must be reported within three (3) working days to BUSEREC. You are not expected to make any changes/adjustments to the protocol including the consent documents. Any trials involving drugs, devices and biologics require approval of the Medicines Control Authority of Zimbabwe before commencement.

Upon termination of the study, a report has to be submitted to BUSEREC.

Yours sincerely

....

BUSEREC CHAIRPERSON

Appendix 2: **Permission from Ministry of Primary and Secondary Education**

All communications should be addressed to "The Secretary for Primary and Secondary Education
Telephone: 732006
Telegraphic address: "EDUCATION"
Fax: 794505

ZIMBABWE

Reference: C/426/3
Ministry of Primary and Secondary Education
P.O Box CY 121
Causeway
HARARE

28 July 2021

Jane M. Kaifa
48 Hurricumming Road
Athlone
Gweru

Re: **PERMISSION TO CARRY OUT RESEARCH IN MIDLANDS PROVINCE: URBAN HIGH SCHOOLS: KWE KWE; SHURUGWI; THORNHILL AND ZVHISHAVANE HIGH SCHOOLS**

Reference is made to your application to carry out research at the above mentioned schools on the research title:

"ADVANCED LEVEL BIOLOGY TEACHERS' PEDAGOGICAL CONTECT KNOWLEDGE(PCK) IN THE TEACHING AND LEARNING OF THE TOPIC BIODIVERSITY: A CASE OF SELECTED MIDLANDS URBAN HIGH SCHOOLS"

Permission is hereby granted. However, you are required to liaise with the Provincial Education Director, Midlands Province, who is responsible for the schools which you want to involve in your research. You should ensure that your research work does not disrupt the normal operations of the school. You are required to seek consent of the parents /guardians of all the learners who will be involved in the research.

You are also required to provide a copy of your final report to the Secretary for Primary and Secondary Education.

R Thabela (Mrs)
SECRETARY FOR PRIMARY AND SECONDARY EDUCATION

PERMANENT SECRETARY
MINISTRY OF PRIMARY AND SECONDARY EDUCATION
05 AUG 2021
CAUSEWAY
ZIMBABWE

Appendix 3**: Permission from the Provincial Education Director**

All communications should be addressed to "The Provincial Education Director"
Telephone:054- 222460

Fax: 054- 226482

Ministry of Primary and Secondary Education
P.O Box 737
GWERU

03 September 2021

Jane M. Kaifa
48 Hurricumming Road
Athlone
<u>Gweru</u>

Dear Sir/Madam

<u>APPLICATION FOR PERMISSION TO CARRY OUT RESEARCH IN SELECTED SCHOOLS IN MIDLANDS PROVINCE: URBAN HIGH SCHOOLS:KWEKWE,SHURUGWI,THORNHILL AND ZVISHAVANE HIGH SCHOOLS .</u>

Permission to carry out a Research on:-

"ADVANCED LEVEL BIOLOGY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE(PCK) IN THE TEACHING AND LEARNING OF TOPIC BIODERVERSITY: A CASE OF SELECTED MIDLANDS URBAN HIGH SCHOOLS"

In the Midlands Province has been granted on these conditions.

1. That in carrying out this you do not disturb the learning and teaching programmes in schools.
2. That you avail the Ministry of Primary and Secondary Education with a copy of your research findings.
3. That this permission can be withdrawn at anytime by the Provincial Education Director or by any higher officer.

The Provincial Education Director wishes you success in your research work and in your University/College Studies.

MIN. OF PRY & SEC. EDUCATION
HUMAN RESOURCES (DISCIPLINE)
MIDLANDS
03 SEP 2021
P.O. BOX 737, GWERU
ZIMBABWE

SHIRICHENA C.
<u>For PROVINCIAL EDUCATION DIRECTOR : MIDLANDS</u>

Appendix 4: **Headmasters consent form**

Headmaster's Consent form

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow teachers and students to participate in this research.
2. Allow the researcher to observe and record at least three lessons.

Confidentiality

The school's, teacher and learner's identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teachers and learners may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: ---[signature]---

Date: ---10/09/21---

DEPUTY HEAD
THORNHILL HIGH SCHOOL
10 SEP 2021
P.O. BOX 558
GWERU

Headmaster's Consent form

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow teachers and students to participate in this research.
2. Allow the researcher to observe and record at least three lessons.

Confidentiality

The school's, teacher and learner's identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teachers and learners may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: ---------------------------------------

Date: ----8/9/21-------------------------------

THE HEAD
ZVISHAVANE HIGH SCHOOL
14 JUL 2021
P O BOX 277 ZVISHAVANE
ZIMBABWE TEL 0392353338/3339

Headmaster's Consent form

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow teachers and students to participate in this research.
2. Allow the researcher to observe and record at least three lessons.

Confidentiality

The school's, teacher and learner's identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teachers and learners may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: ----------------------------

Date: --07/09/21--------------------

THE HEAD
KWEKWE HIGH SCHOOL
07 SEP 2021
P. O. BOX 14, KWEKWE
ZIMBABWE
TEL: (055) 23301/2, 22009

Headmaster's Consent form

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

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1. Allow teachers and students to participate in this research.
2. Allow the researcher to observe and record at least three lessons.

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The school's, teacher and learner's identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teachers and learners may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: Munyukwi ---------------

Date: 08/09/21 ---------------------

SCHOOL HEAD
SHURUGWI No. 2 HIGH SCHOOL
08 SEP 2021
P.O. BOX 15, SHURUGWI
ZIMBABWE TEL: 054252-6621

Appendix 5: **Signed consent forms for teacher participants**

Consent form for teacher

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow the researcher to observe and record at least three lessons.
2. An interview after the lesson observations.
3. Allow researcher to observe and carry out document analysis of the teacher's work books.
4. Completing a questionnaire.

Confidentiality

Teacher identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teacher may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: ---Kachere-----------

Date: -----13-09-21---------

Consent form for teacher

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow the researcher to observe and record at least three lessons.
2. An interview after the lesson observations.
3. Allow researcher to observe and carry out document analysis of the teacher's work books.
4. Completing a questionnaire.

Confidentiality

Teacher identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teacher may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: T.G ------------------------------------

Date: 29/09/21 ------------------------------------

Consent form for teacher

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow the researcher to observe and record at least three lessons.
2. An interview after the lesson observations.
3. Allow researcher to observe and carry out document analysis of the teacher's work books.
4. Completing a questionnaire.

Confidentiality

Teacher identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teacher may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: Churuva

Date: 8/10/21

Consent form for teacher

PhD Dissertation: Advanced Level Biology Teachers' Pedagogical Content Knowledge in Teaching and Learning of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.

My name is Jane M Kaifa. I am researching on Biology teacher PCK in Midlands urban High schools. Ultimately, my work will provide an insight on how the topic Biodiversity is taught and why it is taught that way.

Participation

Participation in the study will result in the participant agreeing to:

1. Allow the researcher to observe and record at least three lessons.
2. An interview after the lesson observations.
3. Allow researcher to observe and carry out document analysis of the teacher's work books.
4. Completing a questionnaire.

Confidentiality

Teacher identities will be kept strictly confidential. Pseudonyms will be used in all published documents and the name and location of the school will not be revealed. Only the researcher will know the participant's identity. The data collected during the study will be stored in a secured area. Teacher may choose to end the participation at any given time during the study and at that time all related data will be destroyed.

Consent

Please read the consent statement below and sign if you agree to participate in the study.

I have read the information presented above and do hereby agree to participate in the study.

Signature: Ethuruva---------------------------------

Date: --------8 | 10 | 21---------------

Appendix 6: **Lesson observation guide**

Name of institution: **Bindura University of Science Education**

Name of researcher: **Jane M Kaifa**

Class Observation Schedule

Teacher:

Lesson	Components to be analysed	Coding			
		limited	basic	proficient	Advanced
	Content knowledge				
	Concept coverage				
	Appropriateness of concept(s)				
	Scientific accuracy of the explanation of the concept				
	Links and/or connections made to other concepts Links made (implicit or explicit) to the nature of science (NoS) and/or scientific inquiry				
	❖ **knowledge of curriculum**				
	appropriate knowledge of goals and objectives				
	Interconnection made with other topics				
	Interconnection made with other disciplines				
	❖ **Knowledge of learners**				

	Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions				
	Teacher uses identified variations in student understanding and learning to guide instruction Teacher uses questioning to probe or extend student understanding				
	❖ **knowledge of instructional strategies**				
	Appropriate sequence for teaching concepts Relevant examples and/or representations are used in the lessons, which appear to be pedagogically effective at portraying the concept				
	Use of strategies that allow for metacognition				
	❖ **Knowledge of assessment**				
	1. Dimensions of science to assess 2.Methods of assessment				
	❖ **Science teaching orientation**				

	1. Beliefs about purposes of teaching science				
	2. Beliefs about science teaching and learning.				
	3. Beliefs about NOS				

Footnotes/ Key

PCK indicator:	Subject matter knowledge			
	Limited	Basic	Proficient	Advanced
Appropriateness of concept(s)	No alignment of concept(s) in lesson	Little alignment of concept(s) in lesson	Adequate alignment of concept(s) in lesson	Close alignment of concept(s) in lesson
Scientific accuracy of the explanation of the concept(s)	Explanation(s) were mostly inaccurate, which did not address the concept(s)	Explanation(s) were somewhat inaccurate, which loosely addresses the concept(s)	Explanation(s) were mostly accurate with only small inaccuracies seen, or they were too brief	Explanation(s) were accurate, which addresses the concept with no inaccuracies
Links and/or connections made to other concepts	No possible links and/or connections are made	Few of the possible links are made, but not connected with explanations	Some of the possible links and connections are made	Many of the possible links and connections are made
Links made (implicit or explicit) to the nature of science (NoS) and/or scientific inquiry	No links made to NoS and/or SI	Few of the possible links to NoS and/or SI are made	Some of the possible links to NoS and/or SI are made	Many of the possible links to NoS and/or SI are made

PCK indicator:	Knowledge of student understanding			
	limited	Basic	Proficient	Advanced
Teacher recognises and acknowledges possible student prior knowledge, difficult concepts, and misconceptions	No recognition or acknowledgement of possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises some possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises and acknowledges some possible student prior knowledge, difficult concepts, and/or misconceptions	Recognises and acknowledges most/all possible student prior knowledge, difficult concepts, and/or misconceptions
Teacher uses identified variations in student understanding and learning to guide instruction	No acknowledgement and/or use of variations in student understanding and learning to guide instruction	Acknowledgem ent of variations in student understanding or learning, but not used to guide instruction	Some acknowledgment of variations in student understanding or learning are used to guide instruction	Many instances where teacher acknowledged variations in student understanding or learning and used these to guide instruction
Teacher uses questioning to probe or extend student understanding	No questions are used to probe or extend student understanding	A few questions are used to probe or extend student understanding	An adequate range of questions are used to probe or extend student understanding	Many and varied questions are used to probe or extend student understanding

PCK indicator:	Knowledge of instructional strategies			
	Limited	Basic	Proficient	Advanced
Appropriate sequence for teaching concepts	No overall flow between concepts and the sequence confuses students	Some flow between concepts and the sequence allows some concept building to occur	Suitable flow between concepts and the sequence allows satisfactory concept building to occur	Clear flow between concepts and sequence allows effective concept building
Relevant examples and/or representations are used in the lessons, which appear to be pedagogically effective at portraying the concept	No examples and/or representations used	Examples and/or representations used that do not appear to be pedagogically effective	Examples and/or representations used have some relevance, but appear pedagogically limited	Relevant examples and/or representations used that appear pedagogically effective
Use of strategies that allow for metacognition	No use of strategies that allow for metacognition	Limited use of strategies that allow for metacognition	Adequate use of strategies that allow for metacognition	Much use of strategies that allow for deep levels of metacognition

PCK indicator: knowledge of curriculum				
	Limited	Basic	Proficient	Advanced
Knowledge of goals and objectives	No overall knowledge of goals and objectives	Limited knowledge of goal and objectives	Adequate knowledge of goals and objectives	Highly knowledgeable
Interconnection with other topics	No connections made with other topics	Limited interconnections made with other disciplines	Adequate interconnections made with other disciplines	Much use of interconnections with other topics
Interconnection with other disciplines	No connections made to other disciplines	Limited interconnections made with other disciplines	Adequate interconnections made to other disciplines	Much use of interconnections with other disciplines

❖ **PCK indicator**: **Knowledge of assessment**				
	Limited	Basic	Proficient	advanced
Appropriate dimensions of science to assess	Inappropriate dimensions assessed	Limited /few dimensions of science assessed	Adequate dimensions assessed	Highly appropriate dimensions assessed
Appropriate methods of assessment	Inappropriate methods of assessment	Limited/few	adequate	Highly appropriate

❖ **PCK indicator**: **Science teaching orientation**				
	Limited	Basic	Proficient	advanced
Beliefs about purposes of teaching science	No knowledge on purpose of teaching science	Limited knowledge on purpose of teaching science	Adequate	Highly appropriate and illustrated during lesson delivery

Beliefs about science teaching and learning	inappropriate	limited	adequate	Highly appropriate
Beliefs about NOS	inappropriate	limited	adequate	Highly appropriate and illustrated during lesson

Appendix 7: Teacher interview guide

Title: **Interview guide for the teacher**

Institution: **Bindura University of Science Education**

Name of Interviewer: **Jane M KAIFA**

1. How do you think the lesson went?

   Knowledge of leaners

2. In what ways did students influence your teaching decisions today?

   Knowledge of instructional strategies

3. How did the teaching strategies help you achieve your goals?
4. Was there a time during instruction when you changed your plan? Tell me more about that.

   Knowledge of the curriculum

5. Did the activities help you achieve the purpose you intended? Why do you say that?
6. What were the critical science ideas in today's lesson?

   Knowledge of assessment

7. How do you know when your students understand?
8. In what way do you assess students learning?

   Orientations to science teaching

9. What do you perceive as the teacher's role in a typical lesson?
10. What do you perceive as the students' role in a typical lesson?
11. How do you think students learn science best?

Appendix 8: Teacher Questionnaire

Name of institution: **Bindura University of Science Education**

Name of researcher: **Jane M Kaifa**

Questionnaire for teachers

My name is Jane M Kaifa. I am studying for a Doctor of Philosophy Degree in Biology education with Bindura University of Science Education. I am carrying out a research entitled **Advanced Level Biology Teachers' Pedagogical Content Knowledge of the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.** The data gathered will be used strictly for academic purposes and will not be disclosed to anyone. Your identity will remain confidential. Your participation is voluntary and should you feel like withdrawing from participation at any stage, you are free to do so.

Your cooperation will be greatly appreciated.

Instructions

Indicate your answers to questions/items in by ticking in the appropriate box or by filling in the spaces provided.

SECTION A: Personal information

1. **Indicate your gender by ticking the appropriate box.**

Male	
Female	

2. **Indicate your teaching qualification.**

Diploma in Education	
BScEd in Biology	
MScEd in Biology	
Other (specify)	

3. For how long have you been teaching 'A' level Biology?

Less than 5 years	
5-10 years	
11-20 years	
Above 20 years	

Section B

Orientation to the competence based curriculum

4. Did you receive any form of orientation to teaching the competence based Biology curriculum?

Yes	
No	

5. If yes, briefly indicate the orientations received on teaching the competence based curriculum.

6. How do rate your teaching of the Biodiversity?

poor	fair	good	Very good	Very good but there is room for improvement	Excellent

7. Justify the rating done above.

8. Do you have access to teaching media recommended by the syllabus or any other media you may want to use for effective lesson delivery?

Yes	No	Other (specify)

9. Do you incorporate cross cutting themes in your teaching

Yes	
No	

10. If yes, give an example of cross cutting themes you would incorporate in the teaching of the topic Biodiversity?

Section C

Teacher PCK

11. What do you perceive is the purpose of teaching the topic Biodiversity?

12. What is your role in a science lesson?

---

13. What do you perceive is the role of learners?

---

14. Does learner prerequisite knowledge affect your lesson planning?

Yes No	

15. If Yes, explain how?

---

16. How do you identify learner misconceptions?

---

17. How do you deal with identified learner misconception?

---

18. Are there any problematic areas to you, in your teaching of the topic Biodiversity?

Yes	
No	

19. How do you deal with the problematic areas?

---

20. During the teaching of the topic Biodiversity, do you relate to other topics?

Yes	
No	

21. If yes, briefly explain how?

____
____
____

22. During the teaching of the topic Biodiversity, do you relate it to other disciplines?

Yes
No

23. If yes, briefly explain how?

____
____
____

24. What determines your choice of instructional strategies?

____
____
____
____

25. Reflect back in your teaching experience, outline an example, analogue, practical or any other technique that you used to enhance learner understanding of the topic Biodiversity.

____
____
____

26. Why did you choose that example, analogue, practical activity or that any other technique?

____
____
____

27. How do you evaluate learner understanding?

____
____
____

28. In light of COVID 19 pandemic, do you think the topic Biodiversity can be effectively taught online?

Yes	
No	

29. If yes, explain the methods that can be used to effectively teach the topic online?

30. Are there any challenges that you faced in the teaching of the topic Biodiversity?

31. What are the possible solutions to the challenges?

Thank you!

Appendix 9: Learner questionnaire

Name of institution: **Bindura University of Science Education**

Name of researcher: **Jane M Kaifa**

Questionnaire for learners

My name is Jane M Kaifa. I'm studying for a DPhil in Biology education with Bindura University of Science Education. I'm carrying out a research entitled **Advanced Level Biology Teachers' Pedagogical Content Knowledge for the Topic, Biodiversity: A Case of selected Midlands Urban High Schools.** The data gathered will be used strictly for academic purposes and will not be disclosed to anyone. Your identity will remain confidential. Your participation is voluntary and should you feel like withdrawing from participation at any stage, you are free to do so.

Your cooperation will be greatly appreciated.

Instructions

Indicate your answers to questions/items in by ticking in the appropriate box or by filling in the spaces provided.

1. Indicate your gender.

Male female	

2. What is the importance of learning about Biodiversity?

____

____

____

3. What do you think teachers must provide you with when learning the topic Biodiversity?

____

____

4. What role do you play during lessons on Biodiversity?

5. Do you think the teacher considers the knowledge you already have in planning for the lessons?

Yes
No

6. If yes did this enhance your understanding?

7. Did you have any misconceptions before the lessons on Biodiversity?

Yes	
No	

8. If yes, what did the teacher do to clear the misconceptions?

____

____

9. Did you face any challenges in learning concepts on Biodiversity?

Yes	
No	

10. If yes, how did the teacher assist you in the problematic areas?

____

____

____

11. Do you think the learning objectives for the topic Biodiversity were achieved?

Yes
No
Partly

12. Which objectives do you think you might need further assistance from the teacher?

____

____

____

13. Did the teacher relate the topic Biodiversity to other topics during teaching?

Yes	
No	

14. Did the teacher relate the topic Biodiversity to other disciplines?

Yes	
No	

15. Did the teaching methods help enhance your understanding?

Yes	
No	

16. Do you have any other methods that you feel could have enhanced your understanding?

Yes	
No	

17. If yes, specify the methods.

____

____

____

18. Did you enjoy the Biodiversity lessons?

Yes	
No	

19. Do you think you are going to apply the knowledge learnt in your day to day live?

Yes	
No	

20. If yes, may you please explain how?

____

____

____

THANK YOU!

Appendix 10: Turnitin antiplagiarism report

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Jane Kaifa jane for plagarism check.docx Submission Details Help turnitin

The outcome of this research led to my design of a PCK model e
the teaching of Biodiversity. Fig 6.1shows the designed m
Biodiversity.

1.8 DELIMITATIONS

This study was delimited in regional area, topic and educational
resource unavailability and limited time the study was carried o
High schools. The study investigated teacher PCK for only one
Furthermore, this study was delimited in educational level of lea
learners took part in the study.

1.9 LIMITATIONS

This study was limited in sample size due to resource unavailabi
both urban and rural teachers. However, this does not compromi
results since an in-depth analysis of teacher PCK for the selecte
collected using different instruments was triangulated.

1.10 DEFINITION OF TERMS

Pedagogical content knowledge (PCK) is a unique fusion of c
different topics in a graspable manner to the learners.

Twenty first century skills are a wide range of abilities, work pr
essential for success in the modern world (Windschitl, 2009). T

solving and critical thinking among others. These abilities are
with how quickly society and markets are evolving nowadays.

Biodiversity is the variety of life forms on earth. It is the dive
sources, such as terrestrial, marine and other aquatic habitat
communities to which they belong. This diversity includes tho
species and ecosystems.

1.11 CHAPTER SUMMARY

This chapter has underscored the need for research on Biology
the major elements of research. The research gap has been situat
problem statement as well as the significance of the study

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Appendix 11: Editor's letter

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University of Zimbabwe
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Harare
Zimbabwe

5 May 2023

Proofreading / Language Editing Certificate

To whom it may concern

This is to certify that I proofread and edited the thesis, '**Teacher pedagogical content knowledge for the topic, 'Biodiversity': A case of selected Midlands Urban High Schools** by Jane Mwakadei Kaifa (B1545126).

I corrected punctuation, spelling, sentence construction, tenses, number and concord as well as minor language errors. I also pointed out ambiguities in meaning and, where applicable, suggested adjustments to the sequence and/or construction of sentences and paragraphs which negatively affected the flow of the argument and/or undermined the cohesion and coherence of the same. To the extent possible, I either removed or rephrased unnecessary repetitions of ideas, indicated omissions and errors where applicable.

I wish the author every success with their final submission and trust that the recommendations they made will be of use to schools, academic institutions and other parties wishing to improve science teaching by high school teachers in Zimbabwe.

Kudzai Gotosa (Dr)

Email: kudzaigotosa@gmail.com