INTEGRATING EDUCATION FOR SUSTAINABLE DEVELOPMENT PRINCIPLES IN TEACHING SECONDARY SCHOOL CHEMISTRY IN NDOLA DISTRICT

by

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Declaration

I, Chama Sarah, do hereby declare that this thesis represents my own work and that it has not previously been submitted for a degree or other qualification at the University of Zambia or any other University.

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Abstract

Chemistry cuts across various disciplines such Agriculture, Medicine, Energy, Mining and Manufacturing as such it is one of the key disciplines to equip learners with knowledge, skills and attitudes to respond to Sustainable Development (SD) issues and consequently contribute to SD. Education for sustainable development (ESD) is an important element of quality education as it envisages life-long approach to learning. Thus integration of SD issues in the curriculum and Education for Sustainable Development (ESD) is critical for equipping learners with knowledge, skills and values necessary to understand and respond to SD issues facing the world today. However, the use of ESD in chemistry education and how teaching might be organised remains unclear. Thus the purpose of the study was to establish how pedagogies used to teach senior secondary chemistry reflect education for sustainable development principles and the integration of the sustainable development issues in the chemistry curriculum in Zambia and consequently to propose a chemistry teaching model anchored on dimensions of ESD. The objectives of the study were to: assess chemistry teachers' knowledge of Sustainable development issues; establish how the chemistry curriculum integrates sustainability issues; explore how the pedagogies used to teach chemistry reflect the ESD principles and this culminated into the development of a chemistry teaching model anchored on ESD. The study used a mixed method approach in which a sequential design was used. A sample of 79 chemistry teachers was drawn from selected secondary schools in Ndola district. The Assessment of Sustainability Knowledge (ASK) tool, document analysis, observation and focus group schedules were used to collect data. The findings showed that chemistry teachers' knowledge of sustainability issues was adequate, about 56 out of 79 managed to obtain a 40% threshold. It was also noted that one of the chemistry curriculum general aims was anchored on ESD, however, there was a mismatch between the aim and specific outcomes. The specific outcomes focused more on the acquisition of knowledge as opposed to transformational learning outcomes. The curriculum contained various sub-topics that speak to SD issues. The pedagogies used were mostly teacher centred characterised by delivery of factual knowledge. In light of the findings, the study proposed and recommended the use of the chemistry teaching model underpinned by expansive learning theory and ESD principles. The model has the potential to enhance teaching and learning of chemistry through the formulation of learning outcomes, creation of learning environments and use of pedagogy that focus on transformative learning and societal transformation. The curriculum developers should align the general aim that speaks to ESD with specific outcomes in order to clearly guide the teachers as they implement the curriculum. There is also need to build chemistry teachers' capacity through continuous professional development (CPDs) so as to help them translate their knowledge on sustainable development issues into classroom decisions and actions.

Keywords: *Education for sustainable development, Sustainable development, Chemistry, Curriculum, Pedagogies*

Dedication

I dedicate this work to my family, thank you for your encouragement and inspiration. Your prayers have been a light unto my feet, throughout this journey.

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LIST OF ABBREVIATIONS

ASK: Assessment of Sustainability Knowledge

CDC: Curriculum Development Centre

DEBS: District Education Board Secretary

ESD: Education for Sustainable Development

MOE: Ministry of Education

NDPs: National Development Plans

NCZ: Nitrogen Chemicals of Zambia

SD: Sustainable Development

SDGs: Sustainable Development Goals

UNESCO: United Nations Educational, Scientific and Cultural Organisation

ZPD: Zone of Proximal Development

CHAPTER ONE: INTRODUCTION

1.1 Introduction

This chapter introduces the study by highlighting the background information on Education for Sustainable Development and secondary school Chemistry teaching. It also looks at Chemistry as a central science and how it links to various disciplines and ultimately to Sustainable Development. The chapter underscores the importance of using pedagogies informed by ESD and the need to come up with an ESD Chemistry teaching model as a guide. Thereafter, the chapter outlines the purpose, objectives, questions and significance of the study. Lastly, the scope, theoretical and conceptual frameworks are presented.

1.2 Background of the Study

United Nations Educational, Scientific and Cultural Organisation (2005) describe Education for Sustainable Development as a United Nations initiative aimed at reorienting education. It is alive to the notion that empowering of citizens with appropriate knowledge, skills, values and attitudes is key in supporting sustainable behaviour ultimately Sustainable Development (SD). The Brundtland report describes SD as "the development which is aimed at meeting the needs of the present generation without compromising the ability of the future generation to meet their own needs" (United Nations, 1987: 17).

Education for Sustainable Development (ESD) envisages life-long approach to learning and as such, it is a fundamental element of quality education (UNESCO, 2017). It promotes cognitive, social, emotional and behavioural dimensions of learning. Further, it can be described as holistic and transformational in nature. This is because it tries to put a learner at the centre of learning through action-orientated learning. UNESCO (2020) outlines that there are four salient dimensions of ESD and these are; learning content, learning outcomes pedagogy and learning environment and societal transformation. In a quest to achieve sustainable development there is need to build a more sustainable world through societal transformation. On the other hand, learning outcomes should emphasise the need to equip learners with necessary knowledge, skills, values and attitudes for them to participate actively in societal transformation for present and future generations (UNESCO, 2015). ESD also calls for the integration of the sustainability issues in the curriculum as part of learning content. These include but not limited to; climate change, disaster risk reduction, biodiversity and sustainable consumption. Pedagogy is key in enhancing a learning environment that promotes interactive, project based and learner centred approaches. As a result, ESD stresses that pedagogies are vital in promoting learner's capacity to use their knowledge in real life scenarios as well as to solve problems they encounter in their communities.

The 2017 General Assembly of the United Nations (72nd) reaffirmed that "ESD is an integral element of Sustainable Development Goal number 4 (SDG4) on quality education and a key enabler of all other SDGs" (UNESCO, 2020:8). Similarly, Armstrong (2011) indicates that ESD is believed to empower learners in a way that enables them to make informed and responsible decisions as well as take actions for the good and welfare of the environment, economic sustainability and an impartial society for all. ESD may also mean imply fostering the addition of key sustainable development issues into teaching and learning; for instance, risk reduction, biodiversity, poverty reduction climate change and sustainable consumption (Lotz-Sistka, Tshiningayamwe, Urenje, Mandikonza & Chikunda, 2019). This is in order to shape a sustainable future, make certain that learners are equipped with adequate knowledge, skills, attitudes and values.

This infers that our needs and those of the future generations can be met by achieving the Sustainable Development Goals (SDGs) stipulated in the Agenda 2030. Education 2030 Agenda pays particular attention to SDG 4 which posits that ensure "inclusive and equitable quality education and promote lifelong learning opportunities for all" (UNESCO, 2015:7). This aspiration has been reemphasised in the Agenda 2063 of the Africa We Want (2014). The Agenda 2063 recognises the significant role of education in transforming lives and communities. This is in a quest to have prosperous, peaceful and sustainable societies. Henceforth, looking at the various challenges that the earth and man is grappling with, there is need to "rethink how we learn to develop knowledge, skills, values and attitudes that will enable us all to make informed decisions, take individual as well as collective action on local, national and global levels", (UNESCO,2020:8).

Zambia is no exception to the aspirations of the Africa we want agenda 2063 and the global agenda 2030. This is evident in the educational policy of 1996, which highlights that "education plays an important role in human resource development as the basis of all development" (Ministry of Education, 1996:2). The policy further reiterates that education is critical in shaping the kind of knowledge, skills, values and competencies needed for economic development. These aspirations have also been nationalised in the vision 2030 which is a national long term plan. The vision 2030 espouses that Zambia must be a "prosperous middle-income nation by 2030" (Government of the Republic of Zambia, 2006:8). This entails that by 2030 Zambians seek to live in a vibrant middle-income country that builds and provides opportunities for an improved welfare of all and supports values for social-economic development. In order to attain this, the vision emphasises the central contribution of education in enhancing Zambia's social economic development.

The vision sets out thematic or strategic areas that focus on attaining sustainable development such as: economic growth and wealth creation; social investment and human development as well as creating an enabling environment for sustainable social economic development (GRZ, 2006). The first theme highlights mining, energy, science and technology as some of the key sectors of the economy. Emphasis is placed on mineral resource exploration that and mitigation of environmental degradation as a result of mining undertakings. There is also a clarion call made on the importance of embracing the use of clean, green and renewable sources of energy that is reasonable and takes into consideration the social, economic and environmental implications. The second theme speaks to attaining lifelong education which is innovative and productive by 2030. While the third theme stress the importance of protecting and conserving the environment so as to attain sustainable social economic development by 2030 (GRZ, 2006). It is clear that the national vision 2030 is grounded on the tenets of sustainable development. It emphasises economic development but also cognisant of the social and environmental impact of this development. It also points to a form of education like ESD as key in building capacity and skills of the human resource as driver of this vision.

On the other hand education is viewed as critical in building capabilities of people to make well-versed decisions about their lives. Further, the vision 2030 envisages the importance of a comprehensive and differentiated curriculum that is open to the social and economic needs of individuals and the community (GRZ, 2006). Tomlinson and Strickland (2005) describe a differentiated curriculum as an adaptation or modification of learning experiences to cater for the diverse needs of learners. The focus is to maximise individual learner's ability to learn. This is in a quest to promote innovative and life-long learning for all, which is a central idea of ESD. In order to give this aspiration, focus it has been reaffirmed in the five year plans, the 7th and 8th National Development Plans (GRZ, 2017; 2022). The 7NDP indicates that building appropriate capacity is largely dependent on the kind of education which promotes skills acquisition and empowers learners with the ability to solve social problems that they encounter. The plans reiterate that active participation of individuals is critical in shaping equitable sustainable development.

The 8NDP repackages the three dimensions of sustainable development into three strategic areas and these are promoting economic transformation and job creation; enhancing human and social development as well as promoting environmental sustainability. In order to attain economic transformation and move towards vision 2030, the plan emphasises promotion of critical sectors such Agriculture, Mining and Manufacturing with a thrust on local linkages. While human and social development advocates for the importance of increasing access to quality education. Environmental sustainability suggests the promotion of green growth, safeguarding the environment and sustainable pathways (GRZ, 2022). These aspirations give impetus to the role of chemistry in Zambia's sustainable development as an underlying science of the key sectors highlighted above. The plan also underscores the form of education like ESD which is inclusive and responsive to environmental challenges.

The 2013 Education Curriculum Framework of Zambia stipulates that life-long learning is responsive to learners' personal and societal needs. As a result, the curriculum implementation framework has guided that both teachers and teacher-educators ought to use teaching techniques that promote active learner involvement and interaction. This is achievable through the planning and delivery of lessons that are aimed at cultivating experiential learning and enhancing learner-centeredness (MoE, 2013). It is claimed that "…learner centered approach develops learners' ability, attitudes, skills and values to work independently and help them to take responsibility of their own learning." (MoE, 2013:15).

Hofstein, Eilks and Sjostrom (2017), points out that science learning is said to be relevant whenever learning impacts learners' lives positively. Science education must prepare learners to lead responsible lives in society. This is through enhancing their understanding of the link between scientific knowledge and societal challenges so as to foster their skills to participate in society's sustainable development. Chemistry is one of the sciences that is critical to SD as it deals with matter, it's properties, various chemical reactions and the use of those reactions to form new substances (Goldberg, 2007; Whitten, Davis, Peck & Stanley, 2010). Hofstein et al. (2017:8) alludes that "chemistry and the industries related to it are at the heart of every developed society". It suffices then to mention that chemistry cuts across a number of disciplines such as Agriculture, Medicine both traditional and conventional, Energy, Mining and Manufacturing to mention but a few. It also underlies the processes that are unique to each discipline as well as social scientific issues such as pollution, climate change and many more. This implies that it is imperative to consider the contribution of chemistry education towards the sustainability of communities. Therefore, chemistry must be taught and learnt in a manner that promotes learner's understanding of the value of scientific knowledge in their lives and society through context-based learning experiences. This may be achieved by opening pedagogy to social-scientific issues and the industry in order to enhance SD. Further ESD can give a stimulus to the relationship between schools, the industry and society (Armstrong, 2011; Eilks & Rauch, 2012; Juntunen & Aksela, 2014).

The Zambia's Education Curriculum Framework of 2013 is underpinned by ESD principle of ensuring lifelong learning. This is also espoused in the curriculum implementation framework that has provided guidance on the use of pedagogies that promote learner's active participation. However, Chama and Nachiyunde (2019) indicated that when chemistry teachers engage their learners in practical activities the focus is on exposing learners to pieces of apparatus, verify and confirm what was discussed during theory lessons. This is unlikely to promote learners active participation both hands-on and minds-on. Ultimately, learners may not acquire sufficient knowledge and skills to solve real life problems. Bridges (2015), states that learners may find it difficult to understand the content because of their need to memorise without making connections among concepts. Teachers need to adapt their chemistry teaching methods so as to promote conceptual understanding. This is imperative in helping learners to apply their understanding to solving societal complex problems such as climate change.
In a similar vein the 2023 Education Curriculum Framework indicate that "the curriculum ought to be relevant and responsive to the needs of the individual, the society, the nation and global dictates" (MoE, 2023:1). There is also emphasis on ESD as one of the cross cutting issues of concern. The curriculum positions ESD as an integral form of education necessary to equip learners with knowledge, skills, attitudes and values to promote environmental sustainability and conservation of natural resources. The curriculum calls to attention the use of various teaching techniques and methods in teaching all subjects so as to promote active, participatory and interactive learning among learners. Therefore, chemistry as a subject is important in promoting environmental sustainability because it encompasses concepts such as pollution.

Secondary school chemistry is important in the sense that it builds the foundation for learners to understand and appreciate scientific principles. It also builds a foundation and prepares learners for higher education in fields such as medicine, engineering, geology and many more. It is also critical in helping learners develop science process skills necessary to understand the world around them. Furthermore secondary school chemistry is essential in helping learners connect chemistry to everyday life. Childs, Hayes and O'dwyer (2015:25) narrate that:

> There are different ways of relating everyday chemistry to the school curriculum and to the interests of secondary students. We could consider, for example, materials that are used every day, or the chemistry of everyday objects, or that of everyday activities students are involved in, or their hobbies or outside interests. We could consider the chemistry involved in everyday issues, topical events that come up in the news media and in discussion; many of these topics are about the environment, energy and resources, and all involve science/chemistry, as well as economic, ethical and social issues.

Besides, it is imperative to note that learner's understanding of concepts and their connections is key in reinforcing the appreciation of complex issues such as climate change, biodiversity loss to mention only two. However, studies have shown that teachers' have challenges in using learner centered strategies in the presentation of certain chemistry concepts because the pedagogy used is said to be fixed on memorizing of concepts and passing of examinations (Nkoya, 2008; Shumba & Kampamba 2017; Chama & Nachiyunde 2019; Mweshi, Munyati, & Nachiyunde, 2020).

1.3 Statement of the Problem

Chemistry is one of the central sciences as such it is a pre-requisite to a number of other science related fields and it is critical to science literacy (Bridges, 2015). Additionally, chemistry is at the heart of nearly all aspects of human development and society because it cuts across a number of disciplines such as Agriculture, Medicine both traditional and conventional, Energy, Mining and Manufacturing to mention but a few (Hofstein et al., 2017). Thus the teaching of chemistry in secondary schools should integrate the principles of Education for Sustainable Development, so as to contribute to the realization of the objectives of the 8NDP and consequently sustainable development.

Education for Sustainable Development encourages pedagogies that promote reflection and critical thinking. This implies that learners are well poised to make observations, develop an understanding and skills for sustainable development (Ssosse', Wagner & Hopper 2021; Kigba, Gakuba & Sentongo, 2021). This connects well to the aspirations of education curriculum framework of 2013. Therefore, there is an increased interest in using learner centered strategies to promote conceptual understanding and the role of chemistry and its processes in economic development. However, Burmeister and Eilks (2013) alludes that ideas for using ESD in chemistry education and how teaching might be organised has mostly continued to be inadequate. Eilam and Trop (2010:19) also add that "lack of clear guidelines with regards to ESD pedagogy contributes to ambiguity and lag of practice". These inadequacies pointed out in literature might also be true to the Zambian context. Therefore, the study sought to establish how pedagogies used to teach senior secondary chemistry reflect education for sustainable development principles and the integration of the sustainable development issues in the chemistry curriculum.

1.4 The Purpose of the Study

The purpose of the study was to explore and acquire understanding of how pedagogies used to teach senior secondary chemistry reflect ESD principles as well as how the chemistry curriculum integrates sustainable development issues.

1.5 Research Objectives

The study was guided by the following objectives:

1. To assess chemistry Teachers knowledge of sustainable development issues.
2. To establish how the chemistry curriculum integrates sustainability issues.
3. To explore how the pedagogies used to teach chemistry reflect the ESD principles.
4. To develop a Chemistry teaching model anchored on ESD principles

1.6 Research Questions

The study was guided by the following research questions:

1. What is chemistry teacher's knowledge of SD issues?
2. How does the chemistry curriculum integrate sustainability issues?
3. How do the Pedagogies used to teach chemistry reflect the ESD principles?
4. How best can chemistry be taught in line with ESD principles?

1.7 Significance of the Study

The study might provide an insight and knowledge needed to transform chemistry pedagogies in order to promote life-long learning. It may also provide teachers with an ESD chemistry teaching model that will guide their presentation of concepts in the syllabus that speak to ESD. This may lead to use of appropriate pedagogies that equip learners with knowledge, skills, values and attitudes needed to solve real life problems in their communities for fostering sustainable development. This in turn is likely to contribute to the attainment of the aspirations of both the 8^{th} National Development Plan and Vision 2030. Additionally, the provide guidance to continuous development providers in terms sharpening the skills of how to repackage and present specific chemistry topics. Further, the findings may help make apparent the critical role of chemistry education in sustainable development. The may also inform curriculum development officers to make the curriculum responsive to sustainability issues. The study is probable to contribute to the body of knowledge in the field of chemistry education and ESD which is one of the prime areas of research.

1.8 Scope/delimitations of the study

The study focused on education for sustainable development as the basis for transforming pedagogies for teaching secondary school Chemistry. Additionally, the purpose of the study was to develop an ESD Chemistry teaching model. The study engaged in the discussion of ESD, pedagogies used to teach secondary school Chemistry and how they reflect sustainability issues. Chemistry teachers from selected secondary schools in Ndola District of Zambia made up the sample. The study sample did not include Chemistry teachers from all the secondary schools in Zambia, but it was limited to one district. However, there might be incidental similarities in terms of background and teaching environments to other Chemistry teachers in different parts of the country.

1.9 Limitations of the study

The study focused on gaining an understanding of how ESD lays the basis for transforming pedagogies for teaching secondary school Chemistry in Ndola district. Despite the study using a mixed method approach, the subjective nature of purposive sampling used for the qualitative part might have affected the diversity of perspectives captured from the target population. Henceforth, the knowledge which was generated from this study may not be generalised to other parts of the country.

1.10 Theoretical Framework

The study was by informed the expansive learning activity theory. The expansive learning theory (concept) is part or rather grounded on the activity theory. It was formulated by Engestrom in 1987. The activity theory can be described as both a historical and a developmental theory (Engestrom, 2001). Expansive learning is considered to be a form of learning in which a learner is part of their own learning and is involved in constructing and implementing new and more complex object for their activity (Engestrom, 1987; 2001; Guberman & Smith, 2021). Additionally, learning is believed to be "transformed from isolated individuals to groups and networks" (Engestrom & Sannino, 2010: 8). The theory considers learners as a community in which transformation, creation of culture and agency occurs (Yamazumi, 2006).

The key ideas underlying expansive learning theory are: expansive learning as transformation of the object, expansive learning as the movement in the zone of proximal development, expansive leaning as cycles of actions and lastly expansive learning as boundary crossing and network building (Engestrom & Sannino, 2020). The description of expansive learning as the transformation of the object focuses on the type learning which fosters new forms of an activity as they are created during the teaching/learning process. The intention is not to promote the mastery of only well-defined, existing knowledge but foster skills. In this case the object is said to be the whole activity system in which the learners are engaged (Engestrom, 2001). Further, Engestrom (2000) argues that learning should not only be restricted to the acquisition of knowledge, skills and attitudes codified by learning institutions but it should foster solutions to pressing societal problems. This is key to the teaching of chemistry as a subject whose content must be applied to solve the some of the current issues facing the world today.

The second tenet is Zone of Proximal Development (ZPD).Vygotsky (1978: 86) defines the Zone of Proximal Development as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." The idea of ZPD was redefined under expansive learning as "the space for expansive transition from actions to activity" (Engestrom, 2010:4). This space provides opportunities for learners to apply their understanding and take actions to accomplish the activity. This aspect underscores the importance of guided learning, learners sharing ideas and knowledge as they engage in various activities during the lesson. Teachers can design hands-on chemistry activities to explore in groups and connect chemistry concepts to real-world applications and sustainability issues. This is likely to promote critical thinking and problem solving among learners, for example, the teacher can engage learners in activities to share ideas on materials and energy, pollution and many other chemistry concepts linked to sustainable development issues.

Expansive learning as cycles of actions, at this point the process of learning is said to undergo a number of actions in a cycle for transformation to occur. The learning process or activity execution experiences internal contradictions as participants begin to question and depart from established norms. This fosters collective change of the object or approach to the activity (Engestrom, 1987). The stages of the cycle are identified by Engestrom and Sannino (2010:8) as "(1) questioning, (2) analysis, (3) modelling the new solution, (4) examining and testing the new model, (5) implementing the new model, (6) reflecting on the process, (7) consolidating and generalizing the new practice". The following is a brief description of the stages of the cycles of action:

1. Questioning: In this action a learner starts to question, interrogate, critique or simply reject existing knowledge or practices. In the context of secondary school chemistry a learners can question, a technique, equation or formula.

This will definitely make them curious and encourage them to seek for answers leading to the second stage which is analysis.

2. Analysis: “Analysis involves mental, discursive or practical transformation of the situation in order to find out causes or explanatory mechanisms. Analysis evokes *“why?”* questions and explanatory principles” (Engestrom & Sannino, 2010:7). This is a critical stage in an ESD driven chemistry classroom, in the sense that learners’ can collaboratively analyse the concept of energy for example. The analysis can focus on various forms energy, their socio-economic impact and how they affect the environment. Explore sources of alternative, clean and sustainable energy.
3. Modelling the new solution: Modelling the new solution involves coming up a tangible product as a result of the relationships and explanations established in the analysis stage. If this is applied to an ESD informed chemistry classroom, requires the teacher to facilitate the process of coming up with a model by learners. Using the same example of the concept energy learners can come up with clean energy related projects that can be considered as alternatives or as a solution to the problematic situation of energy shortages and unsustainable practices.
4. Examining and testing the new model: At this stage action is taken to examine the model, trying it out so as to understand its operational potentials and limitations. At this point learners test their clean energy project either in the laboratory or in class to see if it is working properly.
5. Implementing the new model: This action is about implementation of the new model, at this point learners are set to implement their project. For instance, their clean energy project can be implemented in school, at home or in their local community.
6. Reflecting on the process: - The sixth action is a reflection stage of the process undertaken starting from the questioning action through to implementation. At this point learners take time to understand, the decision made, the resources used and the challenges encountered if any.
7. Consolidating and generalising the new practice: This last stage involves evaluation of the process to check work well, what did not or what areas or components should be revised or adjusted. Using the energy project

example, at the use of clean alternative energy becomes a practice among the learners and their community.

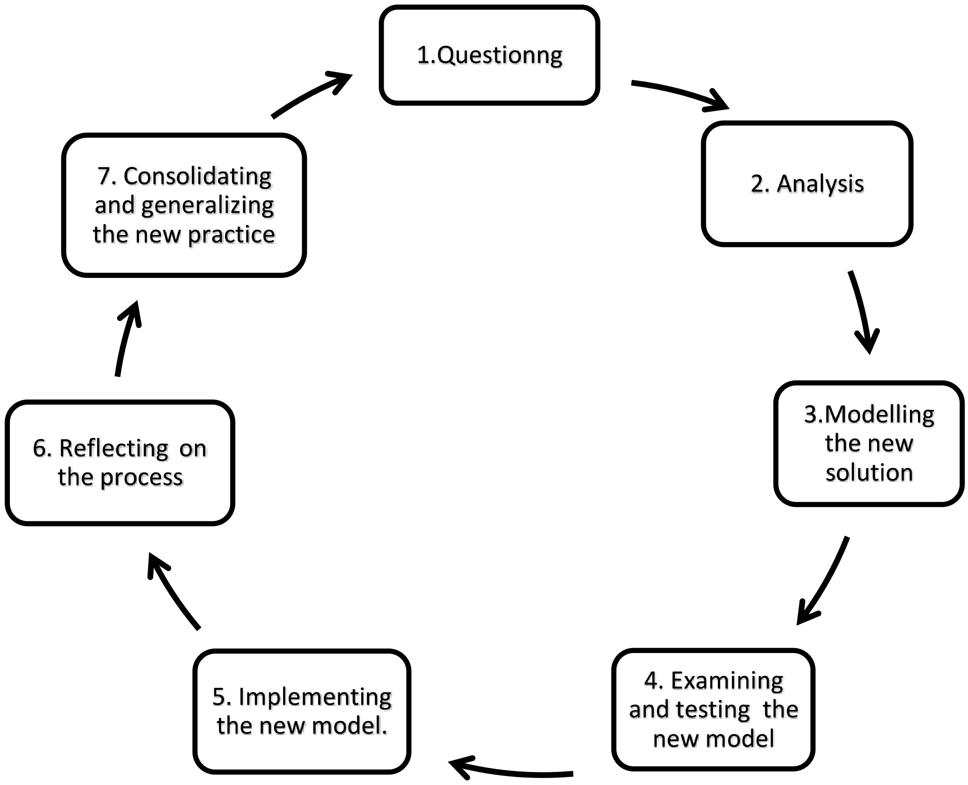

Figure 1: Expansive learning cycles of action (Engestrom and Sannino, 2010:8)

In expansion the focus is not only aimed at elevating people from one level of competence to another but also sideways or horizontal development. This approach forges new partnerships, promotes collaboration, multidisciplinary learning and networks (Engestrom, 2000; Shumba & Kampamba, 2020). Therefore, the theory is key in promoting active participation, collaboration, networking, transformation and multidisciplinary approach to learning. This fosters networking and multidisciplinary approach to problem solving which is key in promoting life-long learning, active participation and societal transformation as ultimate goals of ESD (Amineh & Asl, 2015; Shumba & Kampamba, 2017; Simasiku, 2020).

Expansive learning tenet of forging networks coupled with ESD can be applied to chemistry teaching. For instance a teacher can use practical activities and projects to engage learners in various hands-on activities. In this case practical activities and projects can be designed in a way that enhances learners' application of chemistry knowledge to solve sustainability challenges. For example learners can explore alternative energy sources by working with peers, experts from the industry, neighbouring schools and the community.

Expansive learning theory stresses the social nature of learning. Engestrom and Sannino (2021:13) points out that "lateral interactions across the boundaries between participating activity systems become central. This sideways dimension of expansive learning involves the construction of new social relations". In the context of chemistry teaching, teachers can design collaborative activities that encourage learners to work together through group discussions and explore different perspectives as well as knowledge from other disciplines to develop a deeper understanding of sustainable development issues. These activities are likely to promote active learning and critical thinking while fostering a sense of responsibility towards sustainable practices.

Lastly, the theory provides a lens through which the understanding of how ESD lays a foundation for the transformation of pedagogies to spur conceptual understanding, innovation and new pedagogical practices can be viewed. Expansive learning theory just like ESD promotes participatory learning which when applied to chemistry to teaching can foster conceptual understanding of chemistry concepts. The teacher can use methods that encourage learners to be hands-on through experiments both virtual and physical, projects, group discussions and many more.

It is also important to allude that expansive learning underlies networking and collaboration which is also true to ESD. In this case emphasis is placed on helping learners share ideas and get knowledge from different sources and disciplines. This emphasis is likely to influence the way the teacher would present information to the learners. For instance, if a teacher is teaching concepts such as materials and energy, acids, bases and salts, he/she can come up with activities that will enable learners to work with peers, experts and other players to attain conceptual understanding and contribute to sustainability. It suffices to mention to that expansive learning theory speaks to learning which crosses boundaries entailing a multidisciplinary approach to learning. This is equally one of the principles of ESD, which underscores the need for learners to learn from other disciplines (UNESCO, 2020). With regard to chemistry teaching a multidisciplinary approach may benefit learners and promote understanding. In a situation where a teacher is presenting a lesson on metal extraction, learners can tap knowledge from geography, environmental science and the mining sector. This necessitates opportunities for an expansive and ESD underpinned pedagogical approach.

1.11 Conceptual Framework

The conceptual framework of the study integrated the pillars of Education for Sustainable Development and expansive learning theory. ESD focuses on learning content, learning outcomes, pedagogy and learning environment as well as societal transformation. These pillars provide support by anchoring the teaching of chemistry informed by tenets of expansive learning. The chemistry curriculum is regarded as a starting point to the process of pedagogical transformation so as to attain ESD. This is with regard to understanding the various components of the chemistry curriculum in relation to ESD. There are a number of topics in the chemistry curriculum that indirectly contribute to SD such as metals with a specific focus on extraction of metals as well as the harmful effects of some metals on the environment. The other section is the aspect of non-metals, acids, bases and salts with concepts like the measurement of Potential Hydrogen (PH) of the soil and water for example. The curriculum also has topics such as energetics and chemical reactions focusing on the various energy sources of energy and the energy changes involved. The aspect of learning content looks at how critical issues of interest such as climate change, disaster and risk reduction, sustainable consumption and production that can be integrated in the curriculum. On the other hand, learning outcomes focuses on the promotion of key competencies and skills such as critical thinking, systemic thinking, collaboration and taking responsible actions for present and future generations. On the other hand pedagogy and learning environments looks at the need to enhance teaching/learning in an interactive and learner centred manner. It is also hoped that learners might gain knowledge, skills and values needed to contribute to a sustainable society (Lot-Sistka et al., 2019).

Expansive learning theory considers learning as a process in which a learner is involved in constructing and implementing new understanding collaboratively (Engestrom & Sannino, 2010). This is important in the repackaging and presentation of chemistry concepts. As earlier indicated the chemistry curriculum contains content which is linked to sustainable development directly or indirectly. As such it is critical for the teacher to facilitate the learning process in a manner that enhances learners' active participation in the learning process. In the framework the pillars of ESD feed into the teaching of chemistry informed by expansive learning. The first pillar of learning outcomes guides how the teacher interprets the content in curriculum and set achievable outcomes in their lessons. For instance, a lesson on the importance of chemistry can be expansively taught by showing the relevance of chemistry in the health, energy, food, mining and other related industries.

The second pillar is an opportunity to understand the chemistry content in the curriculum by looking at topics that directly or indirectly contribute to sustainable development. The expansive learning theory advocates for the use of methods that promote active learner participation, collaboration, guided learning and multidisciplinary learning. This is what the third pillar underscores by focusing on pedagogy and environment; this is equally what is envisaged by ESD. The societal transformation pillar is critical because it is a call to action for learners to apply their knowledge to solve societal problems.

Thus, chemistry teaching/learning should endeavour to equip learners with the necessary knowledge, skills, values and attitudes to solve complex sustainability issues facing the world today. For example, under the main topic organic chemistry in the chemistry curriculum, a subtopic on polymers covers concepts such single use plastics and their non-biodegradable nature. In this case the idea is to present the concepts in a manner that encourages learners to raise awareness in their communities such as project work. Learners can use their knowledge and conceptual understanding from the lesson to analyse chemical composition of single-use plastics. They can also search for information from various sources to understand why these plastics take so much time to break down. This knowledge is likely to help them appreciate the significance of reducing plastic production and use. The project activity can also promote probing the harmful effects of plastic waste on environment, water and on the health of the community members. In a quest to solve this problem learner can suggest everyday solutions such as recycling as a way to manage and reduce plastic waste in their local communities. At this stage this stage it suffices to mention that the chemistry concept from the curriculum has been taught in an expansive way and well-grounded in ESD fostering long life learning

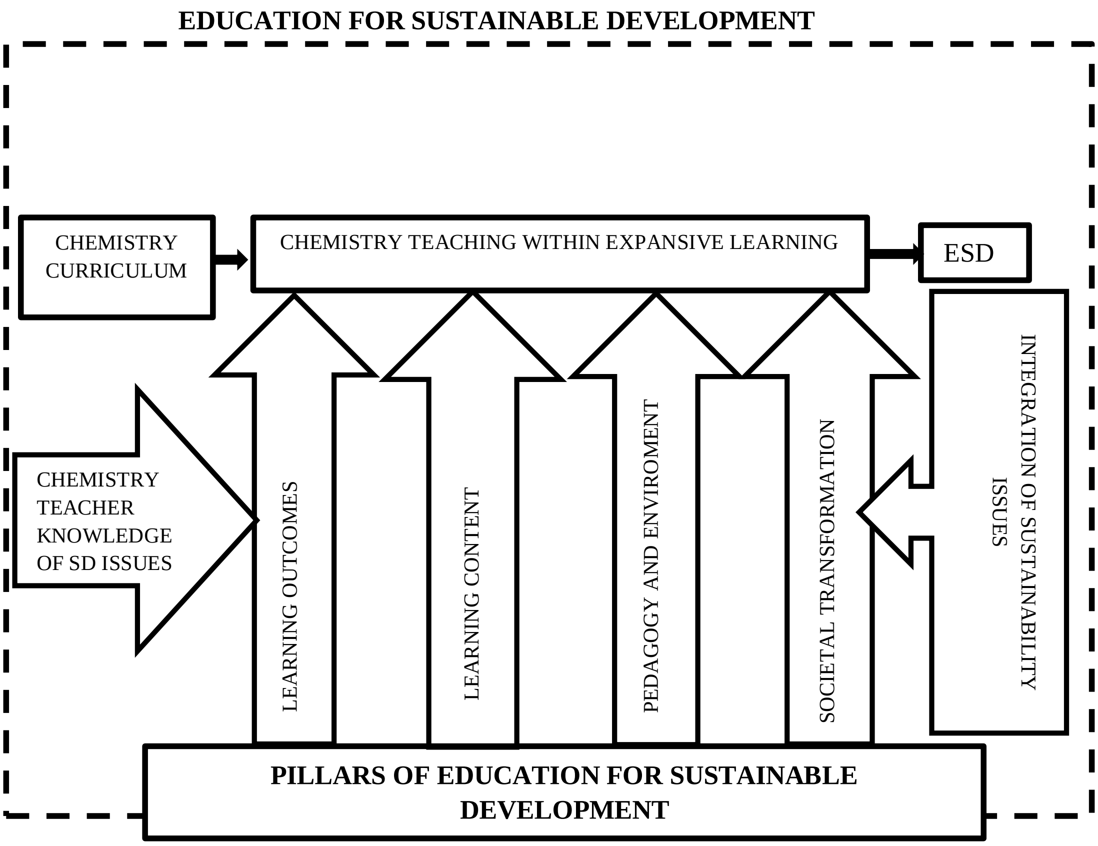

Figure 2: The interaction of ideas in the conceptual framework

1.12 Operational Definition of Terms

In this study, the terms given are used to mean the following:

Education for Sustainable Development*:* The education which empowers learners with knowledge, skills, attitudes and values to contribute to a sustainable future.

Sustainable Development: The development which is aimed at meeting the needs of the present generation without compromising the ability of the future generation to meet their own needs (United Nations, 1987: 17).

Pedagogies: The teaching/learning approaches, methods and techniques used by the teacher to facilitate the learning in a Chemistry lesson.

Chemistry: A branch of science that deals with matter, its properties, the various chemical reactions and the use of those reactions to form new substances.

Expansive learning: A form of learning in which a learner is involved in constructing, applying new knowledge to solve societal issues through collaboration and networking.

Societal Transformation: The use of chemistry knowledge, skills and values to take action about the environmental, social and economic issues in the society.

Sustainability Issues: The challenges that result from the disruptions of the environmental, social, and economic stability to ensure long-term well-being for future generations.

1.13 Summary

This chapter highlighted the introduction of the study through the description of the background information and statement of the problem. The study objectives, questions as well as the significance were also highlighted. Further, the chapter looked at the theoretical framework which underpinned the study, as well as the scope, limitations and operation definitions. In the next chapter literature related to the study is reviewed.

1.14 Structure of the Thesis

This thesis is structured into six chapters which include; the introduction, literature review, methodology, findings, discussion, conclusion and recommendations.

Chapter one: It highlights various components of the study. These are; the background to the concept of education for sustainable development as well as the role of secondary school chemistry in sustainable development focusing on the Zambian context, a presentation of the problem statement, the purpose of the study; objectives of study and the research questions. Further, the chapter highlights the limitations and scope of the study. Lastly the theoretical and conceptual frameworks guiding the study are also presented together with operational definition of terms.

Chapter two: This chapter looks at the review of literature relevant to education for sustainable development and its contribution to the attainment of sustainable development goals, the pedagogies advocated for with respect to education for sustainable development. The review also looks at literature highlighting the link between chemistry education and education for sustainable. The chapter concludes by showing studies on chemistry curriculum and sustainability issues.

Chapter three: The chapter gives a detailed description of the method and materials used in the study. Firstly, the philosophy guiding the study is presented followed by the specific design. Secondly, a description of the population and sample are given as well as the details of data collection and analysis procedures. It also explains the various data collection instruments used and their validation process. Last but not the least the chapter indicates the proposed model development procedure and ethical issues considered in the study.

Chapter four: In this chapter the study findings are presented in line with the objectives: chemistry teachers' knowledge of sustainable development issues, the integration of sustainability issues in the chemistry curriculum, reflection of education for sustainable development in the pedagogies used to teach chemistry.

Chapter five: The discussion of the study findings done in this chapter speaking to the key the highlighted findings; chemistry teachers' knowledge of sustainable development issues, the integration of sustainability issues in the chemistry curriculum, reflection of education for sustainable development in the pedagogies used to teach chemistry. The chapter also evaluates the findings in relation to salient literature and the theoretical framework of expansive learning. A proposed chemistry teaching model is presented at the end of the chapter as a product of the study.

Chapter six: Conclusions are drawn from the key findings of the study. The shows the sustainability knowledge of chemistry teachers, the presence sustainability issues in chemistry curriculum. Over and above it points out the pedagogies used by teachers to teach topics identified to be linked to sustainable development in chemistry curriculum. In the end recommendations are given based on the findings.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature related to the study by looking at the concept of education for sustainable development and its underlying principles. There is also an exploration of discussions surrounding ESD pedagogies as well as Chemistry education and ESD in order to provide focus on the importance of Chemistry and its contribution to sustainable development. The chapter sums up by highlighting the position of the study in the literature.

2.2 Education for Sustainable Development

Education for Sustainable Development is linked very closely to sustainable development (Simasiku, 2020). This is because it is an important component of the sustainable development goals and a medium through which SD can be integrated into the education system or rather in the teaching and learning. Additionally, ESD is characterised by action-oriented, innovative pedagogy which is likely to empower learners with knowledge, skills and values to help address the sustainability issues facing the world today (UNESCO, 2020). The concept of Sustainable Development has been defined by the Brundtland report as "the development which is aimed at meeting the needs of the present generation without compromising the ability of the future generation to meet their own needs" (United Nations, 1987: 17). On the other hand, Sustainable Development can also be described as a social learning process that takes place in local setting (Morgan, 2009). This implies that in this process learners learn to build capacity to live more sustainably.

The global agenda "*Transforming our world: the 2030 agenda for sustainable development"* commonly known as the 2030 agenda has integrated and created a balance among the three pillars of sustainable development that is economic, social and environmental through the 17 SDGs (UN,2015; UNESCO,2017). The 17 SDGs are highlighted in Table 2.1.

Table 2.1: The 17 Sustainable Development Goals

Goal 1: No Poverty	End poverty in all its forms everywhere
Goal 2: Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3: Good Health and Well-Being	Ensure healthy lives and promote well-being for all at all ages
Goal 4: Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5: Gender Equality	Achieve gender equality and empower all women and girls
Goal 6: Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
Goal 7: Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and clean energy for
Goal 8: Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9: Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10: Reduced Inequalities	Reduce inequality within and among countries
Goal 11: Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12: Responsible Consumption and Production	Ensure sustainable consumption and production patterns
Goal 13: Climate Action	Take urgent action to combat climate change and its impacts
Goal 14: Life below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15: Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16: Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17: Partnerships for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development

(UNESCO, 2017:6)

Sustainable Development Goal 4 is dedicated to education and it stipulates that "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UNESCO, 2015:7). The SDG4-Education 2030 agenda advocates for a holistic form of education which contributes to a new model of development. However, UNESCO underscores the importance of education in achieving other SDGs. This is because education has the potential to build capacity of people by equipping them with necessary knowledge, skills, values and attitudes to make informed decisions and respond to local and global challenges. Table 2.2 shows the link between education and other SDGs.

Table 2.2: The link between Education and other SDGs

Goal 1: Education is critical to lifting people out of poverty.
Goal 2: Education plays a key role in helping people move towards more sustainable farming methods, and in understanding nutrition
Goal 3: Education can make a critical difference to a range of health issues, including early mortality, reproductive health, spread of disease, healthy lifestyles and well-being.
Goal 5: Education for women and girls is particularly important to achieve basic literacy, improve participative skills and abilities, and improve life chances
Goal 6: Education and training increase skills and the capacity to use natural resources more sustainably and can promote hygiene.
Goal 7: Educational programmes, particularly non-formal and informal, can promote better energy conservation and uptake of renewable energy sources.
Goal 8: There is a direct link among such areas as economic vitality, entrepreneurship, job market skills and levels of education
Goal 9: Education is necessary to develop the skills required to build more resilient
Goal 10: Where equally accessible, education makes a proven difference to social and economic inequality.
Goal 11: Education can give people the skills to participate in shaping and maintaining more sustainable cities, and to achieve resilience in disaster situations.
Goal 12: Education can make a critical difference to production patterns (e.g. with regard to the circular economy) and to consumer understanding of more sustainably produced goods and prevention of waste.
Goal 13: Education is key to mass understanding of the impact of climate change and to adaptation and mitigation, particularly at the local level.
Goal 14: Education is important in developing awareness of the marine environment and building proactive consensus regarding wise and sustainable use.
Goal 15: Education and training increase skills and capacity to underpin sustainable livelihoods and to conserve natural resources and biodiversity, particularly in threatened environments.
Goal 16: Social learning is vital to facilitate and ensure participative, inclusive and just societies, as well as social coherence.
Goal 17: Lifelong learning builds capacity to understand and promote sustainable development policies and practices.

UNESCO (2016:8)

The link of education to other SDGs is what brings into play education for sustainable development. It redefines education and gives it a renewed purpose and relevance to human development in terms of economic, social and environmental sustainability (UNESCO, 2015). Thus, ESD can be described as education which:

> Empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning, and is an integral part of quality education. ESD is holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment. It achieves its purpose by transforming society (Lotz-Sistka et al., 2019:9).

To reiterate the important role of ESD Target 4.7 of SDG 4 specifically points out that all governments must:

> Ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development (UNESCO, 2015:8).

Education for Sustainable Development focuses on four pillars and these are; learning content, learning outcomes, pedagogy and learning environment as well as societal transformation (UNESCO,2012). The aspect of learning content looks at how critical issues of interest such as climate change, disaster and risk reduction, sustainable consumption and production can be integrated in the curriculum. On the other hand, learning outcomes focuses on the promotion of key competencies and skills such as critical thinking, systemic thinking collaboration and taking responsible actions for present and future generations. Pedagogy and the environment constitute a teaching/learning environment which is interactive and promotes active participation of learners in their own learning.

In order to promote societal transformation ESD equips learners of all kinds with the ability to transform their societies, develop skills for green jobs, embrace sustainable lifestyles and enable them become responsive to local needs. This helps learners to appreciate their context and make education meaningful (Mandikonza & Lotz-Sistka, 2016; UNESCO, 2012; UNESCO 2020). Simasiku (2020:33) explain that “appropriate teaching/learning methods and relevant sustainability learning content is necessary for contributing towards positive ESD learning outcomes amongst learners in classroom contexts”. To this effect, here is a detailed discussion of the four pillars of ESD.

2.2.1 Education for Sustainable Development Learning Content

According to Lotz-Sistka et al. (2019), ESD learning content requires the integration of critical issues such as climate change, biodiversity, disaster risk reduction, sustainable consumption and production into the curriculum. These issues have the economic, social and environmental implications which are the three pillars of SD. UNESCO (2012) also adds that ESD learning content is not obtained from one discipline but various disciplines can contribute to the inclusion of ESD content in curriculum.

2.2.2 Education for Sustainable Development Learning Outcomes

The ESD learning outcomes promotes learners’ development of necessary competencies and skills to contribute to sustainable development. This has been emphasised by UNESCO (2017:7) that

> Education for Sustainable Development aims at developing competencies that empower individuals to reflect on their own actions, taking into account their current and future social, cultural, economic and environmental impacts, from a local and a global perspective. Individuals should also be empowered to act in complex situations in a sustainable manner, which may require them to strike out in new directions

Competencies are a set of attributes a learner acquires as a result of an interaction among the knowledge, skills and values. Table 2.3 highlight eight key ESD competencies learners are expected to acquire.

Table 2.3: Key Competencies for Sustainability

SN	Competency	Description
1	Systems thinking competency	The abilities to recognize and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.
2	Anticipatory competency	The abilities to understand and evaluate multiple futures – possible, probable and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.
3	Normative competency:	The abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
4	Strategic competency	The abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield.
5	Collaboration competency	The abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.
6	Critical thinking competency	The ability to question norms, practices and opinions; to reflect on own one's values, perceptions and actions; and to take a position in the sustainability discourse
7	Self-awareness competency	The ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.
8	Integrated problem solving competency	The overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution options that promote sustainable development, integrating the above- mentioned competences.

(Rieckmann, 2012; UNESCO, 2017:10)

2.2.3 Education for Sustainable Development Pedagogies

Education for Sustainable Development pedagogies focuses on reorienting the teaching/learning practices from teacher centred to learner centred. This is achieved by enhancing participatory learning which is key for conceptual understanding. This negates rote learning and memorisation of concepts hence fostering curiosity, critical thinking and problem solving (UNESCO, 2012). It has been established that ESD pedagogies have been described using various terms which includes but not limited to:

> Deep learning, problem-based learning, transformational learning, experiential learning, active learning, action learning, participatory learning, applied learning, inquiry-based learning, critical pedagogy, service learning, and critical emancipatory pedagogy have all been included in pedagogical discussions about ESD Armstrong (2011:2-3) .

These pedagogical approaches advocated for in ESD are crucial in equipping learners with knowledge, skills and values necessary to contribute to SD through active engagement, social interaction and participatory learning. It also suffices to mention that ESD pedagogies were said to expansive in nature (Armstrong 2011; O'Flaherty & Liddy, 2018). Gibbs (2021) alludes that when learners are exposed to experiences that accord them an opportunity to develop the link between content and real-world issues they are motivated to make self-directed changes in their lives. This may imply that through ESD learners are well positioned to use knowledge and skills beyond the classroom. In other words it is apparent to note that contextualising pedagogy to learner's needs and their environment promotes sound learning. In the same vein, Ssosse, Wagner and Hopper (2021:4) points out that "ESD calls on the reflection of issues around rather than teaching correct answers". To this end ESD envisages pedagogies that encourage learners' actions in various environments and enable them understand the world through their own observations. This entails that the teaching and learning grounded in ESD promotes the integration of sustainability concerns which is a critical dimension of what counts as quality education as well as encourage a multidisciplinary approach to teaching in a quest to enhance the acquisition of knowledge, skills, values and attitudes. This is because it presents both opportunities and challenges for learners to engage in higher order thinking abilities (Bourn & Soysal, 2021; UNESCO, 2015).

Education for Sustainable Development also looks at the multidisciplinary teaching/learning pedagogy that promotes integration of knowledge from different disciplines. This helps learners to create a link between concepts from different disciplines related to the topic at hand. As a result learners are empowered to acquire systems thinking a critical competence of ESD (Eliam & Trop, 2010; Sund & Gericke, 2020). Additionally, these pedagogical practices play a crucial role in ensuring that learners appreciate learning in their own environment. Eilks (2015) holds a view that ESD reorients pedagogies to focus on learner centeredness, experiential learning, inquiry and skills-based learning.

2.2.4 Education for Sustainable Development Learning Environment

The learning environment fosters interaction and active participation of learners in their own learning. The ESD 2030 roadmap notes the importance of learning environment as requisite to effective implementation of education for sustainable development. Emphasis by UNESCO (2020:28) has been put on the need to encourage:

> Learners to become change agents who have the knowledge, means, willingness and courage to take transformative action for sustainable development, learning institutions need, themselves, to be transformed. The entire learning institution needs to be aligned with sustainable development principles, so that learning content and its pedagogies are reinforced by the way facilities are managed and how decisions are made within the institution. This whole-institution approach to ESD calls for learning environments where learners learn what they live and live what they learn.

It can be established from the above comment that an ESD learning environment transcends beyond the classroom to a whole institution and it is an important aspect of the what to learn (content) and how to learn (pedagogy).

2.3 Chemistry Education and Education for Sustainable Development

Education for Sustainable Development provides social scientific issue based approach to the teaching/learning of science. This is achieved by showing the link between industrial application and science content (Eilks, 2015). For instance, there are opportunities to apply the principles of sustainability to practical activities so as to help learners minimise the use of toxic substances. Encourage the use of improvised pieces of apparatus hence fostering creativity among learners. This expands the contribution of practical activities to learners learning by ensuring that they reflect on the link between chemistry and sustainable development for example. Alternatively, ESD fosters the use of low cost experiments, improvised equipment and alternative procedures (Eilks, 2015; Lozano & Watson, 2013). In this case, learners tend to appreciate the science behind every day processes and products

Tsakeni (2018) point out that chemistry education is an appropriate discipline to be used for ESD implementation because it provides context to the integration of ESD in science education. This view was also expressed earlier by Hopkinson and James (2010) in their study aimed at finding practical ways of embedding ESD in Science, Technology, Engineering and Mathematics (STEM) curricula. The study revealed that a number of STEM courses have introduced environmental and social issues through modifications of existing content or completely new courses. Additionally, they also stressed the important connection between the teaching activities of STEM subjects to the social and economic aspects of SD. This was emphasised as the proposed the use of "environmental aspects of students' day to day experience as STEM learners. Much of this experience takes place within laboratories, and there is a growing movement focusing on issues of sustainable laboratories" (Hopkinson & James, 2010:368)

The role of chemistry as medium through which ESD could be implemented cannot be over emphasised. Koulougliotis, Antonoglow and Salta (2021), carried out a study aimed at probing Greek secondary learner's awareness of green chemistry principles integrated in context-based projects related to socio-scientific issues. The study revealed that the integration of green chemistry grounded in ESD is an important step in raising awareness of social scientific issues among learners.

On the other hand, chemistry learners should be accorded an opportunity to relate the Chemistry content learnt in class to their real-life issues of environmental pollution for example. Burmeister et al. (2012) alludes that the learning of chemistry concepts and facts alone is not sufficient to equip learners with the knowledge, skills and attitudes needed to deal with current complex issues such as climate change, pollution, much needed energy and many more. In their comparative study, Sund and Gericke (2020) found that teachers focus on different aspects in their teaching. They tend to dwell more on classroom based teaching as well as the use of teacher-centred approach. This practice perpetuates the transfer of factual knowledge. This is a clear indication that teachers limit the opportunities accorded to learners to develop action competence through active engagement in the lessons.

Education for Sustainable Development demands for a more thorough approach towards the creation of networks between science and society. This is important and it was echoed by Murti and Hernani (2023:3, 4) that:

> Many products in our life are based on chemistry, chemical industry has great opportunities to focus on the environment, both in the manufacturing process and in the end product. Therefore, it has been asserted that chemistry learning should increase students' knowledge and ability to understand the role of chemistry in society, such as how chemistry can affect the future and contribute to a sustainable society.

This implies that chemistry education informed by ESD provides opportunities for learners to appreciate the economic, environmental and societal impact of chemistry (Tsakeni, 2018). There are various SD issues that relate to chemistry that need to be understood through ESD driven chemistry. For example, learners need to acquire knowledge and understanding on the chemical processes that underlie climate change. Similarly, the concept of ozone can be grasped properly from a well-established link between chemistry as a discipline and ESD. The economic issues intertwined in the chemical processes involved in mining, food production, production of every day to day necessities and alternative energy all relate to chemical knowledge (Burmeister et al., 2012; Jegstad &Sinnes, 2015). These issues highlighted also have social implications on the present and most likely on the future generations.

It is uncontested that chemistry as a science plays a critical role in the livelihoods of people. Burmeister, Schmidt-Jacob and Eilks (2013:170) established that "the production of innovative products, modern materials, sustainable energy supplies, medicines, and fertilizers. Simultaneously, chemistry is also related to great challenges concerning the protection and preservation of the environment". The statement made by the authors is call to re-orient chemistry education to promote the acquisition of chemical knowledge on one hand but also foster sustainable practices on the other. An ESD driven chemistry education is poised to help learners to attain values and attitudes towards promoting a more sustainable future. It is envisaged that learners will value and contribute to their local community decisions with regard to the on the applications of chemistry.

2.4 Chemistry teachers' knowledge of SD issues

In the context of chemistry education, integrating sustainability issues is key because chemistry and its processes contribute to environmental challenges as well as solutions. Teachers' knowledge and understanding of sustainable development issues play a crucial role in how effectively chemistry concepts are taught, linked to real world issues and provide opportunities for learners to acquire problem solving skills. Thus, Jegstad and Sinnes (2015) contemplate if at all the way science is currently taught in secondary schools empowers leaners with knowledge, skills and attitudes to needed to participate in and contribute to sustainable development. Shumba and Kampamba (2013) points out that a chemistry teacher is expected to show understanding of the link between science content and societal issues. It is important to note that knowledge on sustainable development is multidimensional in nature. As a result the conceptualisation of this knowledge requires an understanding of the basic knowledge components in the three dimensions of sustainable development.

Burmeister et al. (2013) conducted a case interview study in German on chemistry teachers' understanding of sustainability and education for sustainable development. The findings of the study highlighted that teachers were able to highlight sustainable development issues or problems nested in the environmental domain but had challenges addressing issues in the economic and social aspects. They also found that most teachers did not have a theoretical underpinned understanding of pedagogies that can be used to implement ESD in chemistry teaching. Further, they suggested that specific pedagogical content knowledge is needed, because the topics and objectives of ESD driven chemistry differs from traditional teaching practices. This is an indication that despite the important role of chemistry in ESD implementation, teachers are yet to be well equipped with appropriate pedagogical tools. Habibi and Ahmadi (2023) however, observe that the scope of teachers' knowledge of sustainability issues in chemistry education may vary from teacher to teacher and across different educational contexts.

Teachers have a responsibility to create a link between chemistry concepts and their social, environmental and economic implications. They should be able to assess how chemistry impacts various disciplines. This view is also shared by Jegstad and Sinnes (2015:3) who emphasises that "all chemistry teachers should be able to include the ecological, economic and social perspectives of the chemical topics they teach". However, it suffices to mention that sustainability issues are multidisciplinary in nature henceforth; one teacher might not consider all aspects of sustainability issues related to a chemistry concept. But he/she should be able to collaborate with teachers of other subjects.

It is important to note that teachers' awareness of sustainability issues presents an opportunity for them to build capacity, promote critical thinking and problem solving among learners. This is paramount in equipping them with knowledge to raise critical questions as well as find solutions to societal and local pressing issues (Shidiq et al., 2020). Quiroz-Martinez (2024) carried out a study entitled chemistry teachers' perspectives and understanding in integrating sustainability into teaching a case of Chile. The study was aimed at finding out how Chilean chemistry teachers understand sustainability and its integration into teaching chemistry. Data was collected qualitatively using In-depth interviews with ten chemistry teachers. The findings of the study revealed all the ten teachers claimed to be unsure about what sustainability was. Although they recognised the importance of integrating sustainability into education, most confirmed they needed more knowledge. Nevertheless when they attempted to explain sustainability their focus was more on using resources and environmental protection. Additionally, their understanding of ESD in the context of chemistry was tailored to help learners develop skills and attitudes for living responsibly in society.

2.5 Chemistry Curriculum and Sustainability Issues

Chemistry as a discipline has a significant role in sustainability to shape the current and future generations to live sustainably (Murti & Hernani, 2023). It is therefore, essential to appreciate the presence of ESD in the Chemistry curriculum. Burmeister et al. (2012: 63) contend that

> Adding sustainable development issues to the chemistry curriculum is not a new idea by any stretch of the imagination. For the last two to three decades, many pupils around the world have been faced in chemistry education with issues such as keeping water resources clean, dealing with the effects of acid rain, coping with the hole in the ozone layer and searching for both renewable sources of energy and materials.

In the Zambian context, Shumba and Kampamba (2013) conducted a case study on ESD pedagogical content knowledge and learning as connection. The focus of this study was mainstreaming of ESD into science education. The findings of the study revealed that there is some presence of ESD issues in the secondary school chemistry syllabus but no clear guidance has been provided on the teaching/learning approaches. These findings seem to be similar to the findings by Lozano and Watson (2013) who pointed out that, educators should consider re-orienting the chemistry curriculum in order to make it more sustainability driven for it is critical to helping societies become more sustainable. To this effect the findings seem to suggest that there is need to re-orient and adapt the content in the curriculum to make chemistry teaching reflect social scientific issues. More so a chemistry teacher is also expected to show an understanding of the connection between chemistry content and societal issues as he/she implements the curriculum.

Tsakeni (2018) analysed the opportunities to integrate ESD presented by the chemistry component of the Curriculum and Assessment Policy Statement (CAPS) for physical sciences in South Africa. A document analysis of the curriculum was done using an interpretive design. The findings of the study revealed that the transformative nature of the general aims of the South African National Curriculum Statement is sympathetic to the inclusion of ESD. Additionally, the contemporary environmental issues contained in the chemistry component of the syllabus present opportunities for integrating the social, citizen skills, pedagogical and to a lesser extent, economic pillars of sustainable development into teaching and learning. One salient opportunity to promote ESD integrates the environmental and pedagogical pillars of sustainable development education through the application of green chemistry principles in practical work. This aspect was also emphasised by Murti and Hernani (2023) that it was possible to attain the integration of ESD in chemistry through learning activities and materials.

There are a number of ways that could be used to integrate ESD in chemistry education. The most notable in literature are the four models of how sustainability issues can be applied in chemistry education proposed by Burmeister et al. (2012). These models include; adopting green chemistry principles and apply them to science education practical work; adding SD issues in chemistry curriculum; using controversial sustainability issues for social scientific issues that drive chemistry education and fourthly, making chemistry education a part of ESD-driven school development. Here is a detailed discussion of these models:

i. Adopting green chemistry principles and apply them to practical work

This model focus on the importance of incorporating green chemistry principles in practical work to enhance proper handling of chemicals by learners, use of environmental friendly or less toxic substances and promote efficient use of energy during practical work. There are 12 principles of green chemistry that have been proposed by Anastas and Warner (1998) highlighted in Table 2.4 which could be included in ESD driven chemistry practical activities.

Table 2.4: The 12 Principles of green chemistry

SN	Principle	Description
1	Prevention	It is better to prevent waste than to treat or clean up waste after it is formed.
2	Atom Economy	Synthetic methods should be designed to maximise the incorporation of all materials used in the process into the final product.
3	Less Hazardous Chemical Synthesis	Wherever practicable, synthetic routes should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4	Designing Safer Chemicals	Chemical products should be designed to preserve efficacy of the function while reducing toxicity.
5	Safer Solvents and Auxiliaries	The use of safer solvents and auxiliaries (e.g. separation agents) is the last resort, if it is not possible to avoid them, since these substances are not incorporated into the final products and become part of the waste.
6	Design for Energy Efficiency	Energy requirements of chemical processes should be minimised. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7	Use of Renewable Feed stocks	A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable
8	Reduce Derivatives	Many chemical syntheses follow a multi-step route which leads to sequential chemical transformations (known as derivatisation) that require additional reagents and can thus generate waste. Unnecessary derivatisation should be minimised or avoided if possible.
9	Catalysis	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10	Design for Degradation	The synthesis of chemical products, which after their use, they break down into innocuous degradation products which do not persist in the environment, is required.
11	Real-Time Analysis for Pollution.	Prevention Redesigning methods of analytical chemistry by giving emphasis to real time analysis will lead to minimisation of negative environmental effects by optimising the use of raw materials while minimising the formation of hazardous substances and waste
12	Inherently Safer Chemistry for Accident Prevention	Inherently safer chemistry for accident prevention requires use of less hazardous substances in a chemical process in order to minimise the possibility of chemical accidents including releases, explosions and fires.

Adapted from Koulougliotis et al. (2021:299)

These principles speak to the kind of chemistry that is grounded and informed by ESD. Burmeister, Schmidt-Jacob and Eilks (2013:170) provide guidelines that can guide the integration of green chemistry into learners' practical work. They point out the need to "apply chemical processes that are connected to producing less waste, using smaller amounts of substances (micro scale chemistry), to operate energy efficient procedures, or to replace poisonous and dangerous substances by less harmful alternatives". This underscores the role of chemistry education in enhancing environmental sustainability.

ii. Adding SD issues in chemistry curriculum

In this case the chemical principles behind sustainable development issues are integrated in the chemistry curriculum (Burmeister et al., 2012). Issues like pollution, climate change with a focus on ozone layer depletion and energy related issues can be included in the curriculum. The focus of this this model is to show the importance of chemistry with regard to SD issues as well as help learners to acquire the knowledge about the chemical principles through the curriculum. It is also an opportunity to show the industrial applications of chemistry to produce our day to day products such as soaps, food, cleaning materials and also show the industrial chemistry processes in sectors such as energy and mining (Tsakeni, 2018; Koulougliotis et al., 2021).

iii. Using controversial sustainability issues for social scientific issues in chemistry education

The use of social scientific issues as part of chemistry teaching anchored on using these issues to go beyond the classroom based teaching/learning. Instead, lessons tend to mould sustainable development by fostering necessary skills that learners need to take actions as responsible members of society and solve societal problems (Burmeister et al., 2012; Eilks, 2015). The applicability of this model is unique in its own right in the sense that it includes both the chemical basis of knowledge and an opportunity to help learners reflect on the social discourse around social sustainability issues. It appreciates the practical application of technology, the social implications of industries such as mining as issues that should be learned and explored further. Eilks (2015:17) emphasises that "science education no longer needs to stop at the point where teaching is limited to describing the science and technology theories and knowledge behind sustainability issues and potential avenues of action". As a matter of importance the developmental impact of chemistry is interrogated and assessed in society through social sustainability issues (Juntunen &Aksela, 2014).

iv. Making chemistry education a part of ESD-driven school development

The fourth model is whole institution approach to the integration of ESD with chemistry education. It promotes the inclusion of ESD practices in the day to day activities of schools. The model suggests that school life and teaching should become part of ESD. Educating learners to become active citizens who have the ability to achieve sustainable lifestyles requires an entire school or institution to be involved (Eilks, 2015). There are a number of opportunities that can be used to open chemistry teaching SD issues to develop agents of change, promote collaboration and partnerships.

The aspect of adding SD issues to the curriculum shades more light on certain concepts such as fuels, acids, materials and energy for example that are already part of the curriculum though in an implicit manner. Shadiq (2020) argues that the realisation of ESD in chemistry lessons may not necessarily require specific problems of chemical sustainability. This implies that ESD can be achieved in the curriculum without adding more content but by repackaging what is already correctly.

In contrast, Habibi (2023) conducted a comparative study on sustainability education in the secondary school chemistry curriculum in selected countries. The study focused on the themes of the curriculum such as objectives; content; teaching/learning methods and evaluation methods. The findings of the study revealed that there were similarities among the countries with regards to objective of chemistry education while the differences were noted on content and teaching/learning methods. Further, it was also observed that each country placed priority on the objectives of chemistry education for sustainability according to “basic laws, facilities, national needs and cultural expectations of society” (Habibi, 2023: 2,261). There is need to highlight that the salient goals of SD are hardly present in the Chemistry curriculum because there is no balance between knowledge, skills and attitudes (Jegstad & Sinnes, 2015; Murti & Hernani, 2023).

2.6 Transforming Chemistry Pedagogies through ESD

There are a number of ESD pedagogies that have been highlighted in literature, which includes: active participation learning; multidisciplinary learning; hands-on; collaboration; experiential learning, problem based learning and many more (Armstrong, 2011; Eliam & Trop, 2010; UNESCO, 2012). These pedagogies provide a framework of how chemistry concepts can be taught to promote lifelong learning which is a fundamental principle of ESD. Yamazumi (2006) conducted a study aimed at establishing the relationship between the activity theory and the transformation of pedagogic practice through ESD. The study revealed that through collaboration participants were motivated and actively engaged in various activities that shaped and promoted collaborative learning ultimately fostering their own development. This implies that learning was transformed from individual learners to a group of learners through collaboration. Education for sustainable development pedagogies is said to create:

> Interactive, learner-centred teaching and learning settings. What ESD requires is a shift from teaching to learning. It asks for an action-oriented, transformative pedagogy, which supports self-directed learning, participation and collaboration, problem-orientation, inter- and trans-disciplinarity and the linking of formal and informal learning. Only such pedagogical approaches make possible the development of the key competencies needed for promoting sustainable development (UNESCO, 2017:7).

These pedagogies when applied to chemistry teaching have the potential to promote active participation of learners in their own learning and foster conceptual understanding. It has already been established that chemistry is critical to sustainable development in the sense that chemical processes underlies numerous disciplines. Therefore, grounding the teaching in ESD promotes contextual learning. Juntunen and Aksela (2014:5) suggest that:

> Chemistry teaching with ESD includes new kinds of activities that teach chemistry in context-based social environments - activities that teach students to act for nature based on their own ideas and

experiences. Projects integrated into the subject of chemistry offer learners' opportunities to develop informed personal competencies

The above comment illustrates how chemistry teaching informed by ESD can be transformed in terms of the way content is taught, how the teacher facilitates learning, the examples given and analogies used. The focus is to promote lifelong learning, critical thinking, problem solving, multidisciplinary learning, collaboration and networking.

It is apparent that most of the studies reviewed have appreciated the fact that ESD is critical in making the teaching/learning of chemistry more relevant to the learners and society. They have also acknowledged the critical contribution of chemistry to sustainable development and the importance of the presence of sustainability issues in the curriculum. However, they have not provided guidance on how chemistry pedagogies can be transformed based on the principles of ESD. Additionally, most of the methodologies have dwelled largely on the interviews and focus group discussions with participants. This is a methodological gap because it points mostly to self-report. Therefore, this study proposes to use mixed methods in order to provide additional focus to the discourse on ESD and secondary school chemistry teaching.

Secondly, the studies have indicated that ESD pedagogies are multidisciplinary and context based. But there is also an indication that teachers seem not to have a theoretical underpinned understanding of the pedagogies to use to implement ESD in chemistry teaching. Similarly, there might be no clear guidance provided to the chemistry teachers on how to go about using ESD informed pedagogies. This presents an opportunity for the adaptation of the chemistry pedagogies by grounding them in ESD and expansive learning principles.

2.7 Summary

This chapter looked at ESD and how it has evolved over time and taken a centre as the kind of education critical to sustainable development. It is also clear from the literature that ESD is regarded as pertinent to the achievement of other sustainable development goals in addition to SDG 4 on quality education. Secondly, the literature on pedagogies advocated for in ESD was reviewed.

This clearly, indicated that scholars emphasises the importance of active participation, multidisciplinary learning and experiential learning to mention only a few as some of the pedagogies akin to ESD.

The review of various studies has also showed that Chemistry education as a discipline provides an avenue through which ESD can be achieved. This is said to be achieved by integrating SD related content in the curriculum or simply presenting already available content. Moreover, there is a clarion call from literature to clearly have sustainability issues explicitly present in the Chemistry curriculum. However, there seems to be not so much emphasis on how Chemistry teachers can be guided so that they are able to present their lessons in a manner that promotes the acquisition of knowledge, skills and attitudes needed to participate in and contribute to SD.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

The chapter presents the research methodology. It describes the philosophical underpinning as well as the approach that guided the study. It explains the research design; the sampling procedures used to select the sample and the various data collection instruments used to collect data. It also highlights the target population, study site, the data collection process and how data was analysed. The chapter concludes by discussing ethical considerations, trustworthiness, reliability and validity.

3.2 Philosophical Underpinning of the Study

The study was underpinned by the philosophy of pragmatism. This philosophy holds that there are various ways of interpreting the world and conducting research. Therefore, there are multiple realities and no single view can give an entire picture (Saunders, Lewis &Thornhill, 2012). The emphasis is placed on the research problem as such a researcher can utilise a number of approaches available to understand and interpret the problem. In this case, multiple views provided an opportunity for the researcher to adequately answer the research questions. It is also important to mention that, the researcher was informed by the assumptions that both observable phenomena and subjective meanings can provide knowledge dependant on the research questions. Hence, the integration of various views to better interpret data and answer research questions. It is also significant to note that the researcher used both objective and subjective ontological lenses to answer the research questions. Further, it is highlighted by Creswell (2014:39) that:

> Pragmatism is not committed to any one system of philosophy and reality. This applies to mixed methods research in that inquirers draw liberally from both quantitative and qualitative assumptions when they engage in their research. Individual researchers have a freedom of choice. In this way, researchers are free to choose the methods, techniques, and procedures of research that best meet their needs and purposes.

Therefore, this implies that the philosophy of pragmatism underpins mixed methods approach in the sense that it advocates for researchers to use multiple methods, incorporate diverse assumptions, as well as various data collection and analysis methods. Henceforth, the philosophy of pragmatism informed the approach employed in this study, the study design as well as the data collection procedures.

3.3 Research Approach

The study used a mixed methods research approach. Mixed methods research blends quantitative and qualitative research methods in various ways, with each approach contributing something to the understanding of the research problem (Ary, Jacobs & Sorensen, 2010; Creswell, 2014). Though there are a number of reasons for using mixed methods research, the researcher utilised this approach in order to get diverse data; use the quantitate approach to inform the development of the qualitative component as well triangulation of data to enhance corroboration of findings (Saunders et al., 2012).

It is also important to appreciate that the integration of both quantitative and qualitative approaches in a single study may lead to findings that are dependable in providing an exhaustive explanation of the problem. This is the case because data can be corroborated and triangulated at various stages of the study (Ary et al., 2010). A further, mixed method has a unique strength of leveraging the strength of one approach to counter the weaknesses of either quantitative or qualitative in a single study. Despite the strengths highlighted the mixed method approach may be tedious for a single researcher to conduct because it calls for one to have adequate set of skills in both quantitative and qualitative approaches which may not always be the case (Creswell &Plano, 2007; Ary et al., 2010; Saunder et al., 2012). Based on the reasons put forward, it suffices to indicate that mixed method approach was suitable for this study. This was the case because the researcher was concerned with assessing chemistry teachers' knowledge of sustainability issues and how that knowledge translated or influenced their pedagogical choices.

3.4 Research Design

Saunders et al. (2012) describe a research design as a general plan of how the researcher intends to answer the research question. Similarly, Cohen, Manion and Morrison (2007) allude that the choice of a research design is dependent on the purpose of the study. The purpose of the study was to develop a chemistry teaching model anchored on the principles of education for sustainable development. Therefore, in this study a sequential explanatory design was used, in order to connect the quantitative and qualitative data sequentially. The sequential explanatory design has been described as follows:

> It involves a two-phase project in which the researcher collects quantitative data in the first phase, analyses the results, and then uses the results to plan (or build on to) the second, qualitative phase. The quantitative results typically inform the types of participants to be purposefully selected for the qualitative phase and the types of questions that will be asked of the participants. The overall intent of this design is to have the qualitative data help explain in more detail the initial quantitative results (Creswell, 2014:274).

Therefore, the quantitative data provided base-line information on the overall chemistry teachers' understanding of sustainability issues and their appreciation of education as a driver of sustainable development. The results of the initial phase informed the qualitative methods in the subsequent stages in two ways. Firstly, it provided information needed for the purposeful selection of chemistry teachers to take part in the qualitative phase that is the lesson observation, focus group discussion and interviews. Secondly, the findings provided insights and guidance on the preparation and sharpening of the focus group discussion and semi-structured interview questions. On the other hand qualitative data was also used to explore how ESD can be used to transform pedagogies for teaching secondary school chemistry. These aspects were deemed important in attaining the purpose of the study.

The other reason for using sequential design was to collect diverse types of data, triangulate and attain a better understanding of the research problem at hand (Ary et al., 2010; Creswell & Plano, 2011; Creswell, 2014). However, the study was predominantly qualitative as shown in Figure 3:

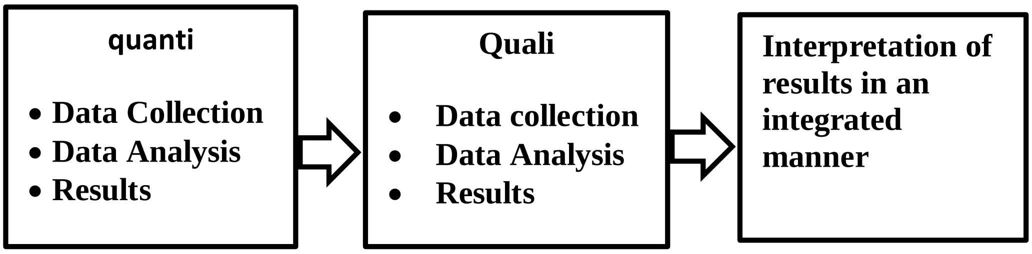

Figure 3: Diagrammatical Representation of Sequential Design

3.5 Study Site

The study was conducted in Ndola district of Copperbelt Province of Zambia. The district is located about 320 kilometres north of Lusaka. The district was chosen as a study site because it has about 23 secondary schools and 13 combined schools. Thus, owing to the number of schools it was assumed that the district would have a large number of Chemistry teachers.

3.6 Study Population

The study targeted chemistry teachers in Ndola district teaching either pure Chemistry (5070) or Science (a combination of chemistry and physics 5124) at senior secondary school level.

3.7 Study Sample

The study sample comprised Chemistry teachers drawn from selected secondary schools teaching pure chemistry and science in Ndola district. The sample size was 79 at 95 per cent confidence level. This was arrived at after the researcher was preview to the population (100) of chemistry teachers in the district as obtained from the office of the District Education Board Secretary (DEBS). This is supported by literature that has determined and provided guidance on the different minimum sample sizes required for different sizes of the population (Cohen et al., 2007). Further, the process of sample size determination is said to be guided by some of the following principles highlighted by Saunders et al. (2012:265).

- The confidence you need to have in your data that is the level of certainty that the characteristics of the data collected will represent the characteristics of the total population.
- The margin of error you can tolerate that is the accuracy you require for any estimates made from your sample.
- The size of the population from which your sample is been drawn

Owing to the principles guiding the determination of sample size alluded to above, a sample size of 79 chemistry teachers out of 100 was deemed appropriate and representative of the total population. The study was conducted in 15 secondary schools of which, 12 were government secondary schools while three were grant aided. It is also important to highlight that 14 of these schools were co-education schools while one was a single-sex school.

3.8 Sampling Techniques

The study used cluster sampling technique in selecting the teachers. Geographical parameters were used as the clustering criteria. The researcher used a list of clusters for secondary schools obtained from DEBS office as a sampling frame. Based on the information obtained from DEBS office, it suffices to mention that Ndola district has a total of four clusters of secondary schools. Cluster one has a total of six schools out of which four are government schools while two are grant aided schools. Similarly, cluster two has a total number of seven schools broken down as; five government schools and two grant aided schools. On the other hand, cluster three has five schools, three government schools and two grant aided schools. The fourth cluster equally has five schools, composed of four government schools and one grant aided school.

Thereafter, each of the school in the four clusters was labelled uniquely and picked randomly. Then all the chemistry teachers from the selected secondary schools in the clusters were included in the sample. The number of schools included in the study per cluster was as follows; five schools each from cluster one and two. While three schools were selected from cluster three and two schools from cluster four. The number of teachers who participated in the study from each cluster is indicated in Table 3.1

Table 3.1: Selection of chemistry teachers from clusters

Name of Cluster	Number of teachers
One	30
Two	20
Three	18
Four	11

The advantage of using cluster sampling is that a group of individuals who are naturally together is chosen rather than individuals (Ary et al., 2010; Saunders et al., 2012). However, selecting a sample of participants who are clustered or grouped may decrease the representativeness of the sample.

On the other hand, purposive sampling technique was used to select teachers for lesson observations, interview and focus group discussion. It is envisaged that in purposive sampling, sample units do possess certain characteristics that may enhance a detailed exploration of the problem under study (Ritchie & Lewis, 2003). Similarly, Patton (2002:46) points out that "the logic and power of purposeful sampling derive from the emphasis on in-depth understanding. This leads to selecting information-rich cases for study in depth which can lead one to learn a great deal about issues of central importance to the purpose of research". Thus, the selection of the teachers was informed by the results obtained using a questionnaire (Assessment of Sustainability Knowledge tool). Those teachers who had exhibited more knowledge (average or above average) on ESD issues were chosen for lesson observation, interview and focus group discussion as they were regarded as being information rich.

3.9 Research Instruments

The study used a number of data collection instruments which included; an adapted Assessment of Sustainability Knowledge (ASK) tool by Zwickle and Jones (2018); Observation schedule; Interview schedule; Focus group discussion schedule and Document analysis schedule to collect data.

3.9.1 Assessment of Sustainability Knowledge (ASK) Tool

The study adopted, adapted and used an ASK tool developed by Zwickle and Jones (2018), to assess Chemistry teachers' knowledge of sustainability issues. This tool consisted of 15 multiple choice questions which captured the three components of sustainable development (Appendix A). Modifications were done to questions 7; 10; 11; 12 and 15 as indicated in Table 3.2 so as to depict a Zambian or rather local scenario.

This made the questions easy to comprehend by the participants. Question 7 looked at the depletion of fish stocks in Lake Bangweulu; while questions 10 and 11 highlighted the issues to do with fuel and electricity prices. On the other hand, question 3 focused on the difference between the wealth of the richest and poorest Zambians; then question 15 looked at the management of waste from the mining industries. It is key to mention that the 15 questions were characterised by a unique correct answer each as well an option "Don't know". This was in order to discourage guessing and allow participants to indicate this option if they did not know the correct answer.

Table 3.2: Contextualisation of some questions in the ASK tool

SN	Original Question	Modified Question
7	Which of the following is a leading cause of fish stocks depletion in the Atlantic Ocean?	Which of the following is a leading cause of fish stocks depletion in Lake Bangweulu?
10	Which of the following is the primary reason that gasoline prices have risen over the last several decades in the US?	Which of the following is the primary reason that fuel prices have risen in the last several decades in Zambia?
11	Many economists in the US argue that electricity prices in the US are too low because…?	Many economists in Zambia argue that electricity prices are too low because…?
12	Over the past 3 decades, what has happened to the difference between the wealth of the richest and poorest American?	Over the past 30 years what has happened to the difference between the wealth of the richest and poorest Zambians?
15	In the US, what do we currently do with the nuclear waste generated by nuclear power plants?	In Zambia, what do we do with the waste generated from the mining industries?

3.9.2 Semi-structured Interview Schedule

The interview schedule (Appendix B) comprised eleven open ended questions and it was developed by the researcher. The instrument was intended for chemistry teachers who took part in the lesson observation. The first part of the schedule was used to explore further teachers' understanding of the concept of sustainable development and education for sustainable development in relation to secondary school chemistry. The set of questions in the second part focused on teachers' choice of learning activities and classroom practices as they present topics linked to sustainable development. On the other hand, the instrument provided an opportunity to further follow up on teacher's pedagogies their classroom actions as well learn from them what stakeholders they could bring on board in a quest to effectively teach chemistry topics related to sustainable development.

3.9.3 Focus Group Discussion Schedule

The instrument (Appendix C) had three thematic areas, whose focus was to get different perspectives on the pedagogies used by chemistry teachers to teach topics related to ESD. The first theme questions were tailored to discuss the various methods teachers used in their lessons. Then the second theme questions stimulated a discussion on how the methods used enhanced learners knowledge, skills and attitudes to participate in solving various sustainable development challenges. The third theme stirred the discussion towards how these methods contributed to lifelong learning; holistic learning; integrated and transformative learning. Therefore, the schedule guided the researcher to conduct an interactive but focused discussion with the participants. The schedule was developed by the researcher

3.9.4 Document Analysis Schedule

A number of documents were analysed to help the researcher ascertain the chemistry curriculum's incorporation of sustainability issues. In order to gain the needed insight, the pure chemistry (5070), the chemistry component of Science (5124) and chemistry schemes of work (Grade 10-12) were analysed using this schedule (Appendix D). The schedule had three structural components and these were; name of document; descriptors and score (ranging from 0-4). This instrument helped the researcher to interrogate the outcomes of the syllabi as well as identify and locate the topics that are related to sustainable development in the syllabi. Additionally, the schedule helped the researcher to establish whether or not the outcome/objectives of the syllabi did point to sustainable development.

On the other hand, the schemes of work were analysed to check the repackaging and presentation of specific topics related to sustainable development. The focus was placed on planned for teaching/learning methods; teaching/learning activities as well as teaching/learning resources in the scheme of work. The scheme of work was picked as opposed to lesson plan or record of work because it provided unique details that the researcher needed to fully capture the integration of sustainable development issues in the curriculum. The schedule looked at how the topics linked to sustainable development were repackaged from the syllabi. The instrument was developed by the researcher and the process was guided by the pure chemistry and science syllabi.

3.9.5 Observation Schedule

This instrument was designed by the researcher and it sought to address objective number three. The focus was to capture the reflection of Education for Sustainable Development in the pedagogies used to teach Chemistry (Appendix E). The schedule was made up of two parts: the first part was intended for the teacher to indicate their identification code, class being taught and topic. The second part consisted of six thematic areas from which various questions were asked. These include the following:

- Teaching approaches used by the teacher
- Teaching Strategies
- Linking of topics to real life and current issues
- Linking of lesson/topic to other disciplines
- Facilitation of classroom learning activities

Henceforth, the observation schedule provided a guide on certain aspects of the lesson that were needed to be focused on. The schedule was used to observe lessons on specific topics in the curriculum that were identified to be linked to sustainable development.

3.10 Validation of Instruments

The researcher sought permission to use the ASK tool from the developers Zwickle and Jones (2018) through the Environmental and Social Sustainability Lab (ESS lab) of Ohio State University. Permission was granted, this was coupled with an explanation of what was done to assure the validity and reliability of the tool. It was tried and tested by the developers using an Item

Response Theory (IRT) analysis, hence it was regarded to be valid and reliable by the researcher. On the other hand, the researcher determined the inter-ratter reliability of the ratings of the document analysis instrument. The researcher performed the document analysis of the chemistry syllabi then invited two colleagues to analyse the chemistry syllabi using the same instrument, thereafter the ratings were compared or correlated. The ratings correlated, which implied that the instrument was reliable and used as it was.

Interview, Observation and Focus group discussion schedules were subjected to peer and expert review in order to sharpen their focus. Once these instruments were developed, they were presented to peers and lecturers during post graduate weekly seminars for the department of Mathematics and Science Education at the University of Zambia. Their critique of each question was key in improving the focus of these instruments, thereafter the instruments were again given to supervisors who are experts in the field to review the questions. Therefore, the researcher was satisfied with the steps taken as part of the validation process to validate these instruments. Over and above that the triangulation of multiple sources of data in the interpretation of findings helped to build a coherent understanding of the problem at hand. This process assured the validity and trustworthiness of the findings.

3.11 Data Collection

The data collection process was preceded by the submission of the study proposal for ethical clearance. The study was cleared and permission to proceed with the data collection was granted by the ethics committee of the University of Zambia. Additionally, in order to gain access to the district, the researcher sought permission from the office of the DEBS. Thereafter, an introductory letter was given to the researcher introducing her to the school Head teachers before gaining access to the participants. Upon the presentation of an introductory letter from DEBS to the head teachers, the researcher was introduced to the Science Heads of Department (HODs). The HODs in turn introduced the researcher to the participants in their respective departments. After which, consent was obtained from participants before participating in the study. The purpose of the study was clearly stated and participants were informed that they may withdraw from the study at any point if they so wished.

The Data Collection Process commenced in January, 2023 in the first term of the School Calendar. An adapted ASK tool capturing the three dimensions of SD (i.e. environmental, social and economic) was administered to all the 79 chemistry teachers in the selected schools. The researcher distributed the questionnaire to the teachers according to the clusters. The teachers were given five days to complete these questionnaires and thereafter the researcher went round to collect the completed questionnaires. It suffices to note that there are a number of benefits of using a questionnaire, these include:

- Participants have an opportunity to respond to the same set of questions
- It is usually a quick and efficient way of collecting data from a large sample of respondents because it is economical in terms of time.

In contrast, some of the weaknesses associated with using a questionnaire have been pointed out in literature such as: merely presenting a single chance to collect data; lack of opportunity for the researcher to probe or go back to the field to collect additional information due to standardised questions (Cohen et al., 2007; Saunders et al., 2012).

Secondly, document analysis of the Pure Chemistry (5070), Science (5124) syllabi and scheme of work were done. Documents provide key information that cannot be obtained using other means (Patton, 2002). This was done in order to identify the outcomes of the syllabi that and chemistry topics that speak to sustainable development as well as how these topics were repackaged in the schemes of work. The scheme of work was analysed to checking for frequency and variation of teaching/learning methods that are likely to promote experiential and participatory learning.

Thirdly, lesson observations were conducted using an observation schedule as a guide which helped to take notes of subtle classroom actions during the lessons. One of the strengths of observation is that it provides the researcher with an opportunity to get a clear description of behaviour in a specific setting (Ary et al., 2010; Patton, 2002). As such the researcher assumed the role of observer-as-participant. This was the case because the identity of the researcher was revealed and the purpose of the study explained. However, this aspect may have observer effect on the participants in the sense that the presence of the observer may cause them to act in a way that is varying with their natural behaviour. A total of twelve lessons were observed on the topics; Extraction of Metals, Acids, Bases and Salts, Chemical Reactions and Organic Chemistry. Each of the six teachers who participated in lesson observation was observed twice in an eighty minutes' lesson. The number of observation was determined by the fact that teachers were at different stages of syllabi implementation for the topics of interest.

It is important to mention that teachers who were observed also participated in a one on one interview. The one on one interview was conducted gain insight and follow up on some of the classroom actions and decisions observed. Immediately after lesson observation the participant arranged for a quiet space, mostly the office of the head of department or chemistry laboratory. The researcher sought permission to record the interview and encouraged the participant to freely share their views. The interview schedule was used as a guide and the interview lasted for an hour.

The focus group discussion with chemistry teachers was the last activity to be conducted this was significant in order to triangulate with data obtained from lesson observation. The participants (12) were invited to the district resource centre for the discussion. Two focus groups were formed each consisting of six teachers, this was in order to maximise the contributions of every participant during the discussion. The discussion provided a platform for teachers to share various perspectives on the methods they used to teach Chemistry as well as their understanding of ESD. Saunders et al (2012:400) describe a focus group discussion as "a group interview where the topic is clearly and precisely defined". The weakness of focus group discussion is that data may be challenging to analyse concisely due to the diverse views of the participants. Equally group dynamics can possibly lead to limited contribution of views by some participants and dominance by out spoken participants (Cohen et al., 2007). Thus, the discussion was regulated by the researcher, who ensured that each and every participant had an equal opportunity and chance to air their views and contribute to the discussion. The discussion lasted for two hours each and it was audio recorded with permission from the participants. Audio recording of the discussion was fundamental in the sense that it accorded the researcher an opportunity to carefully listen and review the discussion later.

The observation, document analysis, interviews and focus group discussion were key in establishing how pedagogies used to teach chemistry reflect ESD principles and how responsive the curriculum is to sustainable issues. Taking into account ethical issues, the participants were identified using codes (initials from the name of the school and numbers) throughout the data collection process. For example, TE1 implies that TE is the name of the school and the participant was the first to receive the questionnaire at that school during distribution. The same codes were used to identify those observed and interviewed. On the other hand, those involved in the focus group discussion were simply identified using numbers (Teacher 1 to 12).

3.12 Data analysis

The quantitative data from the ASK tool was analysed using descriptive and statistics into frequency tables and percentages that were generated in SPSS. Additionally, Kolmogorov-Smirnov and Kruskal-Wallis tests were performed using SPSS version 27.0. While the qualitative data from observations, focus group discussions, interviews and document analysis was analysed using template analysis. Saunders et al. (2012:572) describe a template as "a list of the codes or categories that represent the themes revealed from the data that have been collected". Thus, this mode of analysis uses both deductive and inductive reasoning in the analysis process. It is for this reason that the researcher used both inductive and deductive reasoning to analyse the qualitative data. Deductive reasoning in the sense that the theoretical framework in which the study was grounded provided propositions that guided the predetermining of codes on the template in the analysis process. On the other hand, these codes were amended and revised continuously as data was collected entailing an inductive approach. Predetermining of codes based on the theoretical propositions, research objectives as well as main questions of the data collection tools was essential in generating the themes. The template was flexible to allow for codes to be amended and revised as the data collection and analysis processes progressed. Thereafter, the data was read repeatedly to get the general impression and later organised into categories according to the template. These categories were explored to establish connections, patterns, relationships and themes.

3.13 Model Development Procedure

The model development process followed a generic procedure. The educational problem was identified with emphasis on ESD driven pedagogies to improve the teaching/learning secondary school Chemistry as indicated in the problem statement. Relevant literature was reviewed to shed more light on the problem, positioned the study in a large body of knowledge and pedagogical practices. The literature review also brought to fore the contribution of chemistry as a discipline to sustainable development. Additionally, the role of chemistry in various sectors of development such as Medicine, Agriculture, Mining, Manufacturing and Energy did give impetus and direction to the model development process. The literature review and tenets of the theoretical framework of expansive learning guided the model development. The key ideas of expansive learning there identified as ideal in grounding the model were; the multidisciplinary learning; learning as boundary crossing ; experiential learning and promoting agency among learners.

Data was collected from multiple sources as indicated in 3.9 and this provided primary information for the model. An evaluation of the model was done to check its feasibility how it might contribute to the improvement of existing pedagogical practices in secondary chemistry. The researcher printed copies of the model and went back to the field and distributed to the teachers. The teachers were given sufficient time to study the model thereafter had a one on one discussion with the researcher over the practicability of the model as teaching tool for specific topics linked to education for sustainable development. The model was interrogated by the teachers who earlier participated in lesson observation and focus group discussion.

3.14 Ethical Considerations

Ethical consideration is a key aspect of the research process. This is because the data collection process is dependent on gaining access to appropriate data sources (Saunders et al., 2012). In order to gain access to the district, the researcher sought permission from the office of the DEBS. Thereafter, an introductory letter was given to the researcher introducing her to the school Head teachers before gaining access to the participants. Consent was obtained from participants before participating in the study. The purpose of the study was clearly stated and participants were informed that they may withdraw from the study at any point if they so wished.

Secondly, participants were treated with respect, their identity was kept confidential and anonymous. Permission was obtained to audio record and capture photos during the data collection process. The audio recorded data from focus group discussions and interviews as well as photos were kept in a password protected folder only known by the researcher. The study was cleared by research ethics committee of the University of Zambia (Appendix F).

3.15 Summary

This chapter discussed the sequential mixed method design that was used. The quantitative process informed the qualitative methods of data collection and analysis. The design was underpinned by the pragmatism research philosophy. Additionally, the study involved 79 Chemistry teachers of Ndola district of Copperbelt province Zambia. A number of research instruments were and these include; ASK tool, observation schedule, document analysis schedule, focus group discussion schedule and interview schedule. The chapter also highlighted the ethical considerations, validity and trustworthiness issues as well as model development procedure. The next chapter presents the findings of the study.

CHAPTER FOUR: PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents the findings of the study according to the following sections in relation to the research objectives;

a. Teachers' knowledge of sustainable development issues.

b. Integration of Sustainability issues in the chemistry curriculum

c. Reflection of ESD in the pedagogies used to teach chemistry.

Section 4.2 presents data on to chemistry teachers' knowledge of sustainability issues. While Section 4.3 will present data on how the Chemistry curriculum reflects sustainability issues with a specific focus on objectives/outcomes of the syllabus and some selected topics. Thereafter, the pedagogies used to teach Chemistry and how they reflect ESD principles is presented in Section 4.4. Lastly, a proposed model anchored on ESD and expansive learning will be presented as a product of this study at the end of the discussion chapter.

4.2 Chemistry teachers' knowledge of sustainability issues

In order to ascertain the chemistry teacher's knowledge of sustainability issues the researcher looked at their general performance on the sustainability knowledge using ASK tool (questionnaire) and obtained the total score for each participant. Their scores were categorised in three categories as indicated in Table 4.1. The teacher's responses on sustainability issues were determined based on the categories in Table 4.1. Getting a minimum of 6 questions out of 15 was regarded as possessing average knowledge, while a score of less than 6 was considered as below average. This gave a general pattern in terms of teacher's knowledge of sustainable development issues.

Table 4.1: Chemistry teachers' knowledge of sustainability issues

Category of scores	*Frequency N= 79*	*Percentage*
11-15 (above average)	17	21.5
6-10 (average)	56	70.9
0-5 (below average)	6	7.6

The findings revealed that majority (70.9%) of the chemistry teachers had average knowledge of sustainability issues. Getting a minimum of 6 questions correct out of 15 was regarded as possessing average knowledge. While 7.6% of the participants did not possess adequate knowledge on sustainable development issues because they scored below average.

During a focus group discussion participants were asked to highlight why it was important for them to have knowledge of sustainability issues as chemistry teachers. The common response was that the knowledge was important for every chemistry teacher to effectively handle certain concepts. For example TE1 stated that:

> *In chemistry there are certain topics that we teach such as pollution, energy or fuels, metal extraction and organic chemistry. You need sustainability knowledge to link these concepts to real world issues…you really need to go beyond the classroom to help learners appreciate the chemistry that we teach.*

The findings seem to suggest that teachers were not only aware of sustainability issues but also comprehended how chemistry as a subject presents an opportunity for the integration of these issues in their lessons and practices.

4.2.1 Chemistry teachers' knowledge of sustainability issues in the domains of SD

The study went further to look at the teacher's knowledge of sustainability issues according to the three domains of sustainable development. This was done by identifying and grouping the questions of the ASK tool according to the three domains of sustainable development. These are the environmental, social and economic. The environmental domain consisted of 7 questions as highlighted in Table 4.2; additionally the table shows chemistry teachers knowledge of environmental issues of SD.

Table 4.2: Chemistry Teachers' knowledge of environmental sustainability issues

Question	*Correct response*	*Frequency N=79*	*Percentage*
1.What is the common cause of pollution of streams and rivers?	Surface water running off yards, streets, paved lots and farm fields	22	27.8
2. What does ozone protect us from?	Harmful UV rays	68	86.1
3. Which is the biggest emitter of greenhouse gas Carbon dioxide?	China	59	74.7
5 Which of the following is an example of sustainable forest management	Never harvesting more than what the forest produces in new growth	54	68.4
6.Of the following, which would be considered living in the most environmentally sustainable way	Recycling all recyclable packaging	63	79.7
14. Put the following list in order of activities with the largest environmental impact: A. Keeping a cell phone charger plugged into an electric socket for 12hrs; B. Baking a cake; C. Cooking Nshima; D. Flying in a commercial airplane from Lusaka to Dubai.	D,B,C,A	23	29.1
15.In Zambia what do we currently do with the waste generated from the mining industries	Dump it in landfills	53	67.1

It became apparent from the results that most of the chemistry teachers had knowledge on the environmental domain. As indicated in Table 4.2 chemistry teachers (86.1%) exhibited knowledge on role of ozone in protecting the earth from harmful UV rays. This was supported by findings from document analysis of the chemistry syllabi under the topic Non-Metals. The subtopic Oxygen has a specific outcome that looks at the importance of ozone layer and dangers of its depletion. Hence it was likely that teachers would show awareness about the ozone related question. Secondly, the responses indicated that majority of the teachers (79.7%) had knowledge on what it meant to live in an environmentally sustainable way. On the issue of emission of greenhouse gas Carbon dioxide, the teachers (74.7%) showed knowledge and understanding of this phenomenon. It was also noted that 68.4 % of teachers were aware of what constitutes sustainable forest management. However, the question “what is the common cause of pollution of streams and rivers”? was poorly answered representing a (27.8%). Similarly, question 14 was equally poorly answered, only 23 teachers showed knowledge representing 29.1%.

The focus of the social domain questions was to assess chemistry teacher’s knowledge of social issues of sustainable development such as education levels, equality in terms of wealth and environmental justice. The domain consisted of three questions, as highlighted in Table 4.3:

Table 4.3: Chemistry Teachers' knowledge of social sustainability issues

Question	*Correct response*	*Frequency N=79*	*Percentage*
8.Higher levels of education lead to…	Higher self esteem	50	63.3
2. Over the past 30 years, what has happened to the difference between the wealth of the richest and poorest Zambians	The difference has increased	62	78.5
3. Which of the following is an example of environmental justice	All stakeholders from an indigenous community are involved in setting a quota for the amount of wood they can take from a protected forest next to their village	52	65.8

From Table 4.3 it can be seen that, generally teachers had knowledge about social sustainability issues. On the aspect to do with "what has happened to the difference between the wealth of the richest and that of the poorest Zambians", majority of the teachers 78.5% got a correct score. It can also be deduced that, teachers possessed sufficient knowledge with regard to this issue. It is important to note that despite the participants being in the education sector, the issue to do with the influence of education had a percentage score of 63.3%, slightly lower compared to other social issues. The findings seem to suggest that teachers conceptualised the impact of education as a social issue in various ways. The target of the questions under the economic domain of sustainable development was to look at how chemistry teachers showed awareness of the economic aspect of sustainable development issues. The questions and responses are as highlighted in Table 4.4.

Table 4.4: Chemistry Teachers' knowledge of economical sustainability issues

Question	*Correct response*	*Frequency N=79*	*Percentage*
7. Which of the following is a leading cause of the depletion of fish stocks in lake Bangweulu	Fishermen seeking to maximise their catch	53	67.1
9. Which of the following is the most commonly used definition of economic sustainability	Long term profitability	32	40.5
10. Which of the following is the primary reason that fuel prices have risen over last several decades in Zambia	Increasing global demand for oil	43	54.4
11. Many economists argue that electricity prices in Zambia are too low because…?	They do not reflect costs of pollution from generating the electricity	17	21.5

As indicated in Table 4.4 teachers showed less knowledge of the sustainability issues on this domain of sustainable development compared to the environmental and social domains. The findings indicated that the aspect which was looking at the causes of fish stock depletion in Lake Bangweulu was the highly scored in this category. About 53 participants showed awareness, this represented a 67.1%. It was also important to state that 54.4% had knowledge on the primary reason why fuel prices have risen over the last several decades in Zambia. Similarly, the argument put forward by economists that the electricity prices in Zambia were too low had the lowest percentage score. Out of 79 participants only 17 had knowledge on this matter, which translated into a 21.5%. Conversely, the teachers interviewed acknowledged the importance of energy in different aspects of the economy. Henceforth, they pointed out that energy and the use of fuels was an important topic in Chemistry. For instance, KN1 narrated that, *"learners should be taught that energy controls everything. Therefore, they should know the cost involved and act in a way that saves energy. You know they need to say its morning let switch off the lights or when they finish cooking, they should switch off the stove*". From this narration, it was clear that some participants understood question 11 and its economic implication as a sustainability issue despite the lower percentage score of 21.5%.

4.3 Comparative Analysis of teachers' knowledge in the three domains of SD

4.3.1 Normality Check

Normality test was conducted to determine a reliable test for the teachers' knowledge of sustainable development scores. One of the assumptions for most parametric tests to be reliable is that the data must be approximately normally distributed. There are several methods of assessing whether datasets are normally distributed or not. These methods fall into two categories: graphical (Histogram with a normal approximation curve, Q-Q probability plots, cumulative frequency (P-P) plots to mention but two) and statistical (Shapiro-Wilks test for sample size less than 50, Kolmogorov-Smirnov for greater than 50). Statistical tests for normality can be more precise since actual probabilities are calculated but these should be used in conjunction with either a histogram or a Q-Q plot. Kolmogorov-Smirnov test, histograms and Q-Q plots were used in this study. Kolmogorov-Smirnov test was used because the number of participants was 79.

1. Graphical

a. Histogram

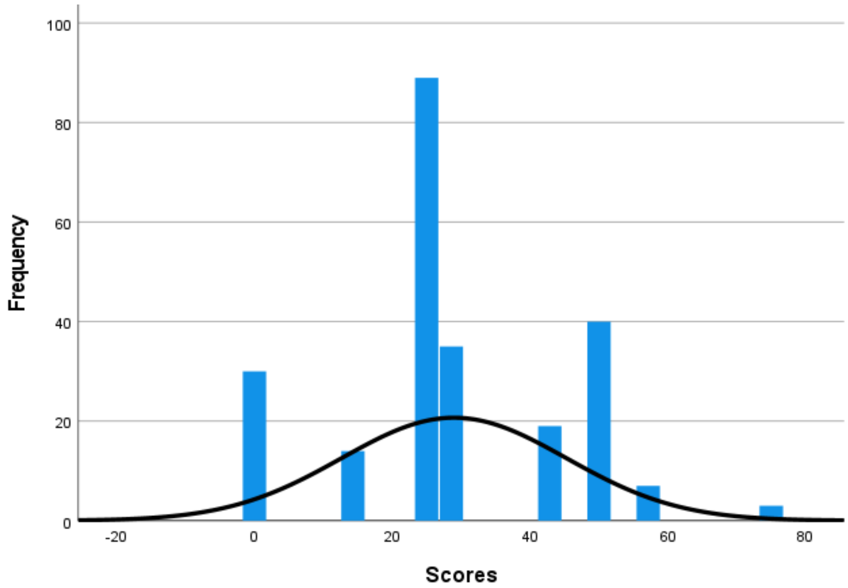

Figure 4: Graphical Representation of Normality test

The data is not normally distributed as shown in Figure 4, it has no peak in the middle and is not symmetrical; the assumption of normality has not been met.

b. Q-Q plot

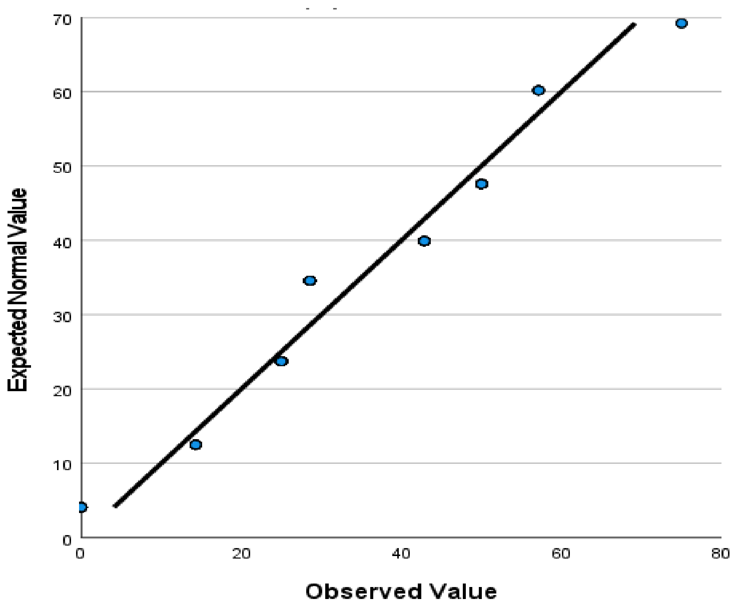

Figure 5: The Q-Q Plot of Normality test

According to Figure 5, the data is not normally distributed because the scatter dots are not close to the line with too much obvious pattern coming away from the line.

2. Statistical

Table 4.5: Statistical Normality tests

Tests of Normality						
	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SD Scores	.218	237	.000	.898	237	.000

The sig-value is less than the alpha value α=0.05, therefore, the results are significant. It can be concluded that the teachers' sustainable development knowledge scores in the three domains are not approximately normally distributed. Since normality has not been assumed for the data set for both graphical and statistical tests, an appropriate non-parametric test was used (Kruskal-Wallis H Test).

To start with descriptive statistics test was done to establish the mean score of teachers' knowledge in the three domains of sustainable development issues. This is highlighted in Table 4.5.

Table 4.6: Mean Score of Teachers' Knowledge in three domains of SD

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Environmental	79	0	75	31.65	17.772
Social	79	0	57	30.56	14.052
Economic	79	0	50	24.68	16.258
Valid N (list wise)	79				

The mean score in Table 4.6 shows the environmental domain had a higher mean score (31.65) compared to the mean score for the social and economic domains. This is an indication that teachers had more knowledge in the environmental domain, followed by the social domain (30.56) and then the economic domain (24.68).

Table 4.7: Hypothesis Test Summary

The dataset tabulated in Table 4.7 is a depiction of the hypothesis testing regarding the independent-samples using Kruskal-Wallis H test.

Hypothesis Test Summary				
	Null Hypothesis	**Test**	**Sig.**	**Decision**
1	The distribution of Scores is the same across the three domains of Sustainable Development issues	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.

As shown from the sig.value of 0.001, the null hypothesis was rejected at the significance confidence level of 95%. Hence, we are 95% confident that the distribution of scores is not the same in the three domains of sustainable development issues. This is attributed to the difference in knowledge of chemistry teachers in the three domains.

Table 4.8: Independent-Samples Kruskal-Wallis Test Summary

Independent-Samples Kruskal-Wallis Test Summary	
Total N	237
Test Statistic	14.944
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.001

As indicated in Table 4.8, the results of the Independent-Samples Kruskal-Wallis test for the dataset comprising the total scores of 237 was 14.944 with degrees of freedom pegged at 2. Furthermore, a two sided test of asymptotic sig.value was 0.001. This is an indication that the test conducted was significant in the evaluation of the hypothesis testing discussed earlier in Table 4.7. With the provision of the aforementioned statistics values, it can be concluded that the results of the test results had an influence on the underpinning of the null hypothesis in view of either to accept or reject the hypothesis.

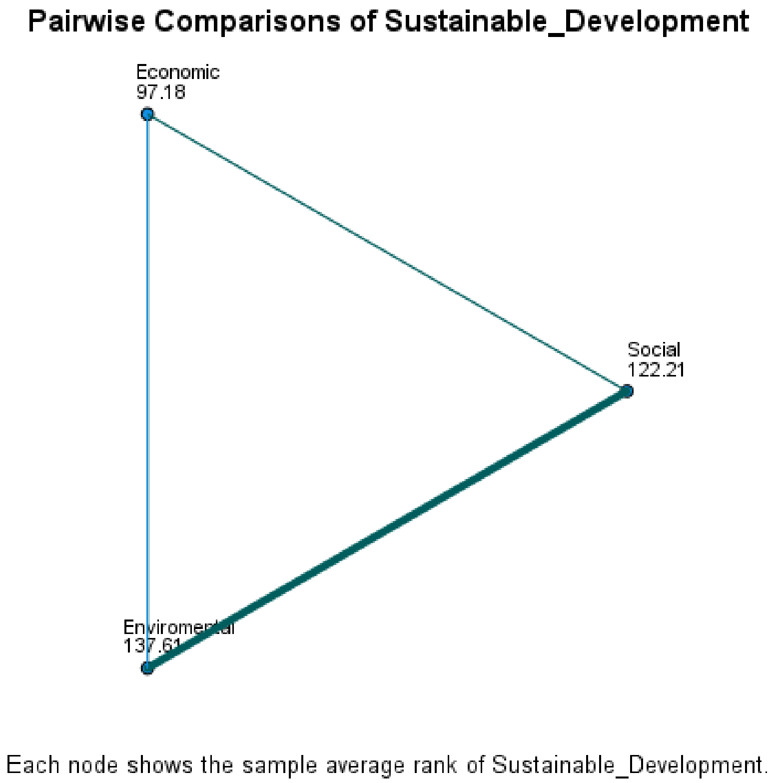

Figure 6: Pairwise comparisons of the three domains of SD

Figure 6 shows the pairwise comparison of the average ranking of the three domains of SD. The figure reveals that average ranking of the three domains of sustainable development namely; Economic, Social and Environmental were ranked using a pairwise comparison test. The results depicts the environmental sustainable development domain was the highest ranked, followed by the social domain and the economic domain was the least. This in itself entails that the participants considered environmental sustainable development domain paramount unlike the economic domain which was the least. To this effect it can be concluded that the economic sustainable development is of little importance in the eyes of respondents. As a result it is safe it is safe to say that majority of the participants' were well vested in the environmental domain of SD than the rest, although there is a very minimal difference when compared to the social domain.

4.4 Chemistry Teachers' understanding of the concept of Sustainable Development

Chemistry teachers' understanding of the concept of sustainable development was assessed by exposing them to different descriptions of the concept of sustainable development. They were asked to identify the most appropriate definition of sustainable development; their responses are as shown in Table 4.5.

Table 4.9: Chemistry Teachers' descriptions of SD

Descriptions of SD	***Frequency***	***Percentage***
a. Creating a government welfare system that ensures universal access to education, health care and social services	29	36.7
b. Setting aside resources for preservation, never to be used	1	1.3
c. Meeting the needs of the present without compromising the ability of future generations to meet their own needs	46	58.2
	2	2.5
d. Building a neighbourhood that is both socio-demographically and economically diverse	1	1.3
e. Don't Know		

It can be deduced from the responses in Table 4.9 that 46 (58.2%) teachers exhibited understanding as they indicated that *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* was the most appropriate and commonly used definition of sustainable development. Teachers showed awareness of the concept of sustainable development. This was confirmed during the focus group discussion when asked to describe sustainable development in their own words, a number of descriptions were given. For instance KN1 described sustainable development as *"the idea of using resources in a way that meets the current* *needs and preserve something that is not used at that particular time for future use".* Similarly TE1 pointed out that*:*

I think…sustainable development refers to a form of development that can continuously go on. If it involves the use of resources for example, resources can be used without disadvantaging the future generations. In short it is the development that has in mind the sustainability of our environment.

It is important to note that on average 58.2% of chemistry teachers had an understanding of what sustainable development is and what it entails. On the other hand, 36.7% opted for a description of SD as "the role of government to create a welfare system that ensures universal access to education, health care and social services." While one teacher indicated "I don't know".

4.5 Chemistry Curriculum and Sustainability issues

The findings to ascertain the chemistry curriculum's reflection of sustainability issues was obtained through document analysis of the pure chemistry (5070) syllabus and science (5124) syllabus; chemistry schemes of work; lesson observation and focus group discussion. The study focused on the following aspects: outcomes/objectives of the syllabi; topics related to sustainable development; repackaging and presentation of topics related to sustainable development.

4.5.1 Outcomes of the syllabi

It was established that there are six general aims in both the pure chemistry and science (a combination of chemistry and physics). Out of the 6 general aims only one indicated in Table 4.10 point to sustainable development or rather sustainability issues in both pure chemistry syllabus (5070) and science syllabus (5124). On the other hand, the remaining five general aims focus more on the knowledge and skills to be acquired without clearly showing the contribution of chemistry to the sustainable development issues. Table 4.10 highlights the general aim 6 which reflects aspects of environmental issues and its sub-aims as indicated in the syllabi.

Table 4.10: General aim 6 and its Sub-aims

Pure Chemistry Syllabus (5070)	Science Syllabus (5124)
Aim: To promote awareness that:	*Aim: To promote awareness that:*
i. Chemistry is subject to social, economic, technological, ethical, cultural influences and limitations	*i. Chemistry is subject to social, economic, technological, ethical, cultural influences and limitations*
ii. The applications of Chemistry maybe both beneficial and detrimental to the individual, the community and environment.	*ii. The applications of Chemistry maybe both beneficial and detrimental to the individual, the community and environment.*
iii. Stimulate interest in and care for the local and global environment.	*iii. Stimulate interest in and care for the local and global environment.*
-	*iv. Develop knowledge and understanding of the scientific and technological applications with their social, economic and environmental implications.*

(MOE, 2013)

The two syllabi were analysed further, this was done in order to go beyond the general aims and look at the specific outcomes at grades; 10, 11 and 12 levels. It was found out that both the pure chemistry syllabus and the science syllabus contain specific outcomes that have environmental, social and economic implications of chemistry. The outcomes are shown in Table 4.11 with respect to how they connect or capture sustainability knowledge directly or indirectly.

Table 4.11: Specific Outcomes linked to SD domains in the syllabi

Specific Outcome (Pure Chemistry)	Specific Outcomes (Science)	Grade/level
i. Explain the importance of Chemistry	*i. Explain the importance of chemistry*	
ii. Demonstrate an understanding of the importance, production, use and effect on the environment of common elements and simple compounds.	*Ii. Demonstrate an understanding of the importance, production, use and effect on the environment of common elements and simple compounds*	10
iii. Demonstrate an understanding of the importance, production, use and effect on the environment of acids, bases and salts.	*iii. Demonstrate an understanding of the importance, production, use and effect on the environment of acids, bases and salts*	11
iv. Illustrate the importance of acid-base reactions	*iv. Illustrate the importance of acid-base reactions.*	
v. Demonstrate an understanding of chemical reactions and energy changes	-	
vi. Explain the advantages and disadvantages of energy sources	-	
vii. Describe the effects and use of fuels on the environment	-	
viii. Describe extraction of metals (Copper, Iron and Zinc)	*v. Describe the extraction of copper, iron and zinc from their ores*	
ix. Describe the uses of copper, Zinc, Iron & Aluminium	*vi. Describe the uses of copper, iron, zinc & aluminium*	12
x. Explain the harmful effects of some metals	*vii. Explain the harmful effects of some metals.*	
xii. Describe the fractional distillation of crude oil Describe the uses of crude oil	*vii. Describe the fractional distillation of crude oil*	
	viii. Describe the uses of crude oil	
xiii. Describe the formation of alcohols	*ix. Describe the formation of alcohols*	

(*MOE, 2013:1; 17; 44;49;61;76;86;89)*

Relating the outcomes in Table 4.11 to the three domains of learning, it has become apparent that most of these outcomes fall under the cognitive domain. While only a few fall under the affective and psychomotor domains in both the pure chemistry and science syllabi. Those outcomes that were identified to fall under the affective and psychomotor domains in Table 4.11 were (ii, iii, iv & v). There seems to be a discrepancy between the general aim and specific outcomes to be achieved in relation to sustainability issues. The general aim points out the importance of raising awareness which is nested in the affective domain while the specific outcomes largely dwell on the cognitive domain.

During the focus group discussion the participants were asked about the importance of outcomes. The participants indicated that outcomes are very important because they act as a guide to select the appropriate of methods, the materials as well as of assessment strategies to employ in the lesson. For instance Teacher 1 stated that *"...outcomes help us to meet the national demands, when coming up with the syllabus what is looked at are the problems the country has and how chemistry as a subject can help solve those problems"*. Additionally, Teacher 2 added *"you know during preparation outcomes are derived from the demands of the syllabus to teach certain competencies. In other words they help you to focus on what content, skills and values you want to teach".*

Teacher 4 indicated that *"...you see! there is a relationship between the outcomes and the choice of methods as well".* However, during lesson observation, it was observed that sometimes there was a mismatch between the outcomes and methods. The outcome would clearly state "demonstrate" providing guidance to the teacher to utilise demonstration or experimentation at one point or the other in the lesson. However, the teacher opted to use lecture method and whole class discussion. When asked why this was the case Teacher 4 was quick to mention that *"sometimes the outcome may be saying practical so that learners are engaged hands-on but there are other factors like nature of the class that may influence your choice of methods"*.

It is important to note that the secondary school chemistry syllabi have pointed out the role of chemistry in contributing to sustainable development. The general aim and its sub aims show how the teaching/learning of chemistry would promote sustainability knowledge, skills and values. Conversely, there is a gap between the general aim and the specific outcomes derived to promote sustainability knowledge in chemistry.

4.5.2 Topics Related to Sustainable Development in the Curriculum

The topics in the pure chemistry and science syllabi are organised in three categories. These categories correspond with the grade/level at which topics are expected to be covered. Additionally, there are 10 main topics in both the pure chemistry and Science syllabi. The findings show that out of the 10 there is no single main topic is directly linked to education for sustainable development, however some content and sub-topics indirectly speak to ESD. This is because the specific outcomes or content under these subtopics highlight the application of chemistry in the production of various products or importance of its reactions and products in different sectors. As a result, this points to a link between secondary school chemistry and domains of SD. In the subsequent narrative, the topics that speak to ESD are presented.

Introduction to Chemistry

This is the first topic in grade 10, it covers knowledge pertaining to branches of chemistry as well its importance. The knowledge to be covered indicates the important role of chemistry in impacting the lives of learners in various ways. The syllabi revealed through content under this subtopic that learning of chemistry is critical to sustainable development because it contributes to the improved livelihood of people. This is the case because its processes are necessary in the manufacturing of everyday products such as soaps, plastics, cement, medicines and food production only to mention but a few. The analysis further shows that the content also indicates the harmful effect of these processes which can negatively impact environmental sustainability. For example, the two syllabi point out "production of undesired harmful by-products" as some of knowledge that should be covered.

Acids, Bases and Salts

This topic is normally covered in grade 11, it was found out that under this topic the teacher is guided to look at concepts concerned with controlling the acidity and alkalinity of the soil. This knowledge when applied in the agricultural sector can help to maximise crop yield. The topic also covers the application of knowledge acquired in the treatment of indigestion and the importance of brushing teeth using tooth paste. When this content can help learners acquire relevant knowledge, skills and values on this topic as well as appreciate the relevance of chemistry in their lives.

Chemical Reactions

This topic has content that relates to education for sustainable development or rather sustainability issues and it is covered at grade 11 level. This topic focuses on a number of concepts namely; rates of chemical reactions; chemical equilibrium; redox reactions and energetics of reactions. Energetics of reactions has components that look at the advantages and disadvantages of energy sources (fuels), the effects of fuels on the environment such as pollution and green house effects. Conversely, a closer look at the two syllabi, revealed that energetics of reactions is not part of the science syllabus. The rationale for leaving out this seemingly important component of chemistry with real life relevance to learners is not clear. During focus group discussion Teacher 2 commented that *"the curriculum must include content that is relevant to learners within their community. That is why there is no interest sometimes…how do you force me to learn things that I will not use".*

Metals

Metals is one of the topics covered in grade 12. There are three specific outcomes that guide the coverage of concepts that can be said to be linked to ESD. Firstly, the topic looks at the extraction of metals with a specific focus on copper (Cu); Iron (Fe) and Zinc (Zn) from their ores. The process of metal extraction has the economic, social and environmental implications. Secondly, the syllabi also indicate the need to look at the uses of Cu; Fe; Zn and Aluminium (Al). This is in order for the learners to appreciate the contribution of chemistry processes economic development and the real life usages of these metals. But the syllabi are silent on the environmental friendliness of the extraction methods.

Thirdly, the syllabi also posit that learners must acquire knowledge about the harmful effects of some metals to humans, plants and the environment in general. However, comparing is listed as the only science process skill to be developed by learners as they learn these concepts. This may not be adequate especially for chemistry content that should go beyond the classroom to the mining sector and the environment. This inadequacy was affirmed during a focus group discussion by Teacher 5 who stated that

> *…you see our syllabus is a challenge sometimes…it does not address the actual needs of society in most cases. On content were you expect emphasis on a lot of skills that is where you find few. You can tell that skills are just listed haphazardly, as long as knowledge is being pumped in this learner. It does not matter what or how they are going to use that information for.*

Non-Metals

Under non-metals the syllabi have highlighted a number of sub-topics to be covered at grade 12 level. These include; Hydrogen (H), Oxygen (O), Nitrogen (N), Chlorine (Cl), Sulphur (S), Carbon (C) and Carbonates . The document analysis revealed that, generally the focus was on describing these non-metals as well as their industrial application. The subtopic Nitrogen (N) and its industrial uses was closely looked at during document analysis this was because it brings into focus the preparation of ammonia a major component needed in the production of nitrogenous fertilizers. The researcher went further, to look at the skills and values that the learners were expected to acquire under this same subtopic. Document analysis revealed that demonstrating and observing were the only skills listed. Nevertheless, this is the knowledge were learners should be engaged hands-on so that they can apply this knowledge in their lives. This gap was echoed by Teacher 2 during a focus group discussion who observed that:

the curriculum brings out a problem, there is so much emphasis on certain topics which in my view are not necessary. I can give you an example; on the use of ammonia to produce fertiliser and the reaction of carboxylic acids and alcohols to produce esters and knowledge about making of soaps that is the large chunk of knowledge that must be promoted in a country like ours. We expect to find a lot of skills and values that the learners are supposed to gain but that is where the curriculum puts less emphasis.

Organic Chemistry

This is the last topic in both the pure chemistry and Science syllabi. It is taught at grade 12 level and consists of the following sub-topics; Saturated and unsaturated Hydrocarbons; Alcohols; Carboxylic acids; Esters and Polymers. Under the subtopic hydrocarbons, learners are exposed to knowledge about organic compounds in general, alkanes, alkenes and fractional distillation of petroleum (crude oil). The syllabi have provided guidance on what the teacher is expected to focus on. For instance, the teacher should endeavour to help learners acquire knowledge on how to obtain different fractions of crude oil at various temperatures. Additionally, look at the domestic use of fuels and the use of crude oil residue in road construction. However, it suffices to mention that the syllabi provide general reference points to the teacher without localising or bringing in the Zambian context. This observation was also made by Teacher 5 during a focus group discussion who narrated that "sometimes the curriculum is a challenge to itself, why do I say so…the things that should be there must be relevant to the learners within their community. That is why leaners do not show interest because how do you force me to learn something that I will not use".

Under alcohols as the second subtopic, learners needed to describe the chemical composition of alcohols; the formation of alcohols and the uses of alcohols among others. The following brief notes are listed under knowledge component of the syllabi as pointers to the knowledge which must be focused on or that which learners ought to acquire. The teacher is expected to highlight that an alcohol is an "organic compound with a hydroxyl group with general formula $C_nH_{2n+1}OH$". While on formation of alcohols the focus is expected to be placed on chemical reactions involving the hydration of alkenes, hydrolysis of esters and fermentation for ethanol. Pertaining to uses of alcohols the syllabi advances that alcohols can be used as fuels; antiseptics; organic solvents and in alcoholic beverages. To this effect, the skills and values components were also looked at, it was established that identifying; comparing; appreciating and awareness were the common skills and values respectively. Despite the skills and values being listed, the syllabi do not show how these skills should be acquired. The subtopic carboxylic acids, has a component that looks at the chemical properties with a particular focus on key chemical reactions such as; their reaction with bases, carbonates, metals as well as their reaction with alcohol to form esters.

4.5.3 Repackaging of topics related to sustainable development.

It was found that in most cases the topics were just lifted from the syllabi and placed in the scheme of work without consideration of how they complemented the understanding of other topics. The excerpt of the scheme of work is highlighted as figure 7

NATURAL SCIENCES DEPARTMENT

CHEMISTRY ELEVEN SCHEMES OF WORK

NAME OF TEACHER ………………………… CLASS ………… TERM ….1…. YEAR …2023……

WEEK BEGINNING	TOPIC	SPECIFIC OUTCOMES	METHODOLOGY	TEACHING AND LEARNING AIDS	REFERENCES
1	Bonding The valence of an atom	❖ Describe valency and valence electrons ❖ Demonstrate how to deduce the valency of an element ❖ Formulate chemical formulae of compounds	Questions and answers	Models of atoms Charts	Progress in science book 10 Excel and advance in chemistry 10
2		❖ Demonstrate how to construct word equations ❖ Formulate and balance chemical equations ❖ Construct balanced net ionic equations	Demonstration Group work	Chart Lesson notes	Progress in science book 10
3	ACIDS BASES AND SALTS Characteristic properties of Acids and Bases	❖ Describe acids bases and alkalis in terms of ions they contain or produce in aqueous solutions ❖ Describe the meaning of Strong, Weak, dilute and concentrated acids and alkalis	Question and answers	Samples of acids and bases Lesson notes	Progress in science pps book 11
4		❖ Describe the pH scale ❖ Describe neutrality, acidity and alkalinity in terms of pH value ❖ Determine the pH value of a solution	Question and answer Group activities	pH meter blue and red litmus papers Universal indicators	Excel and advance in chemistry pps book 11 Golden tips in chemistry

Figure 7: Sample of the scheme of work showing sequence of topics

Figure 7 show that the sequencing of topics in the schemes of work by the teachers was not properly done. One would expect the teacher to first plan for topics such as the periodic table and the mole concept then followed by acids, bases and salts. In this case, chemical bonding and valence of an atom does not link well to the concepts that are supposed to be covered under acids, bases and salts.

4.6 Pedagogies used to teach chemistry and how they promote ESD

To start with the researcher took a closer look at the suggested methods in the schemes of work. It was apparent that same teaching methods were planned to be used from week 1 through to week 13 for all the topics. For example Question and Answer was one of the predominant and frequent planned for methods. During a focus group discussion when teachers were asked about the methods that were appropriate to teach topics that contained ESD related concepts. They responded that most of the methods they planned to use and those used were not appropriate. For instance Teacher 2 pointed out that "*mostly we plan to and use Discussion, Lecture method, Question and Answer".*

It can be deduced from the findings that, the proposed teaching methods were just listed without necessarily linking to the set specific outcomes or content.

Particular attention was also paid to suggested or planned for practical activities and teaching/learning resources to check how appropriate they were to engage learners. This was in to understand how the teachers intended to bring about transformative teaching and learning in response to SD issues. It was established that chalk, chalkboard and charts were the common teaching/learning resources proposed to be used to help them achieve the outcomes. However, it suffices to mention that, the topics that have a direct or indirect link to ESD were required to be planned for in such a manner that would give learners an opportunity to interact with materials and be hands-on as well as go beyond the classroom and engage with either the physical or virtual environment.

On the other hand, the assessment strategies component was dominated by exercises; homework and notes. It was not clear how lesson notes qualified to be a strategy that could be used to assess learners. Conversely, during the focus group discussion when participants were asked about the importance of a clear relationship between the objectives and assessment strategies, they disclosed that it was very important to ensure that the two components speak to each other. Teacher 1 stated that "we have to use the objectives and assessment strategies to evaluate if the methods worked well". Further, it was noted that the scheme of work did not clarify in any way how the values would be enhanced.

Table 4.12 shows the key elements of teaching methods that were used to teach these topics. The observation of some lessons revealed that in most cases, teacher exposition method was used followed by questions. Additionally, the approach used was group work followed by whole class teaching.

Table 4.12: Methods for teaching ESD related chemistry topics

Teacher Code	*Topic Observed*	*Presentations &Analogies*	*Activities learners engaged in*	*Linking Content to real life*
TE1	*Extraction of metals*	-Questions (write the two chemical reactions involved in the extraction of Zinc. -Teacher Exposition - An example of the mining pollution in Mufulira (SO_2)	Group work – learners worked in groups to come up the 2 chemical reactions and reported their answers to the whole class	An example of the mining pollution in Mufulira to explain the effect of SO_2
MS3	*Extraction of metals*	-Teacher Exposition -Questions (What are effects of mining on the environment? What are the advantages of recycling?)	Whole class discussion-the questions were posed to the whole class, learners responded and discussed their responses	-Land pollution- gave an example of mine dumps such as the "black mountain" -Air pollution- Due to emissions such as CO_2 and SO_2 -Waste management, the metals are recycled to other usable products
NC1	*Acids, Bases & Salts*	-Demonstration (the teacher demonstrated the preparation of Barium Sulphate) -Discussion - An example of football spectators to explain spectator ions	-Practical activity (preparation of Barium Sulphate) -Group work- Learners worked in manageable groups	_
AN2	*Acids, Bases & Salts*	-Teacher Exposition -Questions (learners were asked to identify strong and weak acids	Group work (learners identified strong and weak acids in groups	Highlighted that citric fruits are acidic
CH2	*Chemical Reactions*	Discussion(What factors affect rate of reactions Teacher Exposition	Group work- Learners discussed in small groups and reported to the class	_
KN1	*Organic Chemistry (Alcohols)*	- Questions (Asked learners to write structural formula of alcohols; Reactions between alcohols and carboxylic acids to form Esters -Teacher exposition -An example on use of alcohol to produce perfume	Whole class discussion-learners volunteered to try out the questions on the board	_

The aspects of lesson observations captured in Table 4.12 were analysed under the following themes so as to establish how the teaching methods used by teachers linked to ESD.

i. Facilitation of classroom learning and Activities
ii. Engaging learners with the Environment
iii. Teacher Promotion of Lifelong Learning during Lesson Delivery
iv. Linking Chemistry Content to other Disciplines and Current Issues
v. Giving localised and Real Life Examples

4.6.1 Facilitation of classroom learning and Activities

The identified topics that have content which is related to ESD were Introduction to Chemistry; Acids, Bases and Salts; Chemical Reactions; Metals; Non Metals; Organic Chemistry. It was imperative to observe the choices of approaches, methods made by the observed teachers and how they facilitated the learning process so as to promote lifelong learning. In order to establish the approaches used by teachers, the researcher, focused on how participatory, exploratory the lessons were and whether or not these lessons were interactive. It was observed that teachers mostly used questions to promote participation and interactions in their lessons. For example, TE1 used a question to encourage learner participation in the lesson on Extraction of Metals Specifically Zinc. The teacher asked learners to write the reaction between Zinc Blende and Oxygen, about 51 learners were in this class and came up with reactions *i* and *ii*.

i. $2ZnS_{(s)} + 3O_{2(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$

ii. $ZnO_{(s)} + CO_{\,(g)} \rightarrow Zn_{(s)} + CO_{2\,(g)}$

It was observed that the teacher made an effort to promote learner participation in the lesson, however there were no opportunities for exploration because the question was of low cognitive level. The nature of the question and the way it was asked did not encourage critical thinking among the learners. Both chemical equations presented an opportunity for the teacher to explore the poisonous and harmful impact of Sulphur Dioxide (SO_2), Carbon Monoxide (CO) and Carbon Dioxide (CO_2) on both humans and the environment. But instead the teacher put more emphasis on the correctness of the two equations.

As indicated in Table 4.8 it was observed that the commonly used methods were; Teacher Exposition, Question and Answer as well as discussion. However, a review of the schemes of worked revealed that, participants planned to use various methods during their lessons. This was reaffirmed during focused group discussion when teachers were asked to highlight the methods that they usually used. They were quick to mention Question and Answer; Demonstration; Class Discussion, Problem Solving, Discovery and Teacher Exposition. Nonetheless, when asked what methods enhances learners knowledge, skills and attitudes to enable them address environmental challenges in their communities, the participants indicated that experimental and discovery methods were ideal. For instance Teacher 1 said

> *…experimental method maybe ideal, though I did not mention it under the methods I use. The problem with the methods we have mentioned is that… sometimes it makes Chemistry as a subject you should just learn in school. Learners will not appreciate that even just dropping a plastic bottle on the road is actually not good because of what it may do to the environment. So experimental method may help them appreciate environmental concerns.*

Similarly, Teacher 2 added that, *"though discovery method depends on the learners that you have, but it provides an opportunity for learners to be creative and discover their environment. But their findings have to be consolidated by the teacher".*

The findings seem to indicate that, teachers planned to use a number of methods in their lessons. Additionally, they also acknowledged the appropriate methods despite not using them. In the same vain Teacher 5 narrated that *"… you see when I was teaching the topic Alcohols I would have given my learners a small simple project to go and ferment some sugar at home, then bring to class for discussion. But you know this thing of always wanting to look at time, I did not do that".*

A total of 12 lessons were observed, out of which two involved hands-on activities on the topic Acids, Bases and Salts. The teacher provided different chemicals, divided learners in manageable groups to carry out the activity.

Learners, were asked to prepare Barium Sulphate ($BaSO_4$) using Sulphuric Acid (H_2SO_4) and Barium Nitrate Ba $(NO_3)_2$ as shown in Figure 8.

Figure 8: Reagents given to learners to prepare $BaSO_4$

Learners were monitored as they worked in groups and the teacher tried to promote peer learning among learners. Additionally, learners were encouraged to share their results with the entire class by way of writing the chemical reactions. Group one for instance showed the reaction as;

$$Ba\ (NO_3)_{2\ (aq)} + H_2SO_{4\ (aq)} \rightarrow BaSO_{4\ (s)} + 2HNO_{3\ (aq)}$$

Further, the teacher, probed through questions for learners, to highlight the ions that specifically took part in the chemical reaction. Another learner from group 4 was able to show the ionic equation correctly and followed all the steps;

$$Ba\ (NO_3)_{2\ (aq)} + H_2SO_{4\ (aq)} \rightarrow BaSO_{4(s)} + 2HNO_{3\ (aq)}$$

$$Ba^{2+}{}_{(aq)} + 2NO_3^-{}_{(aq)} + 2H^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\ (s)} + 2H^+{}_{(aq)} + NO_3^-{}_{(aq)}$$

$$Ba^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4\ (aq)}$$

It is important to note that, the rest of the ten lessons observed, the teachers did not engage their learners in various practical activities but rather opted to use question and answer as well as whole class discussions. But during the focus group discussion the teachers narrated that, learners learn well and acquire more understanding when they interact with tangible objects. Teacher 1 pointed out that *" I can confidently say that our kind of teaching is not meeting learners needs…we are told, focus on making learners pass the examinations, sometimes there are even pamphlets given so that you make learners cram"*. The researcher also took a close look at the schemes of work to ascertain the activities planned for and methods to be used. The documents revealed that teachers planned to use a number of activities in their lessons and did appreciate the importance of classroom activities and interactions even if they opted not to use them.

4.6.2 Engaging learners with the Environment

It was observed that the chemistry teachers did not engage learners with the environment despite the topics presenting them with opportunities to do so. It was also observed that in most cases teachers used teacher exposition to highlight certain concepts even though there were opportunities to explore those concepts further. These concepts include the environmental effect of SO_2, CO_2 and CO which is as a result of chemical reactions involved in metal extraction. Therefore, Teacher TE1 for example was teaching about extraction of metals and how SO_2 which is one of the gases released in the process affects the environment. The teacher talked of how the gas results in acid rain then ultimately affecting soil fertility. Similarly, another lesson on recycling of metals for example, presented opportunities for the teachers to engage learners with the environment. However, teachers did not engage learners with the environment in any way as they taught these topics. Nevertheless, during the interview when the participants were asked how they would engage learners beyond the classroom, they first started by identifying the topics they felt were linked to sustainable development. Teacher 2 explained that "*during the study of the topic metals we do emphasise recycling, because I feel it does add to sustainable development…when you talk about proper use of resources and recycling it is like you are limiting the excessive usage of resources. So during the lesson on recycling we should just use our physical environment to effectively teach the concept"*.

The findings illustrate that teachers are aware of how certain concepts related to SD should be taught. Thus, during the focus group discussion the researcher, probed why the explanation during the interview differed from what was observed. Teacher 5 responded that *"you see mostly in our lessons we use short cuts, so it is very difficult to instil meaningful learning to the extent of even using the environment when you are using shortcuts".*

4.7 Teacher's Promotion of lifelong Learning during Lesson delivery

Lesson observation, focus group discussion and interview presented an opportunity for the researcher to ascertain how Chemistry teachers promoted lifelong learning in their lessons. The following aspects emerged as points of focus by the researcher to gain insights on how lifelong learning was achieved during chemistry lessons.

4.7.1 Linking Chemistry Content to other Disciplines and Current Issues

It was observed that some teachers were able to link chemistry content to other disciplines. This was evidence of fostering multidisciplinary approach to learning one of the principles ESD. During the lesson on extraction of metals for example, one teacher explained the effect of acid rain on plants as a result of SO_2 emissions which affect the root system of plants and wax cuticle of the leaves leading to excessive transpiration. Learners were able to relate because at the time they had already covered transpiration as a topic in Biology. Another prominent link was noted during the lesson on Acids, Bases and Salts. The teacher emphasised the important role of understanding soil acidity and alkalinity in Agriculture. This was further linked to the use of various fertilisers. During the focus group discussion teachers revealed that

> *Chemistry is a central science…that is why when I was teaching organic chemistry on fuels, there is some sought of knowledge from geography when looking at countries that produce oil, like Saudi Arabia; Nigeria and so on. It shows that this knowledge is not only chemistry but the knowledge is integrated…but only if the teacher is creative enough.*

The participants acknowledged the need to link chemistry concepts to other disciplines to enhance conceptual understanding. However, the link was basically highlighted and not coupled with any activity or action. This was affirmed by Teacher 4 who indicated that

> *…there should be something to show in society, we need to encourage learners to apply what they are learning. I believe chemistry should be taught for life so as teachers we need do more and reflect, for example is what I am teaching this learner going to help him/her out there…is he/she going to help the parents in terms of improving their yield. Honestly I feel our integration of chemistry knowledge with other disciplines and what we are delivering at different levels grades 9, 12 even tertiary is not enough.*

Based on the above comment, it became apparent that chemistry teachers were aware of the importance of teaching chemistry in a multi-disciplinary way. Additionally, the findings seem to suggest that, there were some gaps or rather weaknesses in the way teachers presented these concepts to their learners during chemistry lessons.

4.7.2 Giving localised and Real Life Examples

It was observed that teachers made effort to give localised or real life examples as advocated for by ESD to contextualise the teaching/learning processes. This is in order to help the learners understand the concepts that were being presented. When Teacher NC1 was teaching the topic Acids, Bases and Salts; subtopic identification of acids, the teacher engaged learners through a question on the importance of knowing the acidity of the soil. This aspect gave the teacher an opportunity to talk about the use of fertilisers in Agriculture as well as highlighting the role of Nitrogen Chemicals of Zambia (NCZ) in the production process.

In a similar manner TE1 also tried to connect the content to local issues in order to help learners understand extraction of metals. The teacher reminded the learners of the gaseous emissions from the mines on the Copperbelt commonly known as “Senta”. It was observed that the whole class was familiar with this phenomenon though they did not realise that "Senta" was SO_2 gas. Thus, the teacher utilised the opportunity to highlight how extraction of metals such as Copper may lead to different forms of pollution such as air, land and water. Further, another real life component was discussed on the lesson topic recycling of metals. The teacher gave an example of recycling of scrap metals, which is a common business that learners were familiar with.

It can be deduced that the observed teachers, understood the importance of using localised examples of real life examples to help their learners appreciate chemistry as a subject. However, they would have provided more opportunities through activities or use of other appropriate methods so that learners experienced phenomena. When the participants were asked during the focus group discussion the importance of connecting chemistry to real life or local issues, they responded that it was necessary so that learners could have conceptual understanding and use the knowledge in their lives. The following response stood out; Teacher 4 pointed out that "…chemistry is abstract, sometimes when you are teaching learners will say huh this topic! So you need to bring in real life examples, things that happen in their homes and communities…this makes topics easy to understand".

4.8 Summary

This section shows a summary of the key findings as indicated in the following themes.

4.8.1 Chemistry teachers' knowledge of sustainability issues

- Majority (70.9%) of the Chemistry teachers had knowledge about sustainability issues.
- Teachers' understanding of the components of sustainable development; environmental, social and economic showed that they exhibited more knowledge on the environmental component especially on concepts that are in the syllabi such as the role of ozone. The social component was second in terms of teachers' awareness, while the economic was lowest indicating a percentage of about 21.5% on some issues for instance on an aspect to do with the role of energy.

- On average teachers (58.2%) showed awareness of the concept of sustainable development and they were able to describe sustainable development in their own words.

4.8.2 Chemistry Curriculum and Sustainability issues

- Out of the 6 general aims in the syllabi only one point to sustainable development or rather sustainability issues. The pure chemistry syllabus (5070) general aim 6 highlights the need to promote awareness through its sub-aims that:

  i. *the study of Chemistry is subject to social, economic, technological, ethical, cultural influences and limitations.*

  ii. *the applications of chemistry maybe both beneficial and detrimental to the individual, the community and environment.*

  iii. *stimulate interest in and care for the local and global environment.*

- There seem to be a discrepancy between the general aim and specific outcomes to be achieved in relation to sustainability issues. The general aim points out the importance of raising awareness which is nested in the affective domain while the specific outcomes largely dwell on the cognitive domain.
- There are 10 main topics in both the pure chemistry and science syllabi of which no single main topic is directly linked to education for sustainable development, however some content and sub-topics indirectly speak to ESD.

4.8.3 Pedagogies used to teach Chemistry and how they link to ESD

- Generally, the pedagogies used by teachers were teacher centred and characterised by delivery of factual knowledge.
- It was observed that teachers mostly used questions to promote participation and interactions in their lessons. For example, Teacher TE1 used a question to encourage learner participation in the lesson on Extraction of Metals Specifically Zinc.
- The teachers used activities and questions of low cognitive level to engage learners.

- The topics presented opportunities to use the environment during the lesson but teachers preferred methods such as teacher exposition, discussion and question and answer limited the opportunities to explore the environment.
- The teachers acknowledged the need to link chemistry concepts to other disciplines such as biology, agricultural science and geography to enhance conceptual understanding.
- Teachers understood the importance of using localised examples or real life examples to help their learners appreciate chemistry as a subject. However, only 2 out of 12 observed lessons had opportunities provided through activities to help learners experience phenomena.

CHAPTER FIVE: DISCUSSION OF FINDINGS

5.1 Introduction

This chapter highlights the discussion of findings of the study. The discussion of the findings is structured around the following themes based on the objectives of the study: chemistry teachers' knowledge of sustainability issues; chemistry curriculum and sustainability issues; pedagogies used to teach chemistry; how they link to ESD principles and how best chemistry can be taught in line with ESD principles. In addition, the discussion is anchored on expansive learning as a theoretical framework of the study. The discussion of findings, the conceptual framework, the theoretical framework and literature provides a basis for the proposed model. Further, the discussion chapter culminates into the presentation of a proposed chemistry teaching model underpinned by the tenets of expansive learning as well as Education for Sustainable Development.

5.2 Chemistry Teachers' knowledge of Sustainable Development Issues

Chemistry teacher's knowledge of sustainability issues is important in promoting an encompassing and environmentally conscious approach to chemistry teaching. According to the findings indicated that most teachers had average knowledge of sustainability issues. About 56 teachers fell in the average category representing a 70.9 %. This was an indication that majority of the teachers were aware of sustainability issues. However, the hypothesis summary test in Table 4.7 indicated that the scores in the three domains of SD issues were not the same. This implies that chemistry teachers had different and understanding of SD issues in the three domains.

Sustainable development issues can be categorised into three domains that are important to the understanding of sustainable development. These include; environmental, economic and social issues. It suffices to mention that chemistry teachers' knowledge in the three categories was assessed. It was established that most of the teachers more than 60% had knowledge of sustainable development issues in the environmental domain. This was also confirmed by the results obtained from the pairwise comparisons of the three domain of SD in Figure 6. The environmental domain was highly ranked indicating teachers had more knowledge in this domain.

The For example, most teachers (86.1%) had knowledge on the role of ozone in protecting the earth from harmful UV rays. This was the case because the chemistry syllabi under the topic Non-Metals, subtopic Oxygen indicate some content on the importance of the ozone layer and the dangers of its depletion. Therefore, it was likely that the teachers' knowledge may have been influenced by the information in the syllabi. This resonates with the results by Zhu and Albe (2016) that participants have more knowledge and interest in the environmental domain of SD because they are affected by documents such as textbooks with sustainability information. Despite the fact that on average teachers had knowledge of sustainability issues in the environmental domain, their knowledge was low (27.8%) on the issue to do with "the common cause of pollution of streams and rivers". Similarly, only (29.1%) of teachers had knowledge on the environmental impact of various activities such as phone charging, baking, cooking nshima and flying an airplane from Dubai to Lusaka. This provides an opportunity to develop materials and encourage knowledge sharing activities to help improve teachers' knowledge.

Teachers generally had knowledge of sustainable development issues in the social domain. On the aspect to do with what have happened to the difference between the wealth of the richest and that of the poorest Zambians, majority of the teachers 78.5% possessed sufficient knowledge with regard to this issue. However, it is important to note that despite the teachers being in the education sector, the issue to do with the influence of education had a slightly lower percentage (63.3%) compared to other social issues. It can be assumed that teachers did not regard education as a social sustainability issue as such, they conceptualised its influence in various ways according to their own understanding. Table 4.6 also showed that the mean score for the social domain was 30.56 slightly lower than the mean score for the environmental domain.

The teachers showed less awareness of sustainability issues in the economic domain. About 21.5% of teachers got a correct score on an energy related sustainability issue. This was corroborated with results shown in Figure 6 that the economic domain was ranked the least in comparison to the environmental and social domains of SD. Additionally, the mean score for the economic domain was 24.68 as shown in Table 4.6. Despite the lower knowledge exhibited by teachers in this domain when compared to the environmental and social domains, teachers acknowledged the important role of energy as an economic issue in different areas of the economy. For example KN1 narrated that *"learners must be taught that energy controls everything. They should know the cost involved and act in a way that saves energy…".* It can be noted from this statement that teachers seemed to understand the implication of this aspect of the economic sustainable development issues.

It was clear from the findings that teachers were more knowledgeable in the environmental domain followed by the social and lastly the economic domain. This resonates with the findings from Hazim (2023) who pointed out that teachers' level of awareness in the three domains of sustainable development was ranked highest in the environmental then social and lastly economic. Shumba and Kampamba (2013), adds that a chemistry teacher is expected to show understanding of the link between science content and societal issues. This is supported by one of the underlying ideas of expansive learning, learning as transformation which promotes the fostering of solutions to pressing societal problems (Engestrom, 2000). However, Sund and Gericke (2020) argue that in most cases teachers' knowledge of SD issues comes from the curriculum and informal societal debates. Teachers can use their knowledge to encourage learners to look at complex issues related to sustainability and propose solutions using their chemistry knowledge. Jegstad and Sinnes (2015: 3) add that "we still insist that all chemistry teachers should be able to include the ecological, economic and social perspectives of the chemical topics they teach". Therefore, teachers can also give examples or scenarios that require learners to consider the environmental, social, and economic implications of chemical processes or products but do this they need an ESD informed chemistry teaching model to help guide ground their understanding of these issues.

The teachers' knowledge of sustainable development issues in the domains of SD was important to help ascertain their understanding of the concept of sustainable development. The adequate knowledge in the environmental and social domains seemed to translate into the correct description of sustainable development by 58.2% of chemistry teachers. It can certainly be pointed out that had an understanding of the concept of sustainable development. They were able to describe it according to their own understanding as follows;

> i. KN1: “the idea of using resources in a way that meets the current needs and preserve something that is not used at that particular time for future use”.
>
> ii. TE1: “…sustainable development refers to a form of development that can continuously go on. If it involves the use of resources for example, resources can be used without disadvantaging the future generations”.

The above descriptions of SD by teachers speak to the key elements of the definition of SD commonly used by the United Nations “meeting the needs of the present generation without compromising the ability of future generations to meet their own needs” (UN, 1987:17). The capacity building of the current generation to use the resources responsibly without compromising the ability of the future generations to meet their own needs is attainable through chemistry education. This is because chemistry as a discipline empowers learners with appropriate knowledge, skills and values on concepts such as pollution, recycling and other sustainable practices (Murti & Hernani, 2023). This knowledge if well utilised by learners is likely to contribute to meeting their own needs in their local communities as well as fostering a sustainable future. These key elements (building capacity of the present generation; using the resources responsibly) of the definition of SD are also reiterated in the 8NDP that, building appropriate capacity is largely dependent on the kind of education which empowers learners with the ability and knowledge to solve social problems (GRZ, 2022).

5.3 Chemistry Curriculum and Sustainability issues

The section discusses how the secondary school Chemistry curriculum integrates sustainability issues by focusing on the following aspects; Outcomes of the syllabi**,** Topics related to Sustainable Development in the curriculum, and the repackaging of Topics Related to Sustainable Development

5.3.1 Outcomes of the syllabi

Chemistry education is regarded as an appropriate discipline to be used for the incorporation of education for sustainable development (Tsakeni, 2018). This is because it provides context to the teaching/learning of sustainability issues. The analysis of the pure chemistry syllabus and science syllabus indicates that only one of the six general aims highlight sustainability issues. For example the pure chemistry syllabus (5070) general aim number six highlights the need to promote awareness through its sub-aims that:

i. *the study of chemistry is subject to social, economic, technological, ethical, cultural* influences *and limitations.*

ii. the applications of chemistry maybe both beneficial and detrimental to the individual, the community and environment.

iii. stimulate interest in and care for the local and global environment.

It is clear from the findings that the syllabi have made an attempt to position chemistry knowledge in a manner that it contributes to education for sustainable development. This is because aim number six of the curriculum underscores the importance of chemistry and its applications to humanity. However, it is cognisant of the harmful impact of chemistry on the environment. The aim is a call to empower learners through chemistry to contribute to both local and global environmental sustainability which is an important aspect of ESD. The expansive learning theory which informed this study advocates that learning must be transformed from isolated individuals to groups and networks (Engestrom & Sannino, 2010). But having only one aim out of six in the curriculum highlighting the contribution of secondary school chemistry to SD is not enough. This inadequacy was echoed by Shumba and Kampamba (2013) who pointed out that there is some presence of ESD issues in the secondary school chemistry syllabus. The observation by Shumba and Kampamba (2013) is an indication that there is less focus and emphasis on ESD issues in the secondary school chemistry curriculum. On the other hand it suffices to mention that the remaining five general aims focus more on the knowledge to be acquired without clearly showing the contribution of chemistry to the social, economic and environmental issues. This is important because chemistry underlies processes that are key for development but may also have social and environmental implications. To this effect, Lozano and Watson (2013) propose that there is need to re-orient the chemistry curriculum so as to make it more sustainability driven as well as strike a balance among knowledge, skills and values. Because this is critical in empowering learners to help their communities become more sustainable.

Most of the specific outcomes that speak to sustainability knowledge from grades 10 to 12 fell in the cognitive domain of learning. This seem to be a disconnect from the aspirations of the main aim which speak to learning outcomes that is associated with the promotion of emotions, attitudes and values. The general aim points out the importance of raising awareness which is nested in the affective domain while the specific outcomes largely dwell on the cognitive domain. Therefore, there is a discrepancy between the general aim and specific outcomes to be achieved in relation to sustainability issues. This is likely to make it difficult for teachers to make the appropriate decisions and choices as they select methods to use based on these specific outcomes.

5.3.2 Topics Related to Sustainable Development in the Curriculum

The Pure Chemistry and Science syllabi are structured in such a manner that topics run from grade 10 to 12. There are 10 main topics in both the pure Chemistry and Science syllabi. Of the 10 no single main topic is directly linked to education for sustainable development, however some content and sub-topics indirectly speak to ESD. This lack of clear emphasis on ESD in the curriculum is a gap that may undermine the contribution of secondary school chemistry to SD.

Chemistry is key in highlighting sustainability issues because a number of products in our daily lives are based on chemistry. Therefore, the curriculum ought to be intentional and clear about content linked to ESD. This is critical because it may help teachers to emphasise and enhance learners' appreciation of chemistry's role in society. Similarly, the expansive learning theory provides a framework for harnessing chemistry content and sustainability issues by promoting the teaching of concepts such as waste reduction, energy efficiency and the use of non-toxic substances. Engestrom (2000) argues that learning should not only be limited to the acquisition of knowledge, skills and attitudes codified by learning institutions but it should foster solutions to pressing societal problems. As such chemistry concepts grounded or rather informed by ESD is well poised to foster learners' ability to the mitigation of issues such pollution.

The findings revealed that certain concepts with real life relevance to learners were either not emphasised or completely left out in the curriculum. For instance, Energetics of Reactions a subtopic under chemical reactions is absent in the science syllabus. However, this component is key because it covers content to do with energy sources (fuels); effects of fuels on the environment such as pollution and greenhouse effect. Teacher 2 reiterated that "the curriculum must include content that is relevant to learners within their community. That is why there is no interest sometimes…how do you force me to learn things that I will not use". In a similar manner the topic Metals covers the extraction of metals and uses. But the curriculum is silent on the environmental friendliness of these extraction methods.

Looking further at the syllabi it became apparent that learners were expected to acquire both knowledge and skills so that they can appreciate the role of chemistry processes. Nonetheless, comparing is listed as the only science process skill to be developed by learners as they learn these concepts. This may not be adequate especially for chemistry content that should go beyond the classroom to the mining sector and the environment. This inadequacy was affirmed during a focus group discussion by Teacher 5 who stated that:

> *you see our syllabus is a challenge sometimes…it does not address the actual needs of society in most cases. On content were you expect emphasis on a lot of skills that is where you*

find few. You can tell that skills are just listed haphazardly, as long as knowledge is being pumped in this learner. It does not matter what and how they are going to use that information for.

Jegstad and Sinnes (2015), shares a similar view that the chemistry curricula has placed more emphasis on the content but neglected its application. The levels of learning criticises the notion of only focusing on promoting the acquisition of knowledge as revealed by this study but rather a holistic approach of focusing on knowledge, skills and values. It was established that there was less emphasis on skills and values especially on topics that are linked to ESD. This is a gap in the curriculum because it takes away the opportunities to engage learners hands-on so that they can apply this knowledge in their lives. This gap was also echoed by Teacher 1 who observed that:

... I can give you an example; on the use of NH_3 *to produce fertiliser and the reaction of Carboxylic acids and Alcohols to produce Esters and knowledge about making of Soaps that is the large chunk of knowledge that must be promoted in a country like ours. We expect to find a lot of skills and values that the learners are supposed to gain but that is where the curriculum puts less emphasis.*

On the other hand, the syllabi provide general reference points for the teachers to refer to or as points to emphasise but these points are not localised to bring in a Zambian context. This is contrary to the expansive learning theory which underscores the importance of contextualising concepts so as to enhance learners' appreciation for the subject.

5.3.3 Repackaging of Topics Related to Sustainable Development

The study revealed that teachers did not repackage the topics which contain ESD related content from the syllabi properly. In most cases the topics were just lifted from the syllabi and placed in the scheme of work without a clear link between the previous and current topic to be taught. It can certainly be pointed out that the teachers missed an opportunity to appreciate prior knowledge as well as sequence their work so that they move from known to unknown. Teachers' knowledge of sustainable development issues did not inform their decisions and choices made during scheme of work preparation. It was expected that they would sequence the topics in a way that will facilitate learners' connection of knowledge from concepts in a prerequisite topic to the other.

The suggested practical activities as well teaching/learning resources were also looked at to check how appropriate they were to engage learners on content that speak to ESD. The findings showed that charts and chalkboard were the most common teaching/learning resources planned for while practical activities were not specifically outlined in the scheme of work. This is an indication that teachers missed the opportunity in their planning to help learners interact with materials, engage them both hands-on and with the environment. Hopkinson and James (2010) narrates that there is a connection between the activities of STEM subjects and the social- economic aspects of SD. This is because engineering activities for example, usually encompass use of energy and other objects that can have an impact on the immediate environment. They emphasise that in most cases a greater part of the learning experiences of STEM activities occurs in the laboratories. Henceforth, learners' may encounter day to day issues related to SD as they conduct various laboratory activities. For this reason, a number of steps should be taken to ensure that laboratory activities are done in a way that promotes ESD. For instance, the following practices are highlighted by Hopkinson and James (2010:369) as "areas to reduce waste and improve resource efficiency including make sure nothing toxic goes down the drain, encourage group rather than individual experiments to minimise chemicals used, avoid leaving equipment running unnecessarily, keep hand-outs to a minimum, don't throw away equipment unless completely broken or damaged beyond repair"

Thus, it is important to embrace environmentally conscious laboratory based practices. These may include; responsible handling of chemicals, environmental impact of chemical processes, energy efficiency to mention only three, (Tsakeni, 2018) Further, the expansive learning theory suggests that, incorporation of practical activities and engaging learners hands-on are avenues to promote sustainable practices. Therefore, it is imperative to note that teachers should understand how the content, the outcomes, teaching /learning resources and activities interact as they scheme their work in order to promote ESD.

5.4 Pedagogies used to teach Chemistry and how they link to ESD Principles

This section discusses the following components: Facilitation of classroom learning and activities; engaging learners with the environment; teacher promotion of lifelong learning during lesson delivery; linking chemistry content to other disciplines and current issues; giving localised examples and real life examples.

5.4.1 Facilitation of Classroom learning and Activities

It was important to look at the approaches and methods used by teachers to teach content of the identified topics that are related to ESD in one way or the other. In order to ascertain this, the focus was to highlight how interactive the lessons were. The study showed that teachers mostly used questions to promote participation and interactions in their lessons. For example, TE1 used a question to encourage learner participation in the lesson on Extraction of Metals specifically Zinc. The teacher asked learners to write the reaction between Zinc Blende and Oxygen, learners came up with reactions *i* and *ii*.

$$i.\ 2ZnS_{(s)} + 3O_{2(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$$

$$ii.\ ZnO_{(s)} + CO_{(g)} \rightarrow Zn_{(s)} + CO_{2(g)}$$

It can be noted that the teachers made an effort to promote learner participation in the lesson through questions, however, there were no opportunities for exploration because the question was of low cognitive level. Otherwise the teacher would have probed further using higher order questions focusing on the effects of SO_2 and CO_2 on the environment. Additionally, the topic at hand presented opportunities for exploration through use of hands-on activities, case studies and guided discussions. Facilitating the lesson this is important in promoting critical thinking and problem solving skills among learners if they are able to create a link between chemistry content and societal issues. The idea of empowering learners with capacity to connect content to real life issues is supported by Gibbs (2021) who stated that when learners are exposed to experiences and content that gives them an opportunity to develop a link between content and real-world issues they become motivated to learn and ultimately acquire conceptual understanding. Further, this may imply that through ESD learners are likely to be well positioned to use skills beyond the classroom.

It was also observed that Teacher Exposition, Question and Answer as well as Discussion were the commonly used methods. This observation was at variance with the teachers' responses during the focus group discussion when they were asked to highlight the methods that they usually use in their lessons. The difference in what was observed and what was said is an indication that although chemistry teachers highlighted a number of methods such as Question and Answer, Demonstration, Discussion, Problem Solving and Discovery as appropriate for teaching ESD related topics they needed further guidance. Findings of the study seem to suggest that teachers are aware of a number of methods and they know which methods are appropriate for a particular topic. But they lack a theoretical underpinned understanding of pedagogies that can be used to implement ESD in chemistry teaching (Burmeister et al., 2013). This perspective is also reiterated buy Quiroz-Martinez (2024) that despite the fact that teachers acknowledge the significance of incorporating sustainability issues into the teaching and learning they need more knowledge. Armstrong (2011) also underscores the expansive nature of ESD pedagogies. Thus, teachers should not only highlight the various methods but also strive to use methods that can foster collaboration among learners. By and large use projects to encourage the integration of knowledge from multiple disciplines and forge networks among learners, the community and the industry.

A closer look at the proposed methods of teaching planned for in the scheme of work also showed that same teaching methods were listed from week 1 to 13. Additionally, in instances teachers did not pay attention to the interaction among; learning outcomes, content and methods. For example; an outcome indicated "demonstrate" but methods of choice were Question and Answer; Teacher Exposition. It can be claimed that teachers tend to focus on the transferring of factual knowledge at the expense of promoting conceptual understanding and skills acquisition. This is supported by Sund and Gericke (2020) that teachers are more inclined to classroom based teaching and use of teacher-centred approach. Juntunen and Aksela (2012) advocated that there was need to redesign the Finnish course books in chemistry to integrate more sustainability practices and to highlight social sustainability issues so as to help teachers use student-centred pedagogical approaches.

The general picture from lesson observation was that learners were hardly engaged in hands-on activities. Only two lessons engaged learners in hands-on activities on the topic Acids, Bases and salts. The teacher played the role of a facilitator during the teaching and learning process. There was some aspect of monitoring learners as they worked in groups, encouraged peer-learning and asked probing questions. Despite the fact that most of the observed lessons did not use hands-on activities to engage learners, during the focus group discussion teachers revealed that learners learn well when they interact with materials. It can be inferred from the findings that teachers appreciate the important role of hands-on activities even if they did not use them. This discrepancy takes away from opportunities that teachers need to provide for learners to acquire knowledge, skills and values. The expansive learning theory emphasises the importance of using practical activities and projects to teach. Chemistry content teaching can benefit from practical activities designed in such a manner that promotes active learning, experiential learning and critical thinking while fostering a sense of responsibility towards sustainability.

5.4.2 Engaging Learners with the Environment

The environment whether virtual or physical is an important teaching/learning resource that must be utilised to enhance learners understanding of chemistry concepts. It is also critical to instil a sense of responsibility and appreciation of SD issues. It was established from the findings of this study that teachers lacked awareness of how to engage learners with the environment despite the opportunities presented by the topics they were teaching. In most cases teachers opted to highlight concepts using teacher exposition. This method does not promote active participation of learners in the lesson as such the learning process turns out to be teacher centred.

The topic of metal extraction presented an opportunity to promote an engaging discussion on the effect of SO_2 the environment. This would have led to understanding of pollution both air and land. The teacher neglected to take advantage of these concepts to allow learners to make observations of the physical school environment. For example learners would have been guided to observe the effect of acid rain as a result of dissolved SO_2 and CO_2 on the corrosion of iron sheets. Equally, the effect of acid rain on plants and how it affects soil fertility. These were opportunities that would have been used to explore further beyond the classroom. According (Burmeister et al., 2012) learners should be able to relate chemistry content learnt in class to their real life issues such as environmental pollution. This is because learning facts alone is not enough to equip learners with knowledge, skills and attitudes needed to deal with current complex issues such as climate change, biodiversity loss, pollution of water bodies and use of toxic substances.

In the same vain expansive learning theory advocates that chemistry teachers can connect classroom learning to issues in their community. For example, they can invite experts from environmental organisations and/or arrange field trips to industries. This is for the purpose of promoting experiential and multidisciplinary learning of chemistry concepts. It is expected learners' understanding of chemistry processes, their real life applications as well as their negative impact on the environment and society will be enriched. These experiences may provide learners with real-world examples of phenomena and enable them to take an active role in promoting sustainability. Equally ESD emphasises the need to promote a clear connection between science and society. Therefore it suffices to mention that chemistry education can help address challenges such waste management and pollution in the communities when learners are empowered with knowledge, skills, values and attitudes. Learners can learn about the chemical composition of various types of waste, explore recycling techniques, and understand the environmental concerns of incorrect waste disposal (Tsakeni, 2018).

5.4.3 Linking Chemistry Content to other Disciplines and Current Issues

Chemistry is said to be a central science because it is related to a number of disciplines (Bridges, 2015). The study revealed that some teachers were able to link chemistry content to other disciplines such as Biology, Agricultural Science and Geography. During lessons on extraction of metals, acids, bases and chemical reactions specifically energy sources (fuels). For example, the effect of acid rain on the plants was linked to Biology, while the concept of fuels related to Geography. The teacher used learners understanding of transpiration to illustrate how the root system and the wax cuticle of the leaves of a plant affected by acids as a result of gaseous emissions of CO_2 and SO_2 from the mining industries.

It can be noted that the teacher was aware of the need to enhance learners understanding by using concepts from Biology and Geography. Sund and Gericke (2020) points out that ESD envisages the integration of knowledge from different disciplines. This multidisciplinary approach calls for chemistry teachers to work with teachers from other disciplines to explore the connections between chemistry and other subjects such as Biology, Environmental science, and other social-economic issues. It is likely that learners will be able to understand the implications of chemical processes on the wellbeing as well as be encouraged to consider the social, economic, and environmental issues. However, teachers only highlighted the connection between chemistry and other disciplines using teacher exposition. The challenge with this approach is that it does not encourage learner's active participation in the lesson. It usually promotes rote learning and memorisation of ideas. For this reason teachers missed an opportunity to engage learners' hands-on using activities, higher order questions and projects. Eilks (2015) indicates that ESD reorients pedagogies to focus on learner centeredness, experiential learning and skills-based learning. Regardless of the knowledge teachers had exhibited on the SD issues, it did not translate into classroom decisions and actions.

5.4.4 Giving Localised and Real Life Examples

It was observed that teachers made effort to give localised or real life examples in order to help the learners understand the concepts that were being presented. When Teacher NC1 was teaching the topic Acids, Bases and Salts; subtopic identification of acids, the teacher engaged learners through a question on the importance of knowing the acidity of the soil. This aspect gave the teacher an opportunity to talk about the use of fertilisers in Agriculture as well as highlighting the role of Nitrogen Chemicals of Zambia (NCZ) in the production process. The expansive learning theory also emphasises the importance of understanding actions within a specific context. This implies that chemistry teaching should endeavour to relate chemical concepts to real-world applications and societal issues. For example, when discussing the properties of materials, teachers can highlight the environmental impact of different materials and encourage learners to think critically about the choices they make in terms of sustainability.

It can be deduced from the findings that the observed teachers, understood the importance of using localised examples of real life examples to help their learners appreciate Chemistry as a subject. However, they did not provide more opportunities through activities or use of other appropriate methods so that learners experienced phenomena first hand. It suffices to comment that teachers need specific pedagogical content knowledge and tools to effectively teach chemistry content related to SD, this is because appropriate ESD informed pedagogy can help the teacher to understand their content, context and choose the best methods to use (Burmeister et al., 2013; Gibbs,2021).

5.5 Proposed ESD Chemistry Teaching Model

This component of the discussion chapter presents a proposed Chemistry Teaching model anchored on Education for Sustainable Development and expansive learning theory. The model Figure 9, is considered to be a guide to the chemistry teachers to meaningfully explore the chemistry topics that speak to SD. It is also expected that conceptual understanding would be fostered in a quest to equip learners with knowledge, skills and values necessary to address the social, economic and environmental challenges. The model has three key areas that converge on the chemistry curriculum through to societal transformation and ultimately lead to SD. These are; chemistry content, Learning outcomes, Pedagogy and learning environment. These aspects must interact and be harnessed together during the teaching/learning process. It is envisioned that this interaction will lead to the acquisition of knowledge, skills and values by learners necessary for application of chemistry in real life scenarios. This in turn may enhance the contribution of secondary school chemistry to the environmental, social and economic aspects of SD.

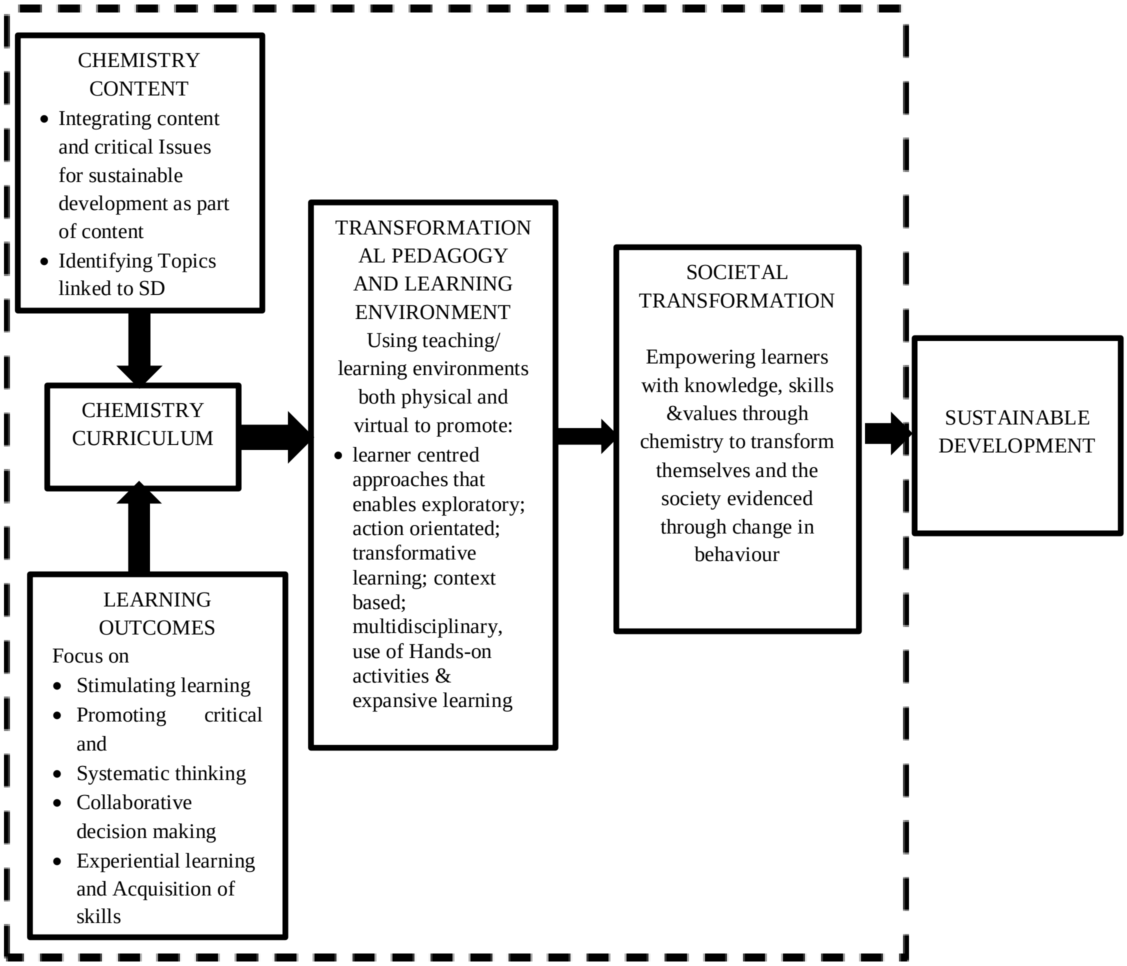

Figure 9: Proposed ESD Chemistry Teaching Model

Chemistry Content

In the first place chemistry content is a key element that should be used as an avenue to integrate SD related knowledge the curriculum. This must include but not limited to critical issues such climate change, sustainable consumption and production as well as risk reduction (UNESCO, 2012). It is also imperative that the topics that contain that SD related content should to be identified explicitly and these include; introduction to Chemistry; Acids bases and Salts; Chemical Reactions; Metals; Non-Metals and Organic Chemistry. Jegstad and Sinnes (2015) narrates that chemistry content knowledge is essential for understanding sustainability issues. Thus, the model makes it intentional and clear that the teacher must be aware of content which is related to SD in the curriculum as well as show understanding of sustainability issues that can be integrated as part of chemistry content. However, Shadiq (2020) argues that the realisation of ESD in chemistry does not always mean having specific problems of chemical sustainability added to the curriculum as part of content. This implies that ESD can be achieved without necessarily adding new content to the curriculum, but critically analyse the curriculum and locate content with chemical sustainability implications. Therefore, it important for chemistry teachers to emphasis more on learning outcomes that focus on equipping learners with knowledge, skills and attitude for them to act sustainably within their local environment.

Learning Outcomes

This is a second aspect of what needs to be considered by each and every teacher during preparation. The teacher should ask himself or herself the question *"what do I want learners to acquire and do to promote personal and societal transformation"?* Answering this question is imperative in ensuring that the outcomes are concise and achievable. The learning outcomes should be set in such a way that they provide opportunities for learners to be hands-on, experience phenomena, work collaboratively and consequently lead to critical and systematic thinking (Burmeister et al., 2013). It suffices to mention that this area of the model enables the teacher to repackage the content as well as create a basis for the selection of methods to be used.

Pedagogies and Learning Environment

The component indicates some of the pedagogies that are typical to ESD. Teachers understanding of curriculum content and learning outcomes that focuses on equipping learners with knowledge, skills and attitude for them to act sustainably is a precursor for the transformation pedagogy and learning environment that lead to transformative teaching and learning of chemistry curriculum. Teacher must strive to give localised and real life examples in order for learners to appreciate the relevance of chemistry in their lives. Jegstad and Sinnes (2015:8) states that "chemistry must be taught in a relevant context, in order to promote full understanding of current sustainability issues". Similarly, the theoretical frame work of the study emphasises that the teaching of chemistry concepts must be done in an expansive manner. In a manner that allows chemistry teaching to go beyond the classroom. This implies that a multidisciplinary approach should be used by drawing on examples and analogies from the day to day activities as well as the local community. Additionally, the teacher can collaborate with experts from different sectors and consult knowledge from other disciplines to help explain chemistry concepts.

When learners are exposed to learning from different experts and disciplines they value collaboration. This will foster and promote peer interaction, active participation in their own learning as well as acquisition of knowledge, skills and values. Teacher should create all forms of learning environments that are interactive and promotes active participation of learners in their own learning (Lotz-sistka et al, 2019). This environment can be physical or virtual and provides a chance for the teacher to leverage opportunities to help present concepts in an interactive manner. The ESD underpinned pedagogies and learning environments are key for transformative learning which a critical element for societal transformation.

Societal Transformation

The expansive learning theory stresses that, learning undergoes a number of cycles where learning experiences internal contradictions and learners depart from established norms. This departure fosters collective change of approach to the activity (Engestrom, 1987; Engestrom & Sannino, 2010). This is the underlying principle for transformative teaching and learning of chemistry anchored within ESD. Chemistry teachers should therefore focus on societal transformation by empowering learners with knowledge, skills, values and attitudes to solve local problems in their communities using their conceptual understanding of chemistry concepts. Eventually this may contribute to learners acting sustainably within their local communities and in long run contribute to societal transformation and sustainable development.

It is clear that the model presents teaching of chemistry within the ESD paradigm that focus on enhancing teachers' capacity in terms of;

a. being knowledgeable of the topics that directly and indirectly speak to sustainable development issues and awareness of the role of chemistry to contribute to sustainable development

b. focusing on learning outcomes that promote experiential learning, acquisition of skills and critical thinking

c. creation of interactive learning environments through the use of the pedagogy that are action oriented, transformative and context based.

In summary, it is important to make mention that the focus of the proposed model is the teaching and learning of chemistry for societal transformation, as opposed to the current model that focuses on knowledge acquisition for passing of the examination and certification.

Evaluation of the Model

The model was evaluated by the researcher through a discussion with the chemistry teachers. The evaluation process was done as the last activity of the study. Six chemistry teachers whose knowledge of SD issues was assessed through the ASK tool, took part in lesson observations, interviews and focus group discussion participated in this process. The model was printed out and distributed the six teachers to study it and they were given three days to do so. Thereafter, they were invited to the district resource centre for discussion. They indicated that the model is feasible and it can contribute to the enhancement of pedagogies and improve the teaching of chemistry. Teacher 1 narrated that *"highlighting the link between pedagogies, learning content and the curriculum serves as a good point because it enhances the value of chemistry in our immediate environment".* They further expressed optimism that the model is likely to:

i. Improve teaching strategies, foster the acquisition of knowledge, skills and values. The model as a teaching tool emphasises the importance of using pedagogies that promote active learner participation, encourage the use of hands-on activities, experiential learning and transformative learning. Juntunen and Aksela (2012:5) commend that:

> *chemistry teaching with ESD includes new kinds of activities that teach chemistry in context-based social environments – activities that teach students to act for nature based on their own ideas and experiences. Projects integrated into the subject of chemistry offer learners opportunities to develop informed personal competencies without first having to define specific long-term goals, or determine where or how these competencies should be used.*

ii. Remind chemistry teachers to give localised and real life examples of the application of chemistry to sustainable issues that will facilitate learners to engage and take sustainable action in their communities. This is a student centred approach to learning of chemistry concepts. It can be highlighted that student-centred approach to learning is likely to be "meaningful when topics are relevant to learners lives, needs and interests when the students themselves are actively engaged in creating, understanding and connecting to knowledge" (Eliam & Trop, 2010:16).

iii. Enhance the relationship between chemistry knowledge and other subjects and understanding of its application in various fields such as agriculture, environmental management, sanitation and manufacturing. This is the aspiration of STEM education in Zambia.

On the other hand, teachers cited some issues that might hamper the effective implementation of the model such as; class size, time and other classroom dynamics. These factors are likely to hamper the effective implementation of the models in the following ways:

a. Class size in most cases determines the methods that a teacher is likely to use to deliver the lesson. A small class size enables teachers to utilise a learner centred approach during chemistry lessons. For example Teacher 3 stated that *"it is easy for me to engage learners in a practical activity when the number is small in class. At least I can effectively monitor what they are doing and provide individualised help when needed".* On the contrary, large class size may present some challenges to enhance active participation in the lesson or use the physical environment as a teaching resource. This is because close monitoring of what the learners are doing may not be effective.

b. Time is critical in chemistry lesson planning and delivery. The time available and allocated to a subject usually determines the choice and decisions made by the teacher in terms of teaching methods and resources utilised. During the discussion, Teacher 1 said *"we normally, focus on completing the content in the syllabus as a result we just use teacher centred approaches so that we do not lose on time. Looking at this proposed model, it may require me as a teacher to plan for hands-on activities that require enough time".*

c. Classroom dynamics are as result of the interaction among the teachers, learners and the physical environment. The interaction of these three aspects is important in ensuring effective teaching and learning (Ahmed, 2024). The teacher facilitates this interaction by making sure that resources are well prepared and the classroom is well organised.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter sums up the study, draws conclusions from the key findings as well as make recommendations to practice and future researchers.

6.2 Conclusion

The study revealed that majority of the Chemistry teachers had knowledge on sustainable development issues. It was also established that teachers showed more knowledge in the environmental component of sustainable development compared to the social and economic components with least awareness being exhibited in economic component. Similarly, teachers showed more knowledge on issues that were closely related to Chemistry such as ozone. They also on average understood the description of sustainable development though they conceptualised it differently.

Chemistry syllabi also pointed out the role of chemistry in contributing to sustainable development through one of its major aims. However, there is a mismatch between the aim and the specific outcomes seemingly derived from it. This is because the aim is nested in the affective domain while the specific outcomes are in the cognitive domain. It is clear that the curriculum has focused more on the acquisition of chemistry knowledge rather than its application. Out of the 10 main topics in the syllabus none was directly related to SD though sub topics were implicitly linked to SD.

Teachers made an effort to promote learner participation in their lessons through questions. But there were no opportunities for exploration because the questions were of low level of learning outcomes. This was coupled with the use of pedagogies that did not provide opportunities to engage learners hands-on; use the environment as part of the teaching resource; create a meaningful link between chemistry content and other disciplines as well as use of local and real life examples.

It can be concluded that even though the teachers exhibited knowledge about sustainable development issues they seemed not to know how best to present chemistry content related to ESD so as to enhance conceptual understanding and foster application of chemistry content to real life issues. They mostly used teacher centred approaches and did not realise the importance of helping learners appreciate the importance of chemistry in their lives. This approach of teaching and learning of chemistry could only lead to certification as opposed to transformative learning which is a key element of sustainable development.

The discussion of the finding within the context of expansive learning theory and pillar of ESD the study proposed an ESD chemistry teaching model for the enhancement of teaching and learning of chemistry through the formulation of learning outcomes, creation of learning environments and use of pedagogy that focus on transformative learning and societal transformation.

6.3 Recommendations

In view of the findings of the study, the recommendations are made to Chemistry education practice (Chemistry teachers, curriculum developers) and future research.

6.3.1 For Practice

- Chemistry teachers should use pedagogies that promote active participation, use of the environment, local materials and examples.
- There is need to build chemistry teachers' capacity through continuous professional development (CPDs) so as to enable them translate their knowledge on sustainable development issues into classroom decisions and actions.
- The curriculum developers should align the major aim that speaks to SD with specific outcomes in order to clearly guide the teachers as they implement the curriculum.
- Curriculum developers should include one major topic in the curriculum that directly and intentionally addresses SD issues.
- Teachers should employ multidisciplinary teaching approach to teach ESD related Chemistry topics to leverage partnerships and promote conceptual understanding.

6.3.2 Future Research

- Future research must endeavour to test the effectiveness of the developed Chemistry teaching model in the classroom over time.

- The study recommends that future research must utilise the model and include learners as part of the sample size so as to appreciate their envisaged importance of chemistry knowledge in their lives.
- A longitudinal study should be done to follow teachers and their learners over time that might have taught and learnt content related to SD using the proposed ESD chemistry teaching model.

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APPENDICES

DATA COLLECTION INSTRUMENTS

APPENDIX A: ASSESSMENT OF SUSTAINABILITY KNOWLEDGE (ASK) TOOL FOR TEACHERS

INSTRUCTIONS:

- Indicate your appropriate answer by **marking** with an **(X)**
- Do **not** write your name on this paper

1. What is the most common cause of pollution of streams and rivers?

a. Dumping of garbage by cities
b. Surface water running off yards, city streets, paved lots, and farm fields
c. Litter near streams and rivers
d. Waste dumped by factories
e. Don't know

2. Ozone forms a protective layer in the earth's upper atmosphere. What does ozone protect us from?

a. Acid rain
b. Climate change
c. Sudden changes in temperature
d. Harmful UV rays
e. Don't know

3. Which of the following countries is the current biggest emitter of the greenhouse gas carbon dioxide?

a. China
b. Sweden
c. Brazil
d. Japan
e. Don’t know

4. Which of the following is the most commonly used definition of sustainable development?

a. Creating a government welfare system that ensures universal access to education, health care, and social services
b. Setting aside resources for preservation, never to be used
c. Meeting the needs of the present without compromising the ability of future generations to meet their own needs
d. Building a neighbourhood that is both socio-demographically and economically diverse
e. Don’t know

5. Which of the following is an example of sustainable forest management?

a. Setting aside forests to be off limits to the public
b. Never harvesting more than what the forest produces in new growth
c. Producing lumber for nearby communities to build affordable housing
d. Putting the local communities in charge of forest resources
e. Don’t know

6. Of the following, which one would be considered living in the most environmentally sustainable way?

a. Recycling all recyclable packaging
b. Reducing consumption of all products
c. Buying products labelled "eco" or "green"
d. Buying the newest products available
e. Don't know

7. Which of the following is a leading cause of the depletion of fish stocks in lake Bangweulu?

a. Fishermen seeking to maximize their catch
b. Reduced fish fertility due to genetic hybridization
c. River pollution
d. Global climate change
e. Don’t know

8. Higher levels of education generally lead to...

a. Lower levels of voter turnout

b. Greater annual earnings
c. Larger family size
d. Higher self-esteem
e. Don’t know

9. Which of the following is the most commonly used definition of economic sustainability?

a. Maximizing the share price of a company's stock
b. Long term profitability
c. When costs equal revenue
d. Continually expanding market share
e. Don’t know

10. Which of the following is the primary reason that fuel prices have risen over the last several decades in Zambia?

a. Growing number of gas stations owned by large companies
b. Increasing oil discoveries overseas
c. Higher rates of tax on oil
d. Increasing global demand for oil
e. Don’t know

11. Many economists argue that electricity prices in Zambia are too low because…

a. They do not reflect the costs of pollution from generating the electricity
b. Too many suppliers go out of business
c. Electric companies have a monopoly in their service area
d. Consumers spend only a small part of their income on energy
e. Don’t know

12. Over the past 30 years, what has happened to the difference between the wealth of the richest and poorest Zambians?

a. The difference has increased
b. The difference has stayed about the same
c. The difference has decreased

d. Don’t know

13. Which of the following is the best example of environmental justice?

a. Urban citizens win a bill to have toxic wastes taken to rural communities
b. The government dams a river, flooding Native American tribal lands to create hydro- power for large cities
c. All stakeholders from an indigenous community are involved in setting a quota for the amount of wood they can take form a protected forest next to their village
d. Multi-national corporations
e. I don’t know

14. Put the following list in order of the activities with the largest environmental impact to those with the smallest environmental impact.

A. Keeping a cell phone charger plugged into an electric socket for 12hrs.

B. Baking a cake

C. Cooking Nshima

D. Flying in a commercial airplane from Lusaka to Dubai

a. A, C, B, D
b. D,A,B,C
c. D, C, B, A
d. D, B, C, A
e. Don’t know

15. In Zambia what do we currently do with the waste generated from the mining industries?

a. Sell it to other countries
b. Dump it in landfills
c. Store and monitor it
d. Re-use it
e. Don’t know

THE END

APPENDIX B: SEMI-STRUCTURED INTERVIEW SCHEDULE

1. What is your understanding of the following concepts?

   a. Sustainable Development (SD)
   b. Education for Sustainable Development (ESD)

1. What topics in the pure chemistry (5070) and Science (5124) syllabi relate to sustainable development?
2. Describe education for sustainable development learning activities that you know. Which ones do you usually engage your learners in during your chemistry lessons?
3. What challenges do you encounter as you use ESD learning activities during your lessons? Suggest some solutions to mitigate these challenges.
4. How do you integrate issues for SD in your chemistry lessons?
5. Do you engage learners in project work? Yes/No
6. If yes what follow up activities do your learners do after engaging them in project work?
7. How can you contextualise topics like introduction to chemistry in your lessons?
8. What illustrations do you use to help you explain concepts related to SD identified in (2).
9. What stakeholders can you bring on board to effectively teach topics related to SD?

THE END

APENDIX C: FOCUS GROUP DISCUSSION SCHEDULE

1. How do you make sure that the methods used in your lesson helps you to achieve the set objectives?
2. Were the methods used in your lesson provide an opportunity for learners to acquire knowledge, skills and attitudes?
3. Did the methods used help learners to use knowledge and skills to address environmental and social challenges in their community?
4. In your opinion what method enhanced learner's knowledge, skills and attitudes to participate solving sustainable development challenges?
5. Based on your experience and classroom interaction with your leaners were methods used appropriate to address learner's needs.
6. What methods do you usually use in your lesson? Are they learner centred?
7. Do the methods you use to teach chemistry help empower learners with the ability to adjust to climate change and other future challenges.
8. How did the methods used contribute to the following:
   a. Lifelong learning
   b. Holistic learning
   c. Transformative learning
   d. Integrated learning

9. Did you learn anything from this experience that will influence your teaching in future?

THE END

APPENDIX D: DOCUMENT ANALYSIS SCHEDULE

0 = Not at all   1= Barely 2 = Partially 3 = Definitely   4 = absolutely

Document	**Descriptors**	**Score**				
Syllabus	**Objectives /outcomes of the syllabus**					
	Are they promoting acquisition of knowledge?					
	Are they promoting acquisition of skills?					
	Are they promoting acquisition of attitudes?					
	Are they fostering respect for the environment?					
	Are they fostering learner's awareness of pollution					
	Are they fostering the 3Rs (Reduce, Reuse &Recycle)?					
	Do they reflect values learners need to acquire?					
	Do they fall in the cognitive domain?					
	Do they fall in the psychomotor domain?					
	Do they fall in the affective domain?					
	Do they foster application of knowledge?					
	Do they promote analysis					
	Do they foster evaluation?					
	Do they foster synthesis and innovation?					
	Topics in the syllabus					
	Is pollution one of the topics in the syllabus?					

	Is climate change explicit in the syllabus?					
	Are there topics in the syllabus that speaks to mining					
	Are the topics in the syllabus that speaks to energy?					
	Are there topics in the syllabus that speaks to agriculture?					
	Are there topics in the syllabus that speak to manufacturing					
	How many are these topics?					
	What topics are these --- --- --- --- ------------------------------------					
	What knowledge are learners expected to acquire in these topics?					
	What skills are learners expected to acquire?					
	What values do these topics envisage?					
Scheme of work	How is the Sequence of topics					
	What teaching/learning activities are frequently planned for?					
	How is the variety of teaching/learning					

	resources					
	Are there opportunities to engage learners with the environment?					
	Are there opportunities for the use of ICT?					
	What assessment strategies are frequently planned for?					

APPENDIX E: LESSON OBSERVATION SCHEDULE

TOPIC:

Teacher ID…………………….

Class……………..

1. The teaching approaches used by the teacher during the lesson.

- *Are they interactive?*

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- *Are they participatory?*

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- *Are they action oriented?*

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- *Do they promote exploration?*

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- *Are they inspiring to leaners to act for sustainability (let us break this down into descriptors acting sustainability)*?

2. The teaching strategies (methods) used by the teacher in the lesson

- *Problem solving*…………………………………………………………………

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- *Experiments/practical activities*…………………………………………………….

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- *Projects*……………………………………………………………………………

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- *Field work*…………………………………………………………………………

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  …………………………………………………………………………………………

- *Experiential learning/Hands-on activities*………………………………………..

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- *Peer learning and role play*…………………………………………………………

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- *Case studies/stories*……………………………………………………………….

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- *Discussion/group work*…………………………………………………………..

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- *Cooperative teaching*……………………………………………………………….

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- *Teacher exposition/lecture…………………………………………………………*

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3. The linking of the topic to real life and current issues
   - *Did the teacher link content to real life issues to promote core competencies?*

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- *Did the teacher connect content to local issues to enhance understanding?.*

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- *Did the teacher show the relevance of the topic to learners needs*?.

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- *Did the teacher integrate environmental issues ((climate change, risk and disaster management, pollution and waste management)?*

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- *Did the teacher integrate developmental issues (energy, innovation and creativity, culture and global citizenry)*?

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4. The linking of the lesson/topic to other disciplines

- *Did the teacher promote critical thinking?*

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- *Did the teacher foster collaboration?*

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- *Did the teacher promote integrated problem solving*

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- *Did the teacher promote inter-disciplinary collaboration (multi-disciplinary)*

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- *Did the teacher promote creation*

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5. Promoting life-long learning during the lesson

- *Problem solving*

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- *Promoting critical thinking and creativity through questions*

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- *Fostering learner adaptability and reflection*

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- *Use of information communication technologies (ICT)*

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- *Promoting independent thinking and learning through projects*

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6. Facilitation of classroom learning and activities

- *Teaching from known to unknown*

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- *Teaching from simple to complex*

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- *Use of the principle of scope and sequence*

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- *Selection and use of appropriate teaching/learning materials, analogies and illustrations*

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- *Using activities to promote conceptual understanding*

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- *Using context based examples to clearly explain the concept*

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- *Engaging learners using higher questions*

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7. The teaching approaches used by the teacher during the lesson.

- *Are they learner centred and interactive?*

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- *Are they participatory?*

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- *Are they action oriented?*

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- *Do they promote exploration?*

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- *Are they inspiring to leaners to act for sustainability*?

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8. The teaching strategies (methods) used by the teacher in the lesson

- *Problem solving*

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- *Experiments/practical activities*

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- *Projects*

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- *Field work*

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- *Experiential learning/Hands-on activities*

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- *Peer learning and role play*

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- *Case studies/stories*

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- *Discussion/group work.*

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- *Cooperative teaching*

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9. The linking of the topic to real life and current issues

- *Did the teacher link content to real life issues to promote core competencies?*

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- *Did the teacher connect to enhance understanding?*

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- *Did the teacher show the relevance of the topic to learners needs*?

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- *Did the teacher integrate developmental issues (climate change, risk and disaster management, pollution and waste management, energy, innovation and creativity, culture and global citizenry)*

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10. The linking of the lesson/topic to other disciplines
    - *Did they promote critical thinking?*

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- *Did they foster collaboration?*

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- *Did they promote integrated problem solving*

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- *Did they promote inter-disciplinary collaboration (multi-disciplinary)*

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11. Promoting life-long learning during the lesson

- *Problem solving*

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- *Promoting critical thinking and creativity through questions*

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- *Fostering learner adaptability and reflection*

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- *Use of information communication technologies (ICT)*

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12. Facilitation of classroom learning and activities

- *Teaching from known to unknown*

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- *Teaching from simple to complex*

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- *Use of the principle of scope and sequence*

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- *Selection and use of appropriate teaching/learning materials, analogies and illustrations*

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- *Using activities to promote conceptual understanding*

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- *Using context based examples to clearly explain the concept*

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- *Engaging learners using higher questions*

THE END

APPENDIX F: STUDY APPROVAL

THE UNIVERSITY OF ZAMBIA
DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

Great East Road Campus | P.O. Box 32379 | Lusaka10101 | Tel: +260-211-290 258/291 777 **Fax:** (+260)-211-290 258/253 952 | **E-mail:** director.drgs@unza.zm | Website: www.unza.zm

APPROVAL OF STUDY

IORG No. 0005376
HSSREC IRB No. 00006464

14th November, 2022

REF NO. HSSREC:-2022-OCT.013

Ms. Sara Chama,
The University of Zambia
School of Education,
P.O. Box 32379,
LUSAKA.

Dear Ms Chama,

RE: "EDUCATION FOR DEVELOPMENT: TRANSFORMING PEDAGOGIES FOR TEACHING SECONDARY SCHOOL CHEMISTRY IN NDOLA DISTRICT"

Reference is made to your submission of the protocol captioned above. The HSSREC resolved to approve this study and your participation as Principal Investigator for a period of one year.

REVIEW TYPE	ORDINARY REVIEW	APPROVAL NO. HSSREC:-2022-OCT-013
Approval and Expiry Date	Approval Date: 16th November, 2022	Expiry Date: 15th November, 2023
Protocol Version and Date	Version - Nil.	15th November, 2023
Information Sheet, Consent Forms and Dates	☐ English.	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	
Number of Participants Approved for Study		

Specific conditions will apply to this approval. As Principal Investigator it is your responsibility to ensure that the contents of this letter are adhered to. If these are not adhered to, the approval may be suspended. Should the study be suspended, study sponsors and other regulatory authorities will be informed.

CONDITIONS OF APPROVAL

- No participant may be involved in any study procedure prior to the study approval or after the expiration date.
- All unanticipated or Serious Adverse Events (SAEs) must be reported to HSSREC within 5 days.
- All protocol modifications must be approved by HSSREC prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address.
- All protocol deviations must be reported to HSSREC within 5 working days.
- All recruitment materials must be approved by HSSREC prior to being used.
- Principal investigators are responsible for initiating Continuing Review proceedings. HSSREC will only approve a study for a period of 12 months.
- It is the responsibility of the PI to renew his/her ethics approval through a renewal application to HSSREC.
- Where the PI desires to extend the study after expiry of the study period, documents for study extension must be received by HSSREC at least 30 days before the expiry date. This is for the purpose of facilitating the review process. Documents received within 30 days after expiry will be labelled "late submissions" and will incur a penalty fee of K500.00. No study shall be renewed whose documents are submitted for renewal 30 days after expiry of the certificate.
- Every 6 (six) months a progress report form supplied by The University of Zambia Humanities and Social Sciences Research Ethics Committee as an IRB must be filled in and submitted to us. There is a penalty of K500.00 for failure to submit the report.
- When closing a project, the PI is responsible for notifying, in writing or using the Research Ethics and Management Online (REMO), both HSSREC and the National Health Research Authority (NHRA) when ethics certification is no longer required for a project.
- In order to close an approved study, a Closing Report must be submitted in writing or through the REMO system. A Closing Report should be filed when data collection has ended and the study team will no longer be using human participants or animals or secondary data or have any direct or indirect contact with the research participants or animals for the study.
- Filing a closing report (rather than just letting your approval lapse) is important as it assists HSSREC in efficiently tracking and reporting on projects. Note that some

funding agencies and sponsors require a notice of closure from the IRB which had approved the study and can only be generated after the Closing Report has been filed.

- A reprint of this letter shall be done at a fee.

- All protocol modifications must be approved by HSSREC by way of an application for an amendment prior to implementation unless they are intended to reduce risk (but must still be reported for approval). Modifications will include any change of investigator/s or site address or methodology and methods. Many modifications entail minimal risk adjustments to a protocol and/or consent form and can be made on an Expedited basis (via the IRB Chair). Some examples are: format changes, correcting spelling errors, adding key personnel, minor changes to questionnaires, recruiting and changes, and so forth. Other, more substantive changes, especially those that may alter the risk-benefit ratio, may require Full Board review. In all cases, except where noted above regarding subject safety, any changes to any protocol document or procedure must first be approved by HSSREC before they can be implemented.

Should you have any questions regarding anything indicated in this letter, please do not hesitate to get in touch with us at the above indicated address.

On behalf of HSSREC, we would like to wish you all the success as you carry out your study.

Yours faithfully,

Dr. J. I. Ziwa

DR. J. I. Ziwa

ACTING CHAIRPERSON
THE UNIVERSITY OF ZAMBIA HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE - IRB

cc: Director, Directorate of Research and Graduate Studies
Assistant Director (Research), Directorate of Research and Graduate Studies
Assistant Registrar (Research), Directorate of Research and Graduate Studies

APPENDIX G: INTRODUCTORY LETTER FROM DEBS

All communications should be addressed to the District Education Board Secretary

Telephone: +260 212 613277/622047

In reply please quote:

No.........................

REPUBLIC OF ZAMBIA

MINISTRY OF EDUCATION

DISTRICT EDUCATION BOARD SECRETARY
P.O. Box 71970
NDOLA

3rd January 2023

TO: Headteachers
Secondary Schools
NDOLA DISTRICT

RE: AUTHORITY GRANTED TO CONDUCT RESEARCH: SARAH CHAMA, SIN 2019100908

Reference is made to the above subject matter.

This letter serves to introduce to you that authority has been granted to the above named to conduct research in project Education for Sustainable Development: Transforming Pedagogies for Teaching Secondary School Chemistry in Ndola District".

You are expected to ensure that She carries out research ethically and also in a way that does not interfere with teaching and learning.

Your usual co-operation will highly be appreciated.

Chanda Chewe
District Education Board Secretary
NDOLA DISTRICT
/rkc