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Investigating 'A' Level Biology Teachers' Content Knowledge on Biodiversity in Midlands Urban: A Case of Four Selected Teachers

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Abstract: This paper reports on part of an ongoing large-scale research on the need to improve science teaching and learning through investigating the Pedagogical Content Knowledge (PCK) of biology teachers for the topic Biodiversity. Six factors have been seen to affect teacher PCK, i.e., content knowledge, knowledge of students, science teaching orientations, knowledge of assessment, knowledge of instructional strategies, and knowledge of the curriculum. This research aimed to examine the teacher's level of content knowledge (CK). A qualitative research paradigm was adopted, and a case study research design used. The case (unit of analysis) was Biology teacher CK, and the subjects were the four teacher participants purposively selected. Lesson observations, teacher interviews and learner questionnaires were used to collect data on teacher CK. A content knowledge analytical framework consisting of five constructs was designed and used to analyse the teacher CK and data triangulated with data collected from interviews and questionnaires. This research revealed that 'A' level Biology teachers' CK vary from teacher to teacher depending on several factors which include teacher identity, planning, workshopping, and motivation among others. Of the four Biology teacher participants, two had adequate CK and the other two exhibited inadequate CK. Inadequate CK was attributed to lack of planning, non-exposure to workshops and lack of teacher motivation. Consequently, this research recommends supervision of teachers from the school level to the national level, a series of teacher workshops on the demands of the competence-based curriculum and constructive teacher identity as well as introduction factors that enhance teacher motivation. Further research on the content knowledge of Biology teachers in other learning areas is recommended.

Keywords: *Biodiversity, Content knowledge, competence-based curriculum, teacher identity.*

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Introduction

Curriculum implementation is one of the main concerns in the education system (Guerriero, 2014). Educators are concerned about choices made on teaching content and methods. This has seen Zimbabwe introduced the competence-based curriculum in 2016. The competence-based curriculum aims to instill 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 places learners in the job creator mode and reduce the unemployment rate of the country. Equipping learners with 21st Century skills also ensures sustainable use and value addition. However, educational reforms typically impose new demands on the already complex and over-loaded work of teaching (Ní Shuilleabhain, 2015). Literature suggests that teachers respond to imposed curriculum change by either embracing change, resisting, and ignoring the change, or modifying the curriculum, with the latter two often the norm (Christou *et al*., 2004). Curriculum implementation may be fraught with problems as it may not be done as intended and it reflects loopholes which create a gap between the expectations of the designers of the curriculum and what really takes place within the classroom. Phaeton and Stears (2016) observed a misalignment between the intended and implemented curriculum caused by teachers' misinterpretation of the intended curriculum. A lot of criticism has ever since been faced, which include inadequate consultations, resource unavailability, and lack of textbooks in line with the curriculum, inadequate teacher orientation and capacitation for the updated curriculum. Some of the criticisms have since been

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addressed. Teachers' attitudes towards curriculum reform are often negative since teachers can feel that their content knowledge is inadequate, their teaching experience does not qualify them for this reform, and that the reform imposes on their disposition towards, approaches to and philosophy of teaching their subject.

In the process of developing competent citizens in society, teachers have been seen to play an active role in the educational reform (Chopoo et al., 2014). Azad and Kalam (2013) posit that teachers can create an enlightened human being through building capacities to enquire, innovate, moral leadership and through the development of the social value system. The teaching profession has been conceptualised as a clinical practice profession and 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 teacher while processing cognitive complex information about the student to decide on alternatives for increasing understanding. The role played by teachers in implementing the curriculum and in facilitating the development of learners is considered an indicator for success of economy, society, politics, and science and technology development (Nind, 2020). Success of the updated curriculum is dependent on the quality of teachers and their cooperation.

Issues have been raised on the content and pedagogical knowledge of teachers. To Shulman (1987) teaching requires the teacher to be equipped with both content knowledge (CK) and pedagogical content. Chang et al. (2020) posit that not only students have misconceptions, without CK teachers may face challenges in teaching the subject effectively and may teach wrong concepts. CK is a body of knowledge and information that teachers teach and that learners are expected to learn in each subject or content area (Chang et al., 2020). For teachers to teach all learners according to today's standards, they need to understand the subject matter deeply and flexibly so they can help learners generate useful cognitive maps, connect one idea to another, and address misconceptions. Teachers need to see how ideas connect across fields and to everyday life. Shulman (1987) noted that understanding content provides a foundation for pedagogical content knowledge that enables teachers to make ideas accessible to their learners. CK affects how a teacher interpret the content goals, the manner through which the teacher responds to questions, the teacher's ability to explain clearly and to ask good questions. Researchers have recognised strong links between CK and good science teaching. Kind (2014) argues that inadequate CK lowers the confidence of the teacher in teaching science, and consequently results in less effective instruction. Kind (2014) noted that teachers with broad and deep subject specific knowledge, and awareness of common conceptions and scientific models can provide rich learning opportunities for their learners. Chang et al. (2020) underscored the need for teachers to possess a thorough and adaptable understanding of the subjects they teach, be aware of the key ideas and facts of their field, how these ideas are related, and the procedures followed to generate new knowledge and assess the veracity of assertions. Therefore, content knowledge is essential to ensure that learners experience positive learning outcomes. Hence, if the 'A' level Biology competence-based curriculum is to achieve its goals, teachers' content knowledge must be assessed.

Literature Review

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 (Chang et al., 2020). This body of knowledge includes the 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 and McNicholl (2007) 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. One of the demands on teachers noted by John Dewey was having a thorough knowledge of the subject content knowledge. Shulman (1987) also 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 engross in class activities that enable learning, for example, being able to proficiently lead free-ranging class discussions of content (Garnett & Tobin, 1988; Roth et al., 1987; Tobin & Fraser, 1990). Such teachers have ample awareness of common alternatives conceptions and scientific models that provide rich opportunities for their learners.

There is a direct correlation between teachers' CK and effectiveness in science teaching (Alshehry, 2014; Fitzgerald et al., 2014; Santau et al., 2014). Contrary, poor CK results in lowself-confidencee 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 since teachers cannot teach what they do not know.

Science Curriculum

A science curriculum is designed to assist children in developing fundamental scientific concepts and comprehension of biological and physical aspects of the universe, as well as the means to acquire knowledge and understanding (Mullins, 2016). Its goal is to instill positive attitudes toward science and to inspire students to investigate and understand how science and technology impact their lives. Working scientifically and designing and making are two main types of skills that the science curriculum is designed to provide students with. The science curriculum stresses value in children learning beginning with their own thoughts and learning through experiences with objects and resources, as well as their peers. Children "invent" new ideas and "develop" new knowledge. Observing and developing theories, forecasting, preparing, and carrying out experiments with a focus on fair research, documenting and evaluating outcomes, communicating, and discussing observations, and expanding thinking to accommodate new findings are all part of scientific work. Designing and creating entails researching and evaluating common artifacts to find realistic solutions to problems. Activities are designed to help children develop their innovative and imaginative abilities.

Nature of Science (NoS)

Research indicates that science teachers must understand the nature of science to teach it (Yuenyong & Thao-Do, 2020). The nature of science (NoS) is a complicated concept. It is difficult for experts to define as it is for students to learn. The NoS reflect 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. It entails a comprehension of science as a method of knowing. As a basis for students' understanding of how science is conducted, NoS components should be included in school science programs. This encourages students to participate in experimental activities and move from merely learning about science to practicing and knowing it.

Teacher Identity

Miller (2009) views teacher identity as influence on teachers, how individuals see themselves, and how they enact their profession in their settings. Miller highlights 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 a social and institutional context. 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 schools and students, institutional practices, curriculum, teaching resources, and access to professional development among other factors. Hence, teacher identity can be seen as what teachers know and do which is continuously performed and transformed through interaction in the classroom. Beauchamp and Thomas (2009) noted that teachers undergo a shift in identity as they move through programs of teacher education and assume positions as teachers in todays' challenging school context and a further identity shift may occur throughout a teacher's career because 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 will build their identities as science teachers and deepen their understanding of social justice problems in science through meaningful teaching experiences in teaching placements and field-based science methods courses. 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 (Izadinia, 2013). 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 science teacher. As a result, teaching entails a process of personal transformation, or identity change, into a specific type of teacher.

Effect of Workshops on Teacher Content Knowledge

Workshops are used to explore a certain subject, share expertise, address issues, or produce something new (Antwi et al., 2016). Workshops support teachers in developing and learning new teaching strategies, strategies of classroom management, technological advancement and improving content knowledge. Henceforth, workshops provide overall continuous growth opportunities for the teachers to make the best use of their abilities. Workshops targeting specific sensitive challenging content areas may lead to teachers' developing the coping abilities to teach the content area and meet the specific task needs of learners. Workshops improve teacher self-efficacy and content knowledge competencies. They help teachers in teaching effectively and handling challenges, leading to better outcomes for learners.

Conceptual Framework

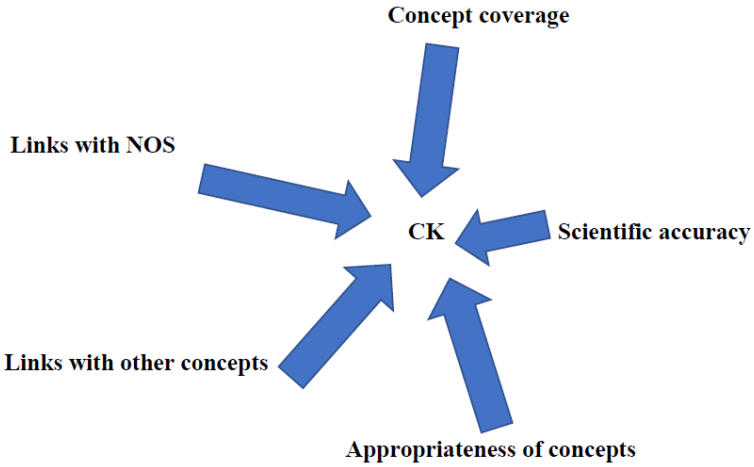

Figure 1. Key constructs of teacher CK

The teacher' content knowledge is determined by the five factors shown in Fig 1. The teacher must have the ability to interpret the curriculum and teach all concepts stipulated by the syllabus, relate the concepts to day to day lives of the learners and reflect on how the knowledge can be used in value addition and economic recovery. This creates an awareness in the learners on why they are learning the concepts. The concepts taught must be appropriateness and accurate, as well as being well linked to other concepts and to the NoS.

Research Questions

1. What level of CK do 'A' level Biology teachers have for the topic Biodiversity?
2. What factors influence the teacher's CK on Biodiversity?
3. Why do 'A' level Biology teachers exhibit the observed level of CK in Biodiversity?

Statement of Problem

Zimbabwe is faced with biodiversity loss and ecosystem depletion through veld fires, poaching, clearing of land for firewood, agricultural and mining among others. This calls for an effective biodiversity awareness campaign that is aimed at addressing this critical environmental issue. The introduction of a new competence-based curriculum with the aim of imparting 21st century skills to learners by the Ministry of Primary and Secondary Education (2016) came as one such endeavor. The teaching of the topic 'Biodiversity' in the most effective way can help in the development of a sustainable economy. However, teachers who are to teach these skills are used to the traditional instructional designs. Hence, their pedagogical content knowledge on biodiversity seems not to match the current demands of the updated curriculum. Biology teachers have not been oriented and capacitated with content and pedagogical methodologies that can be used to produce problem solving and innovative citizens that can help alleviate poverty though value addition and sustainable use. Hence, this study sought to examine the 'A' Level Biology teachers' CK for the topic 'Biodiversity' in the competence-based curriculum in Midlands urban.

Methodology

This study made use of a qualitative research paradigm and adopted the case study research design. The unit of analysis was the biology teacher content knowledge (CK) and subjects for analysis were four teacher participants. A content analysis of the topic of Biodiversity in the syllabus was done to ascertain the demands of the syllabus. This was followed by five consecutive lesson observations for each of the teacher participants. To ensure reliability of the data collected through lesson observations, teacher interviews and learner questionnaires were also administered. Five consecutive lessons were observed and relevant data was captured using an observation guide made using the five key constructs in the analytical framework. A semi-structured teacher interview guide was used in teacher interviews. The interview guide also used the key constructs in the analytical framework. To validate the data collected from interviews and observation, a learner questionnaire was used. Likewise, the learner questionnaire was also constructed using the key constructs of the analytical framework. The use of various data collection instruments (lesson observations, interviews and questionnaires) was intended to cross validate the findings, hence, improve the trustworthiness of the research.

Population

The population consisted of all 'A' level biology teachers and learners in Midlands urban.

Sample

Since this study was qualitative research, focusing on gaining an in-depth understanding of teacher content knowledge, four teachers and their 'A' level learners constituted the sample.

Sampling Technique

Purposive sampling was used to select the four teacher participants and their learners. Two of the teachers were females and two were males. The selected teachers had more than eight years' experience in teaching Biology. Purposive sampling is used to gather information rich cases related to the phenomenon under study. In this case the four teachers were identified as information rich cases, hence, their selection in the study.

Analyzing of Data

Five key constructs for teacher content knowledge were identified in the content knowledge conceptual framework as concept coverage, scientific accuracy, and appropriateness of concepts, connections made with other concepts and connections made to the NoS. Teachers' levels of each of the key constructs were categorized as limited, basic, proficient, and advanced according to the teacher's ability to exhibit certain attributes indicated in table 1.

Table 1. Analytical Framework for Teacher Content Knowledge

Content knowledge				
Key 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 Socioeconomic 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 Socioeconomic 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 Socioeconomic 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)

The teacher's levels of content knowledge were categorized as inadequate, adequate, and advanced, based on the analytical framework shown in table 2 and the observed levels of teacher knowledge shown in Table 1.

Table 2. Evaluation of Content Knowledge

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

Findings/Results

Participants' Information

Ms. Rose is a holder of an MSc Food Science and Nutrition, BSc Biological Science, and a Diploma in Education. She had taught Biology at 'A' level for a period between 5 to 10 years and acknowledged receiving several orientations to teaching the competence-based curriculum which include syllabus interpretation and teaching methods, particularly the learner centered.

Ms. Candy hold a Bachelor of Science Education Honors Degree in Biology. She has experience in teaching Advanced level Biology of over 20 years. Ms. Candy acknowledges that she received several training 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.

Mr. Laz is a holder of a Bachelor of Science Honors' Degree in Biological Science and a Post Graduate Diploma in Education. He had teaching experience for 'A' Level Biology of between five to 10 years. Mr. Laz did not receive any form of orientation for the competence-based Biology curriculum.

Mr. Dee hold a Bachelor of Science Education Degree in Biology. He has experience of teaching 'A' Level Biology of above twenty years. Mr. Dee has not received any form of orientation to the competence-based curriculum.

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 and links, or connections made to the NoS. Teachers' levels of each of the sub constructs were categorized 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 categorized as inadequate, adequate, and advanced basing on evaluations of the teacher's level of the five constructs for teacher content knowledge. Pseudonyms for the teacher participants are Ms. Rose, Ms. Candy, Mr. Dee, and Mr. Lazz.

Analysis of Ms. Rose's CK on Biodiversity

**Table 3. Analysis of Ms. Rose's Content Knowledge in 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 Socioeconomic 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, or they were too brief	Proficient
Links made to other concepts	Some of the possible links and connections are made	Proficient
Links made to the nature of science (NoS) and/or scientific inquiry	No links made to NoS and/or SI	Limited

Concept Coverage

Table 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 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 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 questionnaire and interview. Ms. Rose highlighted the need to conscientize learners on the importance of all forms of life, placing emphasis on sustainable utilization and improving livelihoods through sustainable use. Due to these attributes Ms. Rose is at Proficient level regarding the concepts about biodiversity.

Appropriateness of Concepts

Table 3 shows that Ms. Rose's lessons had 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 into kingdom, and thereafter further classification into phyla was done. Hence, Ms. Rose taught the appropriate concept with adequate alignment of concepts and the appropriateness of concepts was rated proficient. 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 guide learners during the lesson and help learners assess their learning progress (Reed & Michaud, 2010). 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. 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 system, 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. Science teachers must understand the nature of science to teach it. NOS 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 practicing and knowing it. Consequently, Ms. Rose was rated Limited on links made to NoS.

Table 2 was used to evaluate Ms. Rose's content knowledge, and from the summary of ratings made in table 3, Ms. Rose had adequate content knowledge.

Analysis of Ms. Candy's CK on Biodiversity

Table 4. Analysis of Ms. Candy's Content Knowledge on Biodiversity

Subconstruct	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. Socioeconomic 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 diagnostic features to divide kingdoms into phylum. Taxonomic hierarchy, binomial nomenclature, socioeconomic importance of the five kingdoms and conservation, issues of restoration and application of concepts in day to day live were covered. The concepts taught tallies with all the concepts in the content analysis, hence the 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 first lesson Ms. Candy introduced the concept biodiversity and discussed the definition and the different types of biodiversity, *i.e.,* genetic diversity, species diversity and ecosystem diversity. She then moved 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 small of few inaccuracies seen, for example the concept of alternation of generations was explained very well in lesson three, and however the teacher referred to it as the alteration of generations, and then the sporophyte generation was referred to as the saprophyte. This can distort learner understanding since a saprophyte is an organism that 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 emphasized 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 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. Concepts were mainly taught through scientific inquiry through practical activities which is highly commendable. In Ms. Candy's lessons, the processes used to establish knowledge were mainly through the process of scientific inquiry through practical activities and was rated proficient as shown in Table 4

Table 2 was used to evaluate Ms. Candy's content knowledge. From table 4 above, it can be noted that Ms. Candy ranged from "Proficient" to "Advanced" in all her ratings, hence Ms. Candy had adequate content knowledge.

Analysis of Mr Dee's CK on Biodiversity

Table 5. Analysis of Mr Dee's Content Knowledge on Biodiversity

Subconstruct	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 addresses the concept	Basic
Links and/or connections made to other concepts	No possible links and/or connections are 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. Several concepts were not taught. For example, in the first lesson, the presenter defined Biodiversity and no mention was made to the types of biodiversity. The diagnostic features of the five kingdoms were given classification of organisms into kingdoms was done, however no further classification into phylum was done. The socioeconomic importance of the five kingdoms was 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

The 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 the 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 the 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 a 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 lack of knowledge on processes used to establish new knowledge in science. Therefore, Mr. Dee was rated Limited regarding links made with NoS. Table 2 was used to identify the content knowledge level of Mr. Dee. It was noted that Mr. Dee had inadequate content knowledge for the topic of biodiversity.

Analysis of Mr. Lazz's CK on Biodiversity

Table 6. Analysis of Mr Lazz's Content Knowledge

Subconstruct	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 addresses the concept(s)	Basic
Links and/or connections made to other concepts	No possible links and/or connections are 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 in the syllabus. For example, the 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. Laz 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 wasn't 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 was 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 the confidence to comment on student presentations. This could be attributed to not only lack of planning and preparation 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 on 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 alignments 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 6 and table 2

and it was noted that Mr Lazz had inadequate content knowledge. Summary of teacher participants' performance is illustrated by table 7.

Comparison of Teacher Participants' Performance

Table 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 was 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 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, whist 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 amd Mr Lazz had inadequate content knowledge.

The researcher noted that 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 they were teaching. 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 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."*

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 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".

Upon requesting for permission to conduct research from one of the headmasters, 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.

Discussion

Ms. Candy and Ms. Rose had adequate CK. However, when compared to Ms. Rose, though both teachers had adequate content knowledge, 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., 2014; Santau et al., 2014).

To meet today's standards, teachers must understand 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. Özden (2008) noted that content knowledge had positive influence on effective teaching practice. Equally, many researchers such as Halim and Meerah (2002), and van Driel (2021) 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 result 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, the teacher's ability to explain clearly and ask good questions. Hence, teachers with adequate content knowledge interprets 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 in 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 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. Antwi et al. (2016) pointed to 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 also observed in the form of prepared notes for the learners. Hence, planning contributed to the adequate content knowledge. The lesson planning process allows teachers to evaluate their own knowledge with regard to the content to be taught (Reed & Michaud, 2010). 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 used student presentations without even commenting on the presentations. The researcher felt the inadequate content knowledge resulted in a lack of confidence to comment on student presentations. This could be attributed to not only a lack of planning and preparing for the lessons but also to lack of commitment to the profession and lack of motivation. Niemelä and Tirri (2018) highlights that CK is the teacher's understanding of the facts and organization of the subject. The teacher needs to understand how knowledge is constructed and why certain facts are accepted in that discipline. Niemelä and Tirri 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 et al., 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 sees teachers' capability to link concepts to other disciplines as part of CK. Mr. Laz and Mr. Dee did not relate the subject matter to other concepts and disciplines. However, Niemelä and Tirri pointed out there is no assurance that the teachers can link concepts to other disciplines. This may be because in teacher training, their lecturers may be specialist in one area, hence teachers lack exposure to other disciplines and 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 scantiness of CK affects the teachers' ability to deliver science instruction, therefore, outstanding science instruction is cultivated from a comprehensive and profound understanding of science CK. Teachers must 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 teaching strategies, strategies of classroom management, technological advancement and improve 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 and 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 Laz had no 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 what Mr Dee said, *"teachers must plan, and if you don't plan you are planning to fail. One must plan so that lessons are presented in a way that is understandable."* However, 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 delivery. 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 become 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.

Conclusion

Teacher content knowledge vary from teacher to teacher depending on a consortium of factors which include exposure to workshops, planning, teacher identity and motivation. In the current research, teacher CK ranged from inadequate to adequate. Content knowledge is critical for effective science teaching, hence there is need to improve teacher CK to ensure effective syllabus interpretation, scientific accuracy and linking of the concepts to other concepts and to the NoS.

Recommendations

This study thereby recommends workshopping of teachers on syllabus interpretation, 21st century teaching methods and development of a constructive teacher identity among other areas to improve the teacher content knowledge. There is need for teacher supervision on all the requirements of the teaching profession including scheming and lesson planning from school level to national level to improve and ensure that there is effective teaching and learning. Furthermore, there is need for motivating teachers to stimulate their interest in the profession and ensure effective teaching and learning. Further research on the content knowledge of Biology teachers in other learning areas is recommended.

Limitations

This research could have been expanded to include other provinces but due to limited resources and COVID 19 restrictions, the research was confined to one province but had various data sources to cross validate the results.

Authorship contribution statement

Kaifa: Conceptualisation, design, data collection, data analysis, writing. Mukaro: Supervision, editing/ reviewing, critical revision of manuscript. Parawira: Supervision, editing.

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