CHAPTER ONE: INTRODUCTION

1.0. Overview

This chapter provides information on the general background to the study, the problem, purpose and objectives of the study, research questions, significance of the study and finally presents limitations and delimitations of the study; with the definition of terms highlighted at the end of the chapter.

1.1. Background to the Study

The World over, science education has been viewed as one vehicle that may enhance sustainable development (Burns, 2001; Lamanauskas, 2007). However, all countries worldwide have their own problems and unique position on school science education, which in turn, needs to be researched in different ways to improve understanding and approaches to the educational process (Lamanauskas, 2007).

One major difficult pupils experience in science classes, particularly chemistry and chemistry-based components such as environmental science concerns the scientific concepts learnt in class having no immediate link to what they see and use, or in short, everyday experiences (Dahlin, ∅stergaard & Hugo, 2009). To most pupils, chemistry is all about invisible concepts, hence has a general reputation for being difficult. Consequently, pupils find it hard to achieve some correct understanding of the many scientific concepts as they don't make connections between what they learn and everyday life. Pupils find their school science so unfamiliar with their day to day experiences in common use in homes, the environment and many related places and yet there is relevant science behind many of these everyday experiences.

As observed by Holbrook (2005, p. 1), “stress on understanding internal concepts within the chemistry subject itself; concepts such as atomic structure, or chemical bonding, which are almost universally section headings in chemistry classes”, tend to override issues in daily life. Issues of pollution (as related to our environment and health), purity of substances (as related to expiry dates of foods, drugs and also safe drinking water), acids, bases and salts (in relation to the variety of chemical substances that are used daily) as well as concepts on saponification in relation to such ideas as soap-making, for instance, do not seem to be linked to real life experiences of most pupils. However, such ideas and concepts would be a more relevant starting point if only they could be selected to capture pupils’ interest in science and enhance their appreciation of how the subject plays a role in people’s lives (Holbrook, 2005).

Phenomenon-based science education, Context-based science education, Scientific literacy, Inquiry-based science education all argue that pupils ought to link what they learn in science classes with what they see and interact with in everyday life as this has a potential benefit of them seeing the relevance of the sciences taught (Anderson, 2002; Bennett, Gräsel, Parchmann, & Waddington, 2005; Bennett, Lubben, & Hogarth, 2006; Dahlin, ∅stergaard & Hugo, 2009; Osborne & Collins, 2000; ∅stergaard, Dahlin, & Hugo, 2007). In tandem with the view held by these scholars, it is acknowledged that if pupils will not see the immediate link of chemistry to their everyday lives, they will continue viewing the subject as a difficult, abstract and theoretical. Consequently, pupils may be left with the option to memorise scientific concepts for purposes of passing examinations only, after which and beyond the compulsory period, they will drop the subject in preference to other fields of study

(Osborne & Collins, 2000; Bennett et al., 2005; Holbrook, 2005). On the other hand, "if pupils can connect ideas from science class to personally-relevant contexts, they will be poised to revisit these ideas outside of class", therefore understand the material better as well as improve attitudes towards chemistry (Linn, 2000, p. 783 as cited in King, Bellocchi, & Ritchie, 2007, p. 372; King, Bellocchi, & Ritchie, 2007).

In the Zambian context and quest for sustainable development, the apparent lack of the link between school science and its real life applications, may have contributed to pupils' perception that science, particularly chemistry, is difficult, hence lack of interest in and appeal for the subject. Indeed, Zambia, like many African countries, faces a variety of socioeconomic and developmental challenges, whose envisaged mitigation may require, in part, a scientific educational platform to produce the much needed practical scientists and technologists in many fields. To fulfill its aspirations for scientific and technological development, the Ministry of Education (MoE), among other efforts, has identified some high schools to specialise more explicitly in sciences and act as centres of excellence (MoE, 1996). These academic efforts, it is hoped, will augment the output of trainable science-based individuals needed by higher education such as the Universities and colleges as well as industry (MoE, 1996). In accordance with this desire, one such high school has a mission statement that reads "to provide the best senior/high school education to the most intellectually promising young Zambians and moulding them to become the finest scholars/professionals in fields of science and technology" (David Kaunda Technical High School, n.d.). According to Morrison (1998, p.V) ''in Ghana, a group of educators, scientists, teachers, students and industrialists became concerned at the lack of connection of school science with products found in every African villages such as beer, charcoal, fertilisers and aluminium pots.'' In the same vain in the current study, pupils' knowledge and understanding of saponification needed to give them (pupils) a connection to the real world related to such products as soap or indeed the soap-making activity in daily context as the essence of the experience. This, to some extent, serves as indispensable proof of meaningful learning and concrete understanding of scientific concepts.

Inevitably, for the envisaged path to technological development to occupy the relevant centre stage in education, pupils should acquire basic science which offers potential benefits to them and on which technological development depends (Harding & Apea, 1990). Preparing pupils for everyday life (in terms of life choices and chances, for instance) is not only an education's primary goal but central theme for learning (Roth & McGinn, 1997).

As a starting point, the quest for the attainment of scientific and technological development may be sustainably realised if pupils are able to appreciate and link science to its applicability in everyday life. This focus on the application of science develops pupils' capacities to function as responsible participants in their everyday lives and is viewed to have a potential benefit of making pupils see and understand the relevance in the processes and products of scientific knowledge (Bennett, Gräsel, Parchmann, & Waddington, 2005; Holbrook, 2005; King, Bellocchi, & Ritchie, 2007). Many are such scientific concepts in chemistry like fermentation, saponification, oxidation, corrosion, sublimation, evaporation (the list is endless) with links to everyday life experiences. The scientific concepts could be transferred into learning experiences of pupils that mirror real life, hence encourage pupils to develop scientific understanding (King, Bellocchi, & Ritchie, 2007). Muzumara (2008) argues that the way the scientific concept is introduced to the pupils has a bearing on the subject as the pupils may either develop interest or even be put off. The author further refers to ‘Photosynthesis’ as an example of a scientific concept, which, “by using appropriate activities to investigate nature and human made processes, pupils can easily associate the terms used to describe them” (Mazumara, 2008, p. 26). Saponification may not be an exception to such an approach, hence soap-making related activities by pupils are bound to develop scientific immersion in the pupils and further help them develop valuable, deeper understanding.

Saponification is the reaction (process) by which soap is manufactured (Horscroft, 2003; Sinclair & Afolayan, 1993). Saponification concepts are embodied in the Zambian junior secondary curriculum and covered in grade 9 under the topic “Science in industry” (Horscroft, 2003, p. 92). Later, at the start of senior level, that is, under the introduction of chemistry, aspects of saponification in relation to soap are mentioned as important as well as typical local examples of the practical applications of chemistry in everyday life. Again, during the course of the chemistry senior syllabus, saponification comes up under acids, bases and salts as an application of acid-base reaction in everyday life/industry and finally, also towards the end of the chemistry senior syllabus under organic chemistry, particularly, under chemical reactions of esters (i.e. hydrolysis of an ester with an alkali or simply alkalinic hydrolysis of an ester) and uses of higher esters. If the earlier ideas and concepts under saponification at junior environmental science level incorporated more authentic scientific practices with which pupils could engage, the pupils would make more meaning of the science learnt, hence enhance their interest, appreciation and understanding of scientific concepts in future topics. Thus, lifeworld phenomena under saponification would be a more useful starting point to gain entry into grade 10 pupils' understanding of the many scientific concepts considered to lack appeal and relevance by many pupils.

The proposed problem of apparent lack of link between school science and its real life applications, which in turn may have contributed to pupils' perception of difficulty of chemistry, was investigated by involving grade 10 pupils and sought to find out their knowledge and understanding about the saponification concept as well as how they linked it to everyday life processes and products such as soap-making and soap. The motive of the research was that if pupils had learnt the theory about saponification and knew how it related to everyday life, it may be even more meaningful and worthwhile life experience that may help them demonstrate their knowledge of the link between scientific concepts and everyday life experiences. This application of science to everyday life experiences may help the pupils ''appreciate much more fully the crucial role science plays in their lives coupled with the belief that this makes the subject more attractive to study for many pupils'' (Bennett, Gräsel, Parchmann, & Waddington, 2005, p. 1522).

1.2. The Problem

From my experience of teaching chemistry to grade 10, 11 and 12 pupils at a high school in Zambia since 1996, it was apparent that although chemistry is a compulsory subject or component of science, with foundation topics placed as early as the junior phase (upper basic level), it seemed pupils did not link the scientific concepts taught in class to everyday life experiences. In many instances, the pupils' daily actions and expositions seemed to show that their school science had very limited applications in their daily life situations apart from merely remaining as theoretical, memorised mechanical knowledge for the purpose of passing examinations only. As a result, most pupils moving from junior to their first grade at senior secondary school persistently complained that they found and considered chemistry a difficult, theoretical, abstract and irrelevant subject (with others calling it a subject full of rumour mongering), and questioned whether it was really important and necessary for them to learn chemistry. Contrary to their perceptions, as regards the importance of chemistry, a lot of the pupils' everyday lives, directly or indirectly, rested heavily on the processes and products of chemistry and this could have been evidently clear if they were able to link science to applications in everyday life. To my knowledge of the literature reviewed, there has been no research done in Zambia to investigate pupils' understanding of specific scientific concepts such as saponification and how pupils link the scientific concepts to everyday life phenomenon, as a starting point for pupils to seeing the relevance of chemistry. Hence, this research sought to investigate saponification as one scientific concept which is related to a very familiar phenomenon of soap-making in everyday life. The study was thus an attempt to address the existing contextual weakness and knowledge gap in the teaching of chemistry and chemistry-related topics in environmental science at the point of transit from junior to senior level of secondary education.

1.3. Purpose and Objectives of the Study

The intention and direction which created the setting of the study were as follows:

1.3.1. Purpose

The study investigated grade 10 pupils' knowledge and understanding of saponification and its link to everyday life experiences of soap-making.

1.3.2. Objectives

According to Saunders, Lewis, and Thornhill (2007) objectives articulate evidence of the researcher's refined sense of purpose and direction of the research with greater specificity of what will be measured.

The objectives of this study were:

1. To explore the grade 10 pupils' understanding of the term "saponification".
2. To find out how grade 10 pupils link saponification knowledge to everyday life.
3. To investigate to what extent grade 10 pupils apply saponification knowledge in everyday life.
4. To enquire how science teachers facilitate for pupils to link the saponification knowledge to everyday life (pupils' reference to the teachers' facilitation role can never be excluded).

1.4. Research Questions

The study was guided by the following research questions:

1. What do pupils know about the term saponification?
2. How do pupils link saponification knowledge to everyday life?
3. To what extent do pupils apply saponification knowledge in everyday life?
4. How do environmental science and chemistry teachers facilitate for pupils to

link the saponification knowledge to everyday life (such as soap-making)?

1.5. Significance of the Study

It was hoped that the findings of this study could lend important grounds to help challenge a rethink for the need for change in the teaching approaches prevalent in chemistry and chemistry-related sciences, such as environmental science. Through the curriculum the change could be achieved by moving away from the overloaded traditional content-based to phenomenological competence-based and its partly overlapping elements such as the context-based and scientific literacy that incorporate everyday life applications and competencies. The aim of these approaches would be to keep pupils' interest, motivation and familiarity in science rooted in lifeworld experiences that they can apply in various ways in their environment (MoE, 1992). Dahlin, ∅stergaard, and Hugo (2009) argue that teachers who facilitate pupils' exploration of commonly experienced phenomena involving particular scientific concepts could use the acquired rich experience of the everyday phenomena to support pupils in their rich understanding of the related scientific concepts. In this regard, Dahlin, ∅stergaard, and Hugo (2009) see such approaches of teaching not only as relevant starting points for the teaching and learning process but also as a point of departure for the learning process to real life situations. To this effect, the practice-based programme of pre-service science teachers at the Norwegian University of Life Sciences has embarked training of science teachers to develop abilities of relating to common phenomenon experienced everyday with a view to develop a phenomenological learning process which they could in turn possibly impart on their pupils (Dahlin, ∅stergaard, & Hugo, 2009). Such "empirical studies with pre-service teachers exploring, for instance, the phenomenon of sound have been reported by ∅stergaard and Dahlin (2009)”, cited in Dahlin, ∅stergaard and Hugo (2009, p. 208) and point to “a shift of focus from imparting or transmitting ready-made scientific knowledge to cultivation of both teachers’ and pupils’ competencies which the pre-service science teachers would offer to pupils in their future teaching’’ (Dahlin, ∅stergaard, & Hugo, 2009, p. 207).

In the Zambian context, the findings of the study may be useful to science teachers, teacher educators, standard officers, curriculum planners, policy makers and all other stake holders in science education who are involved in shaping educational policy, process and practice, with the view to improve the educational process. For instance, the findings:

- may lend influence and support to some aspect of general teaching styles or approaches of some concepts in chemistry with everyday life practical applications (Ratcliffe*,* 2007). Hence, teachers would refocus their approach to teaching of certain content in chemistry with practical value to society so as to help pupils recognise the usefulness of chemistry beyond the classroom and examinations purposes. This may, in turn, translate beneficial scientific knowledge into reality, at large, as well as help boost enthusiasm and develop more positive attitude to chemistry in pupils (Bennett, Lubben, & Hogarth, 2006).
- may help curriculum planners to be more concise with the extent of practical detail in the syllabus in order to allow pupils recognise the long-term usefulness and appreciate the applicability of chemistry in everyday life.
- may help policy makers to rethink and reformulate educational policies that give adequate support and time to teaching and learning of chemistry.

- may, in general, add more information to this area and try to bridge the knowledge gap between what is taught in chemistry as scientific concepts and lifeworld phenomena.

1.6. Limitations and Delimitations of the Study

This section provides a brief overview of some limitations and delimitations to the study that could be considered while reading through the findings of this study and probably before one could think of generalising the findings (external validity) to some similar research settings.

1.6.1. Limitations

Limitations generally identify some potential weaknesses of the study (Creswell, 2003), as well as constraints or drawbacks to the study, both theoretical and practical, over which the researcher has little or no control (Nyagah, 1995).

Due to the limited time frame stipulated for the study and also the limited time schedule for the pupils participating in the study, it was not possible to extend the study to the more senior grades in the school or to follow up the same participants when they covered concepts on saponification again in the eleventh grade and also when they covered the saponification related concepts in the twelfth grade to see how they linked scientific concepts to everyday life experiences after experiencing the same concepts over and over as they progressed grade-wise. Also, due to the limited time frame for the study, saponification as a case was investigated only, though several cases such as teachers as a case (for example, to investigate how learning may be enhanced through teachers' facilitation role and ability to link scientific concepts to everyday life experiences), the school as a case, pupils as a case (with experimental and control groups), could have been of interest as well.

From the methodology perspective, the use of English in all the instruments may have led to inaccuracies as well as differences in understanding and interpretation of the same questions by the respondents. This was largely due to the fact that English was a second language for all the respondents, but more crucial would have been the language attitude influenced by the region of origin of pupils as they came from different parts of the Country such as rural, peri-urban and urban. Thus, the difference in the language competencies may have affected the type of responses given by the respondents as some might have faced problems such as difficulty in selecting the right word to best deliver their message with simplicity or may even have picked the wrong understanding of the question that was posed. To try to minimise these difficulties, the researcher, being the main data collection instrument, was present in all the data collection methods to help clarify, where possible, pupils' misunderstandings as they arose. Additionally, they were also given more time to think about the questions and to frame their responses when soliciting for their initial ideas in writing. It was hoped, in this way the pupils had ample time and help to select their words and correct understanding.

1.6.2. Delimitations

Delimiting involves establishing boundaries, exceptions and reservations in order to narrow the scope of the study (Creswell, 2003). According to Nyagah (1995) delimiting a study is to purposefully and consciously make the research manageable through taking certain actions on aspects such as the topic area, the size of the population, choice of specific participants or sites, a type of research design as well as the geographical location of the study. However, Nyagah warns that it is crucial not to delimit a study to an extent that would affect its internal and external validity.

The study was limited to grade 10 pupils and to chemistry application of an obvious phenomenon involved in soap-making. The pupils who reached the stage of the empirical project were not necessarily expected to follow any well-controlled laboratory experiment that involved things like recording the concentration of the locally made alkali or writing any formula or equations. These abstract activities of calculations, formula and equations, if anything, took the centre stage of classroom theory work whose immediate lifeworld link had not been seen or rather appreciated by the pupils, hence made chemistry teaching and learning unpopular and irrelevant in the eyes of the pupils (Holbrook, 2005). Also, the first grade of the senior phase (the grade 10 pupils) took part in the study as they were capable of giving the information of interest on saponification since they were considered knowledgeable on the saponification concepts from the junior phase (grade 8 and 9) and also the reinforced understanding of the practical applications of chemistry from their current senior grade. Due to the limited time, financial and material resources available for the study, it was not possible to extend the study to other schools within or out of Lusaka province. However, the research could be replicated with similar case subjects, if any reader had questions or challenges on the case study (Berg, 2007).

The current study only involved saponification concepts of chemistry linked to soap-making phenomenon, although there are many other scientific concepts in chemistry which are in turn associated with different phenomena that could be linked to everyday lives of the pupils. Thus, any other scientific concept with phenomena linked to everyday life could have been studied. Similarly, in a study to enhance science teachers' conceptions of some selected phenomena, Ogunniyi (2010, p. 27) explored teachers' beliefs on their "need to enhance pupils' understanding of diverse natural phenomena and to relate such understanding to their biophysical and sociocultural environment" as part of the learning outcomes demanded by the new South African natural science curriculum.

Also, the study only involved grade 10 pupils who took the subject solely as chemistry (commonly referred to as pure chemistry, probably for lack of a better term) and with in-depth syllabus content at a high school of excellence as opposed to the science syllabus (combined or physical) which was not as detailed. "For those with a more positivist orientation who have concern about generalising to similar types of individuals, groups, or event" (Berg, 2007, p. 295), the findings of the current study may be generalised to similar groups of pupils in other schools including those who take only science (combined or physical) as concepts on saponification are covered by all at junior level. According to (Berg, 2007, p. 294, 296), case study generalisation arises from the fact that "there is always a scientific benefit and value gained from a case study as it offers information that can be seen as useful beyond the individual case". Furthermore, "the notion that human behaviour is predictable is seen as a necessary assumption for all behaviour science research and thus, a single case could provide general understanding of similar cases, hence its scientific value" (Berg, 2007, p. 296). In the same manner, Yin (2003) sees case studies as generally providing understanding about some similar groups and can be generalised to theory. Merriam (1998) also argues that due to the particularistic feature of focussing on a particular situation, event, program, or phenomenon, a qualitative case study can examine a specific instance but illuminate a general problem. In light of the particularistic feature seen by Merriam (1998), Berg (2007,

p. 295) further notes that "there is clearly scientific value to gain from investigating some single category of individual, group, or event simply to gain an understanding of that individual, group, or event".

1.7. Operational Definition of Terms

This sub-section provides the operational definitions as used in this study.

Co-education school – school with both sexes of pupils (i.e. with both boys and girls).

Empirical Project – the practical activity done by the pupils to prepare simple soap using locally available materials.

Empirical study – a study in which "any conclusions drawn are based upon hard evidence gathered from information collected from real life experiences or observations" (Kumar, 1996, p. 6).

High school – senior secondary school offering grade 10 to grade 12 of secondary education (the last 3 years of secondary education).

Junior secondary – the first two years of secondary education (grades 8 and 9).

Life world – "the world as it is encountered in everyday life in relation to the direct world of science" (Kvale & Brinkmann, 2009, p. 29).

National Policy – policy document on Education (entitled 'Educating Our Future', MoE, 1996).

Pupil – primary or secondary schoolchild.

Pupil-centred – learning and teaching approach in which "the education process centres on the pupil to play an active role in developing the necessary intellectual qualities" (Ministry of

Education, 1996, p. 44), hence, “emphasis in teaching and learning is laid on the development of science process skills, problem solving skills and acquisition of hands on experience” (Tawana & Rollnick, 2009, p. 303).

Pure chemistry – chemistry which includes a combination of theory and examinable practical component (as opposed to physical or combined science which does not have an examinable practical component).

Regular pupils – secondary school pupils in the formal schooling system who attend classes and learn in the morning (as opposed to those who attend classes and learn in the afternoon).

Saponification – the reaction (process) which takes place in soap-making (Horscroft, 2003; Matthews, 1992; Sinclair & Afolayan, 1993).

Secondary School – 5 years of formal education after the 7 years of primary education.

Soap-making – practical /lifeworld/application of making simple soap using animal fat/vegetable oils and alkali.

CHAPTER TWO: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.0. Overview

This chapter provides the theoretical perspectives that locate the origin of this research and the review of the relevant literature on related studies which guided this study undertaking. However, "it is unclear what the difference is between theoretical framework and literature review as part of the theoretical framework one has to perform a literature review and the two may consist of partly overlapping elements" (E. ∅stergaard, personal email communication, February 21, 2010). Similarly, Kumar (1996) sees reviewing the literature as being interrelated to the theoretical framework, hence the paradox: "until you go through the literature you cannot develop a theoretical framework and until you have developed a theoretical framework, you cannot effectively review the literature" (p. 31). This adds to the voice of other scholars who suggest that theoretical framework and literature review may as well be pulled and considered together and simply called theoretical framework (van der Valk & de Jong, 2009; E. ∅stergaard, personal email communication, February 21, 2010) or simply called literature review (Berg, 2007). Kombo and Tromp (2006) seem to support this interrelationship as they argue that in order to understand theoretical framework, an analysis of theories has to be done.

2.1. Theoretical Framework

A theoretical framework is a collection of interrelated ideas based on theories, derived from and supported by evidence that helps to explain or predict phenomena that occur in the world (Creswell, 2003; Kombo & Tromp, 2006).

Phenomenology was largely used to inform this study. According to a working definition by Dahlin, ∅stergaard and Hugo (2009), phenomenology is a basic philosophy of knowledge in which human experience is considered significant for our understanding of the world around us. Saunders, Lewis and Thornhill (2007) simply regard phenomenology as the way in which humans make sense of the world around them. It (phenomenology) has also been defined as a philosophical stand point that focuses on the world of everyday life as regards to the essence of direct experience (phenomenon) taken at face value (Cohen, Manion, & Morrison, 2007; Merriam, 1998). Thus, in its application in science education, phenomenology is both a philosophy of knowledge and a qualitative research approach (∅stergaard, Dahlin, & Hugo, 2008).

Apart from the study being approached from a phenomenological bent, the theoretical framework consists of elements of different, partly overlapping theoretical perspectives on science education which include context-based science education, scientific literacy, inquiry-based science education and problem solving. The ever-growing context-based science education was used to inform the study as both phenomenology and context-based sciences have a focus on bridging the gap between scientific concepts and phenomena in everyday life (Berg, 2007; ∅stergaard, Hugo, & Dahlin, 2007). Bridging the gap between scientific concepts and phenomena is particularly important if pupils are to appreciate that the science they learn in class is relevant and is not alienated from their everyday life experiences (everyday life experiences being the knowledge, activities and observed behaviours in pupils' routine lives). Routinely, pupils are always in contact with or encounter natural phenomena (directly or indirectly) with scientific constructs in their daily activities such as drying clothes, adding sugar to water (dissolving sugar), using soap, salt and perfumes on clothes, to mention but a few. For instance, as they use soap they are indirectly, whether they always do realise or not, in contact with the products of fats and alkalis which come from within their own environments, hence an aspect of natural phenomena impacting on their day to day living. As Wellington (1989) observes, school science ought to help and give opportunities to pupils through the important role that science can play in class and out of class. In the case of environmental science or chemistry, the science could be used to solve problems as in problem-solving or to have a refined understanding of the surrounding world as in scientific literacy, for instance. Wellington (1989) further notes the following as some of the important functions as part of practical work in teaching science:

- to help pupils link classroom work with natural phenomena and vice versa; to link natural phenomenon to science concepts through the practical interaction with materials found within the environment.
- to help the pupils interpret and make sense of their natural phenomena through linking science experiences and ideas.

According to Abrahams and Millar (2008) practical work in science entails "activities in which the pupils manipulate and observe real objects and materials" (p. 1945). Eilam (2004) notes that the utilisation of an everyday phenomenon rather than a well-controlled laboratory experiment ought to promote understanding of pupils' constructed mental models while encountering a new phenomenon using everyday materials.

Indeed, ability to link natural phenomena to day-to-day life is an essential aspect of effective learning which the African Forum for Children's Literacy In Science and Technology [AFCLIST], (2004) sees from the perspective of science teaching being more effective when the instructions proceed from the known to the unknown. In this case, the link between the known (such as fats and ash), usually taken for granted and not in practice connected to the seemingly unknown or more complex (the soap, alkali), thus defines the concept map which shows how the two aspects of phenomena relate to each other. However, this learning process can be regarded as a two-way process like a bridge that can be built from either end; hence a two-way process from everyday life phenomena to scientific concepts and vice versa; from scientific concepts to everyday life phenomena, as displayed by Figure. 1 which follows:

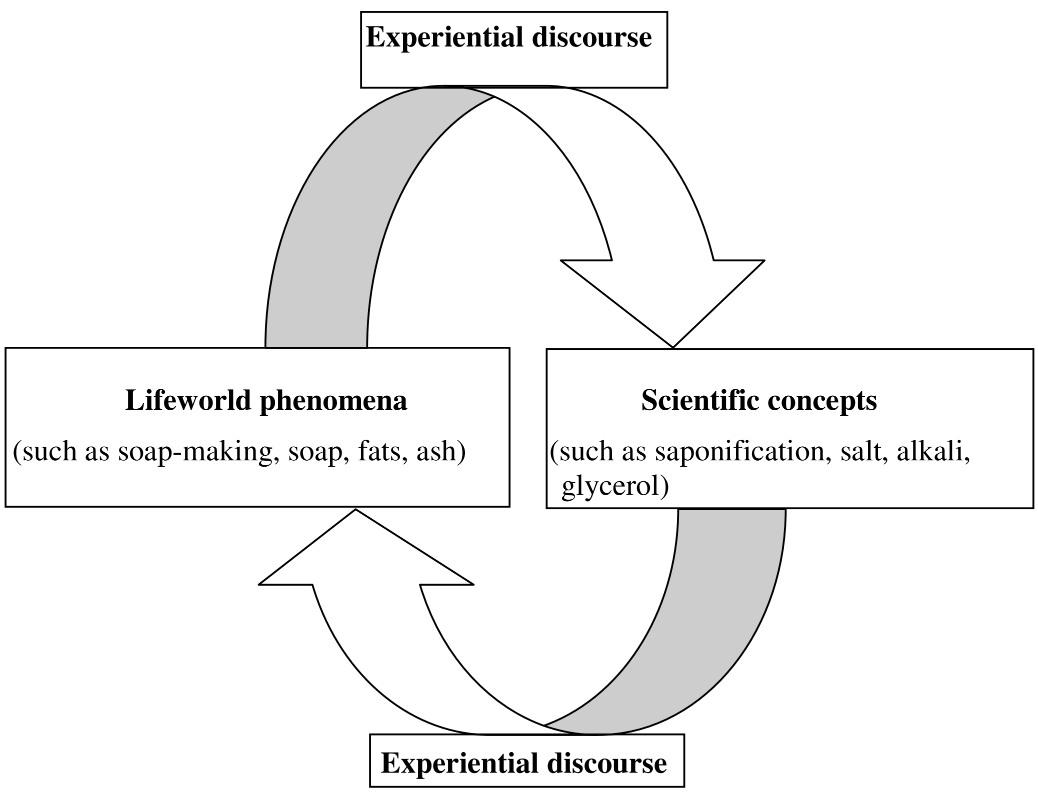

Figure 1. Bridging of lifeworld phenomena and scientific concepts (adapted from ∅stergaard, Dahlin, & Hugo, 2007, p. 125).

∅stergaard, Dahlin, and Hugo (2007) observe that ‘‘Phenomenological science education has the potential of bridging the gap between the experienced lifeworld of the pupils and that of the scientific concepts’’ (p. 123). According to Dahlin (2001) discourse and practice produce solidified and significant terms fundamental to experience and nature. The experiential discourse from phenomena to scientific concepts and vice versa represents the “purposeful actions; cognition, consideration and behaviour” (Broks, 2007, p. 27) and processes which pupils use to express their knowledge in context in various activities, applications and reflections. From Figure 1, linking lifeworld phenomena and scientific concepts, starting from whichever side of the linkage (from phenomenon to scientific concept and vice versa), the linking process involves passing through solidly, consolidated experiences leading to meaningful understanding of the phenomena emanating from the engagement with either knowledge creation (lifeworld phenomena or scientific concepts). The interplay of experience between the authentic process used by the pupils in the empirical project and the emerging scientific concepts relating to saponification during their active engagement develops appreciation and deeper understanding of the phenomena (See also Savage, 1998). More importantly, the purposeful actions of the pupils during experiential discourses from phenomena to scientific concepts and/or vice versa (Figure 1) culminate into “learning - an active process where pupils are engaged in sense-making, relating new ideas and concepts to prior ideas” (Finkelstein, Adams, & Perkin, 2010, p. 48). According to Savage (1998) when pupils experience science through making sense of their own world, their active extension of understanding is exciting as they feel confident and self-empowered due to their knowing that they are in control of their learning and further realisation that they are not being asked to discard their knowledge but to use it to expand their understanding.

Phenomenologically, the science provided in secondary school should have connection with everyday life experiences. Indeed, a lot of what the pupils are taught as early as gardes 8 and 9 (Junior Secondary School) e.g. separation techniques, changes of state, air, water and metals; have applications in everyday life at home, in industry and our environment. Perhaps, it is this ability which pupils would achieve in authentic practices through application to real-life phenomena when they do what they say and think they know in science which has allowed some scholars to see "chemistry as one of the enabling sciences" (King, Bellocchi, & Ritchie, 2007, p. 3).

2.2. Literature Review

2.2.1. Introduction

Literature review is the task of reading through existing works, relevant to a research undertaking in order to acquaint oneself with available knowledge in the area of interest prior and throughout the study undertaking (Kumar, 1996).

The review of the relevant literature was aimed at analysing similar and supporting works by other scholars and researchers. Apart from sharpening understanding and investigation of the research problem, review helps deepen the formulation of the theoretical framework as well as create awareness of the current state of knowledge in the area through identifying and addressing possible gaps in the knowledge area (Kombo & Tromp, 2006; Bell, 1999; Kumar, 1996). From the review it was found that there was a gap or silence in the literature on phenomenological studies aimed at revealing pupils' meaning-making and face-value of scientific concepts in aspects of science education as no research had been done with a phenomenological or context-based bend in the Zambian context. Hence, the current research study sought to address the problem of lack of link between the scientific concepts and phenomena in everyday life that may be resulting in pupils finding chemistry as an abstract and irrelevant subject, through providing knowledge on pupils' understanding of the familiar concepts of saponification (found in the Zambian curriculum) and its link to everyday life as a way of gaining entry into the knowledge gap and its related contextual weakness of having no phenomenological studies in science education done in Zambia.

The presentation of the literature reviewed started with the more general literature and finally literature with a direct bearing upon the research study (Berg, 2007). Hence, in this regard, the more specific research-grounding literature on phenomenology in science education was presented last.

The study was informed by literature from such areas of scholarship as context-based/science-technology-society (STS) education, perspectives on problem solving and phenomenon-based science education. The researcher also reviewed the Ministry of Education national policy document on education in Zambia, the junior and high school science syllabi as well as the recommended/approved pupils' textbooks for use in environmental science and chemistry.

The scholars in phenomenological science education, context-based education, problem-solving, inquiry-based learning also see ability to link scientific concepts and phenomenon experienced in everyday life as having a permanent impression on pupils in terms of knowledge, skills and understanding (Dahlin, 2001; Dahlin, 2003; Osborne & Collins, 2000; ∅stergaard, Hugo, & Dahlin, 2007; Bennett, Gräsel, Parchmann, & Waddington, 2005; King, Bellocchi, & Ritchie, 2007; Eilam, 2004; Volkmann & Zgagacz, 2003). This view takes the standpoint that the potential to link scientific concepts to everyday life experiences makes pupils appreciate more meaningfully the relevance of what they learn in science (both as chemistry and environmental science) and also makes the subject more interesting as they now make concrete connections to everyday life (Bennett et al., 2005; ∅stergaard, Dahlin, & Hugo, 2008).

2.2.2. Scientific Literacy

Apart from looking at scientific literacy from the conceptual overview, the term was used in this study to include sources of literature that may be seen by other critics as not being informed by research or not academic literature; materials such as the recommended environmental science textbooks, chemistry textbooks for secondary schools as well as advance chemistry and the Watchtower, Awake publications.

According to Bennett et al. (2006) and the National Research Council [NRC], (2008), the acquisition by pupils of scientific knowledge, understanding, abilities, attitudes, skills needed to make informed decisions about scientific issues affecting people's lives is called scientific literacy, also regarded as public or basic understanding of science by others (Laugksch, 1999).

Understanding the world around us has presented itself as a major challenge more so in modern times of rapidly evolving scientific knowledge and research findings due to the information gap between society and the informed world of science. In the Zambian context, the value of scientific literacy cannot be over emphasised as pupils are undoubtedly a major vehicle of scientific awareness to the public, more importantly in rural areas where literacy levels are very low. Arguably, school science with the approved science textbooks could act as essential ingredients for scientific literacy. In this regard, the immediate face value of school science learnt meaningfully tends to acquire more significance and could be transferred immediately into beneficial gains for the public by the pupils. The scientific literacy thus achieved by pupils at school would in turn enhance their informed and appropriate actions "on scientific matters that may be affecting their lives and those of other members of local, national, and global communities of which they are part" (Bennett et al., 2006, p. 348). Currently, more information and debate, with a scientific grounding, is needed by the public on a number of issues ranging from human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS) pandemic, global warming, genetically modified organisms to contemporary awareness of such effects as prolonged exposure to and contact with technological gadgets such as cellphones. With specific reference to HIV/AIDS, Kelly (2000, cited in Baxen & Breidlid, 2009) reiterates that formal schooling might be an important single weapon to fight HIV/AIDS transmission as it has the potential, through the pupils, to transmit messages which can lead to change, for instance, in sexual behaviour. Somehow, with this realisation that the lives of the general public (personal and societal) are more and more influenced by science and technology, the role of scientific literacy should be placed high on the agenda for school science as research continues to observe that,

> …science education is not contributing as it could to understanding and addressing such global issues as Feeding the World's Population, Ensuring Adequate Supplies of Water, Climate Change, and Eradication of Disease in which we all have a responsibility to play a role. Students are not made aware of how the solution of any of these will require applications of science and technology, along with appropriate and committed social, economic and political action. As

> long as their school science is not equipping them to be scientifically literate citizens about these issues and the role that science and technology must play, there is little hope that these great issues will be given the political priority and the public support or rejection that they may need (Linder, Östman, & Wickman, 2007, p. 8).

Indeed, the science curriculum in Zambia has space and aspirations for scientific literacy in schools. One of the general aims for the science syllabus is "to enable pupils acquire knowledge and understanding so as to become confident citizens in a technological world as well as make informed decisions on scientific matters" (Curriculum Development Centre [CDC], 2000, p. vii). Notwithstanding the fact that the Zambian science curriculum has equally other important contextual scientific issues to address, school science and scientific literacy, in particular, has the potential to be a propagation node for pupils' understanding of scientific concepts and phenomena. As Roberts (2007, p. 9) argues with simplicity, "scientific literacy is primarily a concept about curriculum goals".

Understanding and awareness of the world around us is a vital component for survival and progressive technological prosperity of mankind. Historically, the manufacture of soap has been common societal scientific knowledge that dates far back to the ancient times. (Watchtower Bible and Tract Society , 2005) notes that one of the detailed recipes for soap-making was in the 12th Century and since then the chemical process used to produce soap, referred to as saponification, has not undergone much change and many industries continue to flourish on this product of saponification.

2.2.2.1. Saponification in the recommended textbooks of the Zambian Science Curriculum.

The importance and relevance of saponification and its related concepts as far as soap-making is concerned is evident in the Zambian curriculum from its occurrence both at junior and senior levels of the school curriculum. Thus, the knowledge area of saponification (with its related link to soap-making) would be used to epitomise an aspect of classroom science linked to an essential commodity, which deals with simple scientific methods and single out a concrete, observable outcome of school chemistry. Practically, the concepts under saponification with related link to soap-making phenomenon would help the pupils to learn what is relevant and further excite them to know that these ideas and skills would help them solve problems in their daily life situations using cheaply sourced, locally available, biodegradable materials. “Our relationship to nature is primarily a doing, not a knowing relationship since our consciousness as well as our ability to think is based on our already being and acting in the world” (∅stergaard, Dahlin, & Hugo, 2008, p. 97). Hence, consciousness is in the first place not a matter of “I think” but of “I can” (Merleau-Ponty, 1962, p.137 as cited in ∅stergaard, Dahlin, & Hugo, 2008, p. 97). Pupils should thus not only think and say that they know, but should also be able to do what they say and think they know. Other studies support the notion as science is generally viewed as an empirical subject through which pupils could develop their own concrete understanding of scientific concepts more meaningfully (Luckay & Laugksch, 2008).

At the junior level, however, saponification is taught through practices such as discussion, and reading through the chapter on separation techniques and their application in industry used in Zambia with the major objective that “pupils should be able to state the separation techniques used in soap production and realise the chemical industries making soap found in Zambia" (MoE, 1992, p.51). As prudently observed by Linder (2010), relating characterisations of learning to meaningful and effective classroom practices whose essence the pupils can capture, possesses a serious challenge in many science classes since much of the teaching and learning practices lack much distinctive, enabling clarification. It is clear from such teaching approaches, as also observed by Lubben and Bennett (2009, p. 149), that "the reasons for using everyday experiences in science teaching are diverse and ambiguous". What seems to be ambiguous is that at the same time, the MoE (1992, p. vii) hopes, through this teaching, to develop "mastery of useful scientific skills in pupils which they can apply in various ways in their environment". The biggest challenge thus still remains that there is no one clear cut outlined simple way to act as a yardstick to determine such achievement of mastery of useful scientific skills (such as through common assessments, laboratory activities to be followed strictly or even methodologically appropriately trained teachers). For instance, though the basic education level environmental science syllabus advocates the pupil-centred teaching approach (MoE, 1992), there are also multiple unchecked assumptions and expectations of what the teacher ought to do to adopt this pupil-centred approach. The teacher is for example expected "to be innovative and thus provide extra information on methodology, conditions under which the experiments should be carried out and also suggest alternative apparatus for experiments" (MoE, 1992, p. vii).

From the way the material is presented in the grade 9 environmental science textbook and the objectives set therein it is quite likely that what goes on in class may not be in line with nor reflective of the expectations of the learner-centred approach in the teaching of such scientific concepts such as those of saponification. The MoE (1996) further attests to this fact by acknowledging that many pupils who leave grade 9 have restricted educational experiences and are lacking in the knowledge, understanding and skills expected of their attainment level. Ogunniyi (2010, p. 27) also argues, that presumptions that science teachers themselves are always well equipped to assist their pupils relate understanding of their diverse natural phenomena to their biophysical and sociocultural environment are "contrary to a plethora of earlier research findings".

The saponification concept and its related soap-making phenomenon may not be as demanding and costly to use to show or demonstrate relevance for functionality in everyday life since cheap biodegradable materials may easily be sourced and used. Sinclair and Afolayan (1993) briefly describe saponification used in soap production from the process to the product, using more traditional approach of boiling animal fat and wood ash. From this perspective, it is hoped, the value and link to everyday experiences of indigenous knowledge of soap-making is not only important, but also evident. These materials may not only be simple but also readily available, hence could be used to allow pupils see simple and familiar materials being converted into what they have always perceived as a more complex and more modern industrial product. In recognition of the budget constraints that teachers face to conduct practicals in science subjects, Thomas (2007) supports such use of low-cost practical resources. The recommended grade 9 environmental science textbooks used in the Zambian curriculum, however try to bring out the process and procedure in more skeletal and abstract form of flow chart on soap-making. At the pupils' level of understanding, not only is the flow chart deficient of a comprehensive authentic empirical procedure on soap-making, but it also lacks the actual practical activities and details that could be followed by pupils during simple soap-making to help them build a permanent living memory of saponification.

The following Figures (Figure 2 and 3) show outlines of flow charts that characterised the grade 9 environmental science textbooks in the two approved textbooks for use in Zambian schools, with the average age of pupils of about 15 years.

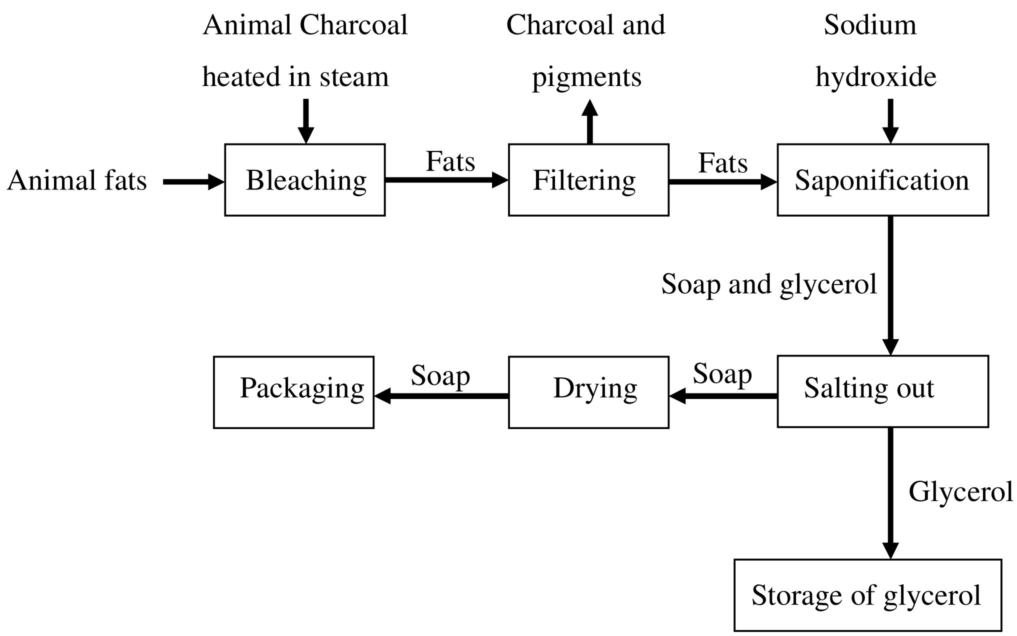

Figure 2. Main stages in the manufacture of soap (MoE, 1992, p.103).

Figure 3 below represents the Flowchart of soap manufacture found in a more recent textbook for environmental science, also representing the soap-making process, in terms of the required materials, the main scientific activities involved and other procedures, diagrammatically as in the illustration of the main stages in the manufacture of soap in Figure 2 above.

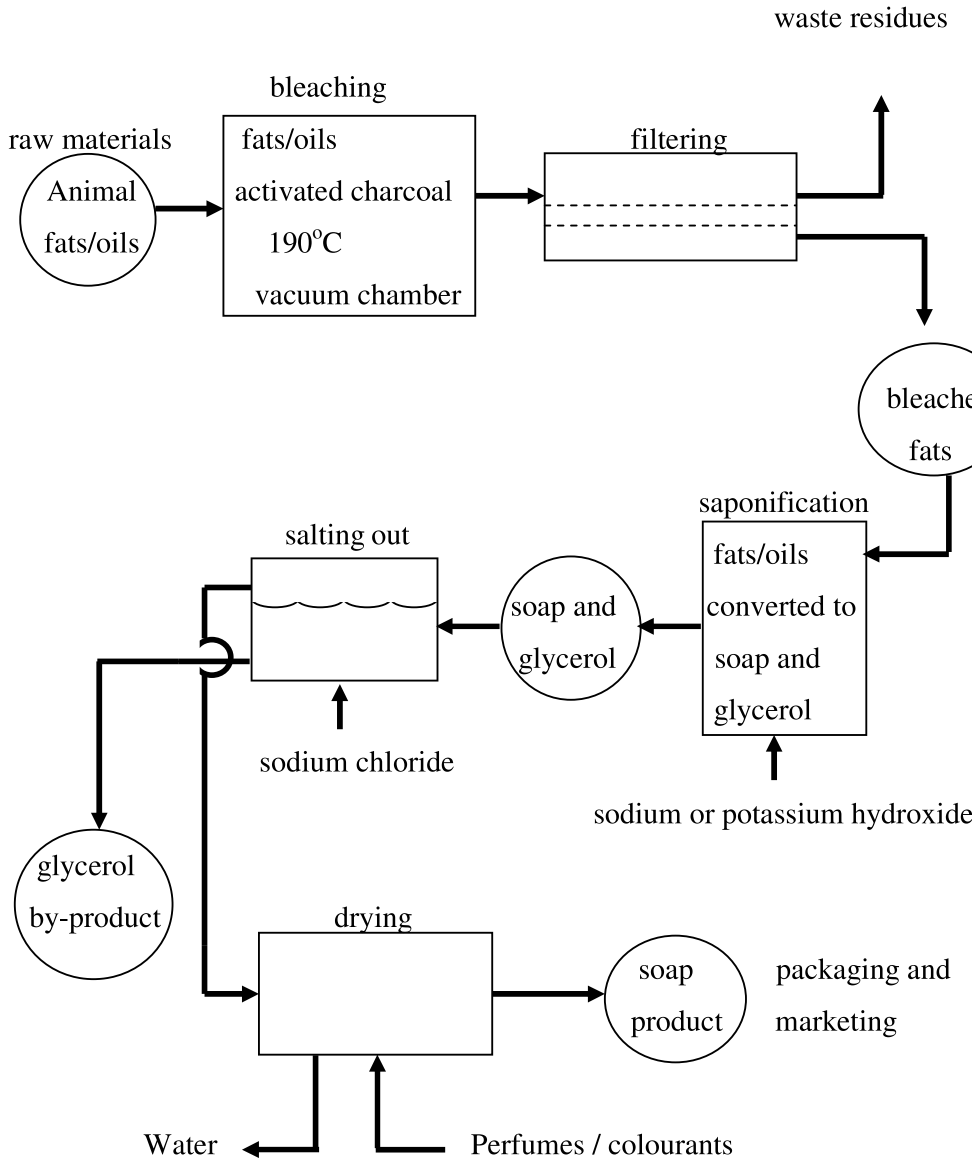

Figure 3. Flowchart of soap manufacture (Horscroft, 2003, p. 112)

Figure 2 and 3 featured as landmarks and prominent outlines of flow charts on soap-making in the two different approved textbooks for environmental science at grade 9 used to display the process and procedure of saponification as practiced in industry. A likely challenge to contemplate about with the use of the diagrams as the flowchart as teaching aids could be that if the pupils are never going to perform the saponification process practically themselves to see what each of the stages entail in reality, and later on never going to work in these industries, then they will find it difficult to continue seeing the relevance of saponification through the flowchart to everyday life. As a result the pupils will be mostly inclined to achieve mastery of what will then appear to be a complex network of linkages in the flow chart through memorisation. Osborne and Collins (2000) found that pupils find those aspects of science which have no direct application in everyday life to be least useful. Furthermore, pupils found it difficult to see how such knowledge, displayed largely in flowcharts as the "industrial processes such as crude oil distillation and the blast furnace was relevant to their everyday life if they were never going to separate crude oil nor extract metals" (Osborne & Collins, 2000, p. 21, 53). However, from the flowchart only, without active pupil engagement in the actual process and procedure that resulted into integral processes of the stage by stage build-up of saponification practice outlined by the flowchart it may not be farfetched to argue that such presentation of soap manufacture process was more of abstract. These approaches and major trends in present science teaching which are prevalent in science education where the abstract models tend to be taken as more real than the phenomena themselves have received a lot of criticism, particularly from the phenomenological critique point of view, since not only do the approaches contribute to pupils' alienation from nature but also from science at large (Dahlin, 2001). According to Nieuwenhuis (2007) it is important for pupils themselves to explore the richness, depth and complexity of phenomena as only then do they begin to develop a sense of understanding of the meanings attached to phenomenon and their social context. Nieuwenhuis (2007, p. 59) concludes that from the interpretivist perspective, "the human mind is the purposive source or origin of meaning".

2.2.3. National Policy and Science School Syllabi

The MoE national policy guidelines for high school spells out the need to prepare individuals who are soundly grounded in science and problem solving skills for the conclusion of life in school and the commencement of adult life (MoE, 1996). According to the national policy on education both the junior and senior levels of secondary education have placed emphasis on the sciences to give pupils adequate understanding, knowledge and a worthwhile educational experience that will make them recognize the usefulness and appreciate its applicability in everyday life (CDC, 2000; MoE, 1992). To attest to this, one of the aims of the chemistry high school syllabus in Zambia is in fact, to allow the pupils acquire sufficient knowledge and understanding that would help them recognise the usefulness and appreciate the applicability of science in everyday life (CDC, 2000).

What seems to be prominent in all the foregoing is that school science ought to manifest its relevance through its practical applications in the daily life activities of the pupils if it is to be appreciated, other than having the same traditional reputation for difficult in schools. The national policy on education recognises the rich diversity of the educational process and the diverse need to cultivate qualities and potentialities of each pupil, with no intent to mould all the pupils according to the same pattern (MoE, 1996). One way in which to achieve this and develop the full potential of the pupils in science is that they need to learn and be taught in ways that promote familiarity with the things they meet in everyday life in order for them to see the relevance of school science. Not only will this make them attach more meaning to the scientific concepts learnt in school science but will also give the pupils more authentic application of science in everyday life, hence acquire a meaningful life time experience and long-term memory. To enhance the effectiveness of meaningful and quality learning the Ministry of Education in its policy sets great store to “promote the development of a curriculum that is comprehensive, balanced, integrated, diversified and above all, relevant to the real needs of both pupil and society” (MoE, 1996, p. 45). Inadvertently, as a starting point, pupils need to relate what they learn in science to everyday life for them to showcase appropriate practices of science and be seen as having acquired an education content which is relevant to them and the society.

2.2.4. Perspective on Problem-solving

If the education system is to serve its intended purpose and live up to expectations, then the goal to educate the pupils to be problem solvers ought to be upheld (Roth & McGinn, 1997). Furthermore, Roth and McGinn (1997, p.18) point to a major concern in science education in which ‘‘the kinds of problems pupils do in school to practice their problem-solving competence have little to do with the problems they will need to solve in everyday settings’’, hence, as observed by Holbrook (2005) pupils view chemistry as unpopular and irrelevant. Roth and McGinn further see learning to solve problems through transfer of classroom skills to everyday settings as primary endeavour for education.

Saponification knowledge may not just end at the classroom level as theory whose real value cannot be tapped meaningfully by the pupils themselves because its main product, soap, is an important commodity in the maintenance of good health and hygiene in everyday life. Historically, the making of soap is one of the oldest human endeavours of chemical syntheses and in modern times, soap has been and is seen as a necessity rather than a luxury with regards to its cleansing power, hence, importance to hygiene and good health (Matthews, 1992; Morrison & Boyd, 1987).

Thus, pupils from different backgrounds, more especially from the rural settings can use saponification to solve real problems which they face in their communities using school knowledge and understanding of soap-making. In these rural settings the concern for hygiene and good health affects everyone though not all members of the communities may afford or access commercially made soaps, yet within the same communities there are school children or school dropouts who came across soap-making related phenomenon at school. These school going children or school dropouts could utilise their knowledge to help solve their own problems in the community if only they experienced a meaningful science curriculum that exposed them to soap-making phenomenon. As argued by Millar and Osborne (1998, cited in Osborne and Collins, 2000), school science education must be seen as an end-in-itself and avail pupils who attain it an opportunity to harness its usefulness in their everyday lives. Going by this argument of formal school science, it is thus imperative not only to regard school science as preparation for higher school grades or education only but as an end for the given level and group of pupils who have attained it, but also a beginning to finding solutions to many problems in life, be it technological, domestic or hygiene related.

Utilisation of real and meaningful scientific knowledge acquired from school reflects not only exemplification of the applications of science but also a useful relationship between theory and practice. According to ∅stergaard, Dahlin, and Hugo (2008, p. 96), ‘‘the relation between life world experiences and scientific knowledge is not one of opposition but of continuity, though the continuity is often neglected and forgotten”. Sinclair and Afolayan (1993) further cite a case study at Kgalagardi soap industries (Pty) Ltd in Gaborone, Botswana, as a typical example where byproducts of slaughtering provide the major raw materials needed by the industry. As regards to similar simple raw materials required for saponification by pupils, there are plenty of such byproducts as animal fats within our environment in Zambia, which even contribute to foul smells as they degenerate when carelessly dumped. Such materials may instead be saponified to produce relevant products for the home, but which are also environmental friendly. While solving the problem of foul smells by removing byproducts of slaughtering in the environment and used to produce a saponification product, the solution for the problem of hygiene and health is equally tackled at the same time. Hence, by engaging pupils with the kind of science education which fosters their interest, appreciation and understanding of science, school science would translate into relevant solutions in everyday life and solve many problems in contemporary life.

2.2.5. Inquiry-based Science Education

For some time, inquiry has been used as the central word that characterises good teaching and learning in sciences (Anderson, 2002). Inquiry is said to be an active learning process as it focuses on the learning process in which pupils are engaged actively in doing some activities that help develop knowledge and understanding of scientific ideas, including understanding how scientists study the natural world. Thomas (2007) argues that through engaging relevant practical work, pupils can develop appreciation for scientific inquiry, explore scientific concepts for themselves, hence increase their understanding and enthusiasm for science. Through involving both activity and skill, inquiry further promotes pupils' effective procedural understanding, for the long term knowledge acquisition.

By engaging in various activities such as during the making of a saponification product (soap), pupils in turn get more information from as many sources as would make it possible for them to gain the deep understanding and direct immersion in the emanating scientific concepts. In the process of inquiry on saponification, pupils thus make observations, meet procedural steps first hand which allow them a chance to experience the natural world as it relates to the science in everyday life. At the same time, the pupils gain knowledge ownership as they are present and become deeply involved in the process of knowledge construction and understanding of concepts. Krystyniak and Heikkinen (2007) see inquiry as a way of learning both science content and skill, but also as an opportunity for pupils to formulate and conduct their own scientific investigations. .

2.2.6. Context-based/Science-Technology-Society Education

Context-based approaches are approaches adopted in science teaching and learning that focus on specific context and applications of science as a starting point for developing understanding of scientific ideas and concepts as well as illumination and reinforcement of scientific theory (Bennett, Lubben, & Hogarth, 2006; Whitelegg, & Parry, 1999, as cited in Bennett, Gräsel, Parchmann, & Waddington, 2005). The approaches rely on the strength to use everyday situations which pupils are familiar with, through which to introduce scientific ideas and concepts relevant to a given situation (Whitelegg, & Parry, 1999 cited in Bennett, Gräsel, Parchmann, & Waddington, 2005; Bennett, Lubben, & Hogarth, 2006; George, & Lubben, 2005).

Science-Technology-Society (STS) education approaches are those that mainly emphasise the links between science, technology and society (Aikenhead, 1994, cited in Bennett, Lubben, & Hogarth, 2006). These approaches focus on science education that develops understanding of science and technology aspects which have value and use in a range of everyday contexts (Bennett, Lubben, & Hogarth, 2006; Osborne, &

Collins, 2000). Through STS approaches the role of science and technology in society is emphasised in different ways such as technological artefact, process or expertise, which all reflect the interactions between technology and society (Aikenhead, 1994, cited in Bennett, Lubben, & Hogarth, 2006). STS approaches to science education are believed to make peoples' lives easier and better in society as their benefits manifest in so many ways such as communication, transport, predicting weather, all of which have links to everyday life.

The growth of all these different approaches in science education are aimed at promoting practical applications of science in real life experiences that actively engage the pupils with the materials in the natural environment. Indeed, the practical activities which are relevant to the life applications of the pupils may not be done at school for various reasons which may include time constraints for the teachers to prepare for such practical activities, financial implications attached to the practical materials, dangers of chemicals to the pupils as well as disposal/contamination concerns of chemical washouts but are however important. Among the several major and persisting worries that have been identified to be common to the teaching of high school science in many countries is the seemingly alienation from the sciences of so many young people (Hoffman, Häußler, Lehrke, 1998, cited in Bennett, Gräsel, Parchmann, & Waddington, 2005).

In a broad generalisation it has been observed that chemistry curricula tend to put the subject first and applications a poor second (Holbrook, 2005). As a starting point for developing concrete understanding of scientific ideas, high school science and chemistry in particular, needs to be relevant to pupils' everyday lives, experiences as well as equip them with scientific knowledge and abilities needed for them to cope as adults in modern societies (Bennett et al., 2005). According to Lubben (2002), science educators, teachers and curriculum developers, in both developed and developing countries, are aware that students are more likely to be interested in the science being taught at school if they can see how it relates to what they do in their daily lives.

2.2.7. Phenomenological Science Education

Phenomenology is a philosophical stand point that focuses on the world of everyday life as regards to the essence of direct experience (phenomenon) taken at face value (Cohen, Manion, & Morrison, 2007; Merriam, 1998). According to Dahlin (2003), phenomenology has been applied both as a theory of science and as an empirical method of research within the disciplines of human and social sciences. Thus, in a phenomenological study, emphasis is on the ability to let the phenomenon 'speak' on its own through direct experience (phenomenon) that is commonly experienced in everyday life (∅stergaard et al., 2007; Merriam, 1998). Phenomena represent things we experience in our everyday lives as we interact with nature, which, according to Cohen (2007, p. 21), "we directly apprehend through our senses as we go about our daily lives". According to ∅stergaard et al., (2007, p. 128), "phenomenology is an attempt to restore the value of direct experience of things, which includes both natural phenomena and pupils and their approaches to understanding the world."

"Phenomenological critique of current science education has observed that many pupils in science lessons find themselves faced with purely an abstract and cognitive world, separated from their everyday life experiences" (∅stergaard, Dahlin, & Hugo, 2007). It is thus not uncommon "in science lessons where the phenomena of nature are hardly touched upon to see pupils who can no longer participate with their eyes, ears and hands'' (Wagenschein, as cited in ∅stergaard et al., 2008, p.93). In Wagenschein's argument, the common practice of most science classes of today are highlighted; that of the teacher rushing through abstract theories, concepts, definitions, technical terms, equations, formulae, mathematical calculations, the virtual instruments and instrumentation (as they are simply mentioned in class and never shown to or experienced authentically by the pupils). The loss of contact between lifeworld phenomena and scientific concepts, as noted by ∅stergaard et al. (2007, p. 124) is as a result of lack of "stepwise transformation of everyday phenomenal experience into an understanding of the same phenomenon structured by scientific concepts". Thus, the stepwise transformation could involve "the investigation and identification of different stages of the learning process, between phenomenon, as embedded in pupils' lifeworld, and scientific concepts, as introduced in science lessons" (∅stergaard et al., 2007, p. 125). Thus, observed phenomenon of soap-making can be used by pupils to reflect the essence of the saponification concept and vice versa. According to Goethe (1971, cited in Østergaard et al., 2007, p. 94) "there is no gap between phenomena and the theory explaining them; phenomena themselves become the theory, provided one discovers how to arrange them in a self-illuminating order or structure".

Despite these arguments and views which identify the gap between everyday life phenomena and the related scientific concepts which could be rooted in lifeworld experiences of the pupils during the learning process, "there is still lack of empirical evaluations to support such a phenomenological approach to science teaching" (Dahlin et al., 2009, p. 207). Furthermore, whereas attempts have been made by others such as Cossa, Holtman, Ogunniyi, and Mikalsen (2008) to find out students' understanding of scientific concepts of cell division as well as how students understood the related biological phenomenon employing phenomenological approaches, and Uamusse, Mutimucuio, & Bonga (2008) to consider integrating local or indigenous knowledge on concepts of alcohol in abid to promote the understanding of scientific concepts in grade 10 chemistry, no studies have been conducted in Zambia on pupils understanding of scientific concepts. It was thus hoped that the current study would address such a contextual flaw and also the knowledge gap of exploring ways and other teaching methodologies to enhance pupils' understanding of the many scientific concepts encountered in chemistry or related components. As a way of addressing the above-mentioned contextual weakness this study was exploratory in nature as not much has been written about the topic and the population being studied (Creswell, 2003). Also, in the current study, the approach was opposed to the study by Cossa et al. (2008) or Uamusse et al. (2008) where the laboratory session or integration of indigenous knowledge on alcohol concepts acted as an intervention and thus students' activities during laboratory sessions, for example, were observed and recorded, then were preceded by a pre-test and again a post-test after the laboratory activities. Overall, their findings in both studies revealed improved students' understanding after the laboratory activities or in the other case, after integration of indigenous knowledge.

Thus, the current study sought to gain insight into the possible knowledge gap between saponification as scientific concepts and its link to pupils' everyday life. ∅stergaard, Dahlin, and Hugo (2007) argue that lifeworld phenomenon and scientific concepts might be connected through choosing some everyday concepts as a point of entrance for moving towards scientific concepts. The authors further argue that by developing a rich authentic picture of a phenomenon it is easier for pupils to link scientific concepts to everyday life. However, since the interactions of pupils and teachers could never be separated before and during the investigation, the study also provided, directly and indirectly, insights about teachers' approach and focus of saponification facilitation in science/chemistry lessons as well as how they connect scientific knowledge to everyday life outside the classroom.

Hence, phenomenology and its partly overlapping elements of the different theoretical perspectives reviewed in this section were seen as having an appropriate synergy of theories to help understand and investigate how pupils related saponification concept to its everyday life essence of soap-making and gain in-depth insight into their understanding of the concept.

CHAPTER THREE: METHODOLOGY

3.0. Overview

The chapter presents the methodological approach for this research. The methodology explains how the study was conducted in order to answer the research questions and meet the research objectives (Nyagah, 1995). Berg (2007, p. 346), views methodology as an "overall description of the research procedures and strategies." Maree and van der Westhuizen (2007) regard it as a description for the entire research strategy and tactics.

The methodology chapter includes information on the research design, criteria of selection of the case study, study site and population, study participants (sample) and sampling procedure, data collection methods (research instruments and data collection procedures) and ethical considerations.

3.1. Research Design

A research design is a plan showing the procedure (including arrangement of conditions for data collection and analysis) used to investigate the research problem (Kumar, 1999). Kombo and Tromp (2006) describe it as the structure of research which shows how all the main parts of the research project will be conducted in order to address the research questions.

A qualitative case study strategy was used in this research as it was intended to gain in-depth insight of the pupils' knowledge and understanding of saponification concepts and how they linked saponification concepts to everyday life phenomena. According to Gay (1996), Merriam (1998), Yin (2003), Kombo and Tromp (2006) and Berg (2007), a case study method involves in-depth, holistic (comprehensive) description and analysis of one or a few illustrative cases used to investigate phenomenon with real-life context. In addition, “case studies strive towards understanding how participants make meaning of a phenomenon under study” (Nieuwenhuis, 2007, p. 75). The major focus of the case study was as encompassed in the following definition, as provided by Yin (2003, p. 13), “a case study is an empirical inquiry that investigates a contemporary phenomenon with its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (phenomenon and context are not always distinguishable in real-life situations).”

Since much had to be learnt from the study participants themselves direct information was collected from them and analysed in a bid to build an understanding based on their ideas (Creswell, 2003).

Through the single phenomenon case that was studied, useful insights beyond the case were provided that could be used to make broader generalisations (i.e. analytic generalisations) of the study (Yin, 2003; Berg, 2007; Merriam, 1998). In the current research, the case of learning saponification concept as linked to everyday life phenomenon was studied. In this study, the saponification case was used to solicit pupils’ understanding of saponification concepts, though generally their understanding could have as well provided insights into many other scientific concepts in science which also have important links to everyday life. Though generalisation was not the purpose of this study, the findings of the study would be used to generalise to all appropriate pupils in a similar school system, thereby helping to understand other similar cases, phenomena or situations (Gay, 1996;

Cohen et al., 2007), hence manifesting the scientific value of a case study (Berg, 2007).

The case study main parts were structured as shown in Figure 4 below.

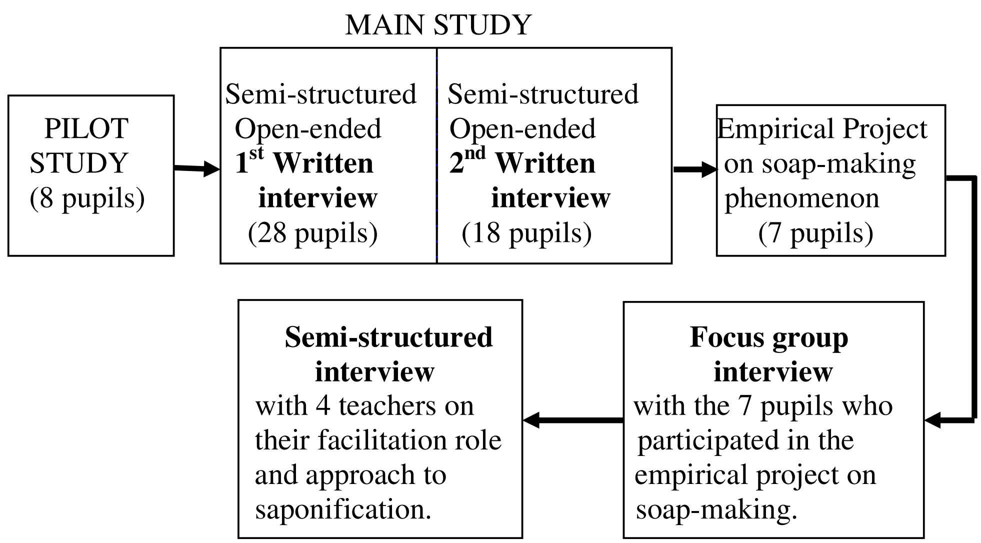

Figure 4: Overview of the research structure.

According to Creswell (2003, p. 167), a "visual model or diagram or figure to illustrate the specific research design helps the reader to understand the procedures".

As illustrated in Figure 4 above, the main study was preceded by the pilot study.

3.2. Criteria of Selection of the Case Study

The case of the concept of saponification related to the phenomenon of soap-making was chosen mainly because the soap-making presents such an essential phenomenon which produces an important commodity (soap) of everyday importance to pupils' daily lives. Through the phenomenon of soap-making the pupils would in turn see the link to simple local materials in the environment (i.e. the raw materials locally available from which they could demonstrate the knowledge and ability of their understanding of science concepts. As far as man's desire for cleanliness came into realisation, the use and popularity of soap has been paramount in daily life from as early as babyhood (Morrison & Boyd, 1987). The saponification reaction used in simple soap-making, for example, may not be as complicated and could be achieved from familiar, biodegradable materials which could as well be easily sourced cheaply from the local environment. Muzumara (2008) acknowledges the need to relate school science to experiences that are familiar to pupils' daily lives and from which the pupils' could use their own ideas to provide the necessary raw materials to exemplify the nature of scientific theory.

3.3. Study Site

The case study was conducted at a co-education high school in Lusaka with representative nation-wide enrolment to capture diverse pupils' scientific knowledge, understanding and link of such scientific knowledge to everyday life. This would also provide, it was hoped, general understanding about how pupils linked scientific knowledge to everyday life with their different school backgrounds. The school, being boarding, was seen as an ideal choice of site due to the ready availability of pupils who could participate in the research during their free times both in the afternoons as well as at weekends and also due to its accessibility to the researcher.

3.4. Access to the Study Participants

To begin with, the Deputy Headteacher of the school was met to explain to him the purpose and relevance of the study. After permission was sought, the form of informed consent of pupils' participation was signed by the Deputy Headteacher who also happened to be a representative of the Parent Teacher Association (PTA) since the responsibility of looking after the children in the boarding was entrusted to the school. According to Kumar (1999, p. 193), "people, who are dependent upon you for a service, and children, are among those that are not considered to be competent to give consent, hence are excluded from giving permission". Through the office of the Deputy Headteacher, a meeting was arranged with the teachers who taught the grade 10 classes in the school to explain to them about the study and also asked them to make their timetables available to the researcher so that the teachers and the researcher could liaise on the use of the laboratory space to be used as the main possible venue for the research meetings and other follow-up activities too. The teachers were also asked to avail their plans on conducting extra lessons with their respective classes well in advance to the researcher so that the researcher's meetings with the participating pupils did not coincide and interfere with any such school activities, be it after lunch or over the weekends. The Deputy Headteacher made further arrangements to create a platform for the researcher to meet pupils and inform them about the research study, their important role in the study and also to urge the pupils to voluntarily and willingly feel free to take part in the study.

3.5. Study Population

Gay (1996) and Kombo and Tromp (2006) define a population as the larger group of individuals of interest to the researcher from which the sample is taken to which the results of the study would be generalised.

The study population was 255 grade 10 regular pupils, both male and female, at a co-education high school in Lusaka. The choice of the population was largely due to their possession of particular information of interest having come from a wide diversity of school backgrounds where concepts on saponification ought to have been covered as part of the junior science curriculum and now experiencing chemistry content together. The grade 10 pupils had also covered many aspects of practical applications of chemistry, local as well as international examples, at the beginning of grade 10. They were thus considered better placed to understand the concepts and principles involved in saponification. In addition, the grade 10 pupils were themselves not yet overwhelmed by a lot of their own school work and would also be followed up easily even in the coming year, if need be for more data gathering process of the study than would be either the current grade 12 or grade 11 pupils. Thus the study was not expected to interrupt their own academic programme and performance much as they still had two more years to write their final high school examination.

3.6. Participants (Cases) and Sampling Procedure

According to Cohen et al. (2007) a sample is a set of respondents or smaller group of the total population selected from a larger population under study for the purpose of the investigation.

The study initially commenced with a total of 32 pupils (4 drawn from each of the eight grade 10 classes), but 4 withdrew (leaving 28) from the study right at the stage of the first semi-structured open-ended written interview, citing lack of ideas about saponification that the semi-structured open-ended interview solicited, hence could not answer most of the questions. In total 8 females (29 percent) and 20 males (71 percent) were involved in the study at inception. The age of the pupils ranged from 14 to 19 years (with an average age of 15.6).

The participants for the case study were purposively selected from the grade 10 pupils who acknowledged that they had come across saponification concepts in their previous grade and unanimously volunteered to take part in the first semi-structured open-ended interview in each class where the researcher explained the purpose, relevance and importance of the study. Semi-structured open-ended written interviews were thereafter administered to the participants by way of "collective administration of a captive audience" (Kumar, 1999, p. 113), during the class by class visit in the evenings when the pupils were attending the preparation (prep) sessions. The approach, despite being time-consuming on the part of the researcher, had the advantage of having a high response rate since very few pupils may refuse to participate in the study just after making a plea to them (Kumar, 1999). This captive audience method used to administer the semi-structured open-ended written interview is regarded by Kumar (1999) as the quickest and best way of collecting data when it comes to the accuracy of the responses since clarity of the questions is easily done by the researcher and also enables the researcher the opportunity to explain the relevance and importance of the study during the personal contact with the study participants.

Based on each pupil's independent demonstration of knowledge and understanding of saponification concepts exhibited in the first semi-structured open-ended written interview, the 18 successful pupils were then given a follow up in form of the second semi-structured open-ended written interview some three weeks later. Thus, only pupils with some knowledge or idea of saponification concepts (as outlined by the objectives/observables in Table 1 for the analytical framework) proceeded to the second semi-structured open-ended written interview as information rich cases of interest who could offer a meaningful perspective on saponification. The information rich cases of interest helped to understand the problem under investigation for in-depth analysis of the problem (Creswell, 2003; Kombo & Tromp, 2006).

During further investigation and following the pupils' outline of the process and procedure of making a simple product using saponification method solicited in the second open-ended written interview, the seven successful participants went on to demonstrate their link of saponification to everyday life phenomenon, in which they attempted to make simple or crude soap. The seven pupils went further to participate as information rich sources in the study in a focus group interview at the end of the project.

Finally, the pupils' responses were collaborated with 4 teachers' general perspectives of their actual practice through interviewing the teachers on their facilitation role and approaches to saponification. Of the four teachers, two were environmental science teachers and the other two were teachers of chemistry.

3.7. Data Collection Methods

Generally, the two main methods by which data was collected in the study were interviews and observations; with interview guides and observation schedules being the main instruments used during data collection (that is, interview guide for semi-structured open-ended written interviews with pupils, interview guide for focus group interview with pupils, interview guide for semi-structured oral interviews with teachers and observation schedule with pupils engaged in the soap-making). According to Nieuwenhuis (2007, p. 87), "an interview is a two-way conversation in which the interviewer asks the participant questions to collect data and to learn about the ideas, beliefs, views, opinions and behaviours of the participant". The qualitative interview, as a research method offers opportunity to access people's basic experience of the lived everyday world (Kvale & Brinkmann, 2009). "Observation is the systematic process of recording the behavioural patterns of participants, objects and occurrences without necessarily questioning or communicating with them" (Nieuwenhuis, 2007, p. 83-84). As a qualitative research method, observation gives a privileged access to participants' deeper understanding of the phenomenon being observed (Nieuwenhuis, 2007).

As underscored by Merriam (1998), data is the information recorded from the environment from which, depending on his or her interest and perspective, the researcher can make sense. In other words, this data is not out there waiting to be collected like garbage but has to be noticed first by the researcher and treated as data for the purpose of the study (Merriam, 1998). Dewey (1993, cited in Merriam, 1998) argues that collecting data always involves selecting what data will be needed and the techniques of data collection, based on, among other things, the research problem, theoretical orientation and purpose of the study. Data collection, according to Kombo and Tromp (2006, p. 99), is the "gathering of specific information for purposes of proving or refuting some facts".

According to Merriam (1998, p. 28), "case study does not claim any particular methods for data collection as any and all methods of gathering data can be used in a case study, although some methods are used more than others". Merriam further singles out interviewing as probably the most common form of data collection in qualitative educational research and it has often been employed as the only source of data in numerous studies. Bell (1999) notes that the frequently employed methods for data collection in case studies are observation and interviews, though no method is excluded as methods of collecting information are selected based on the appropriateness for the task. According to Platt (1992, cited in Yin, 2003, p. 13) "a case study strategy is preferred when circumstances and research problems are appropriate rather than an ideological commitment to be followed whatever the circumstances". Furthermore, Yin (2003, p. 15) observes that, "case studies can be based on any mix of quantitative and qualitative evidence (as the contrast between quantitative and qualitative evidence does not distinguish the various research methods) and need not always include direct, detailed observations as a source of evidence."

As a final preparation for data collection, a pilot case study was conducted and was more formative and intended to help refine data collection plans, both in terms of content of data and the procedures to be followed (Yin, 2003). In this regard, the pilot was used to try and test the clarity of questions in the research instruments as well as check if the pupils' responses were in line with the research questions. Generally, according to Bell (1999, p. 127-128) "all data-gathering instruments should be piloted to test how long it takes recipients to complete them, to check that all questions and instructions are clear and to enable the researcher to remove any items which do not yield usable data". Merriam (1998) agrees with the idea of a pilot and adds that it provides an idea about pupils' responses from the emerging insights through which it is possible to make necessary adjustments to refine or even reformulate the questions if necessary. Thus, the pilot, according to Yin (2003), helps refine the data collection plans, both in terms of content of data and the procedure used. The pilot provided the researcher a template with which to compare the empirical results of the case study as well as act as a test for beginning to measure and judge the quality of the research in terms of its validity and reliability. As

Merriam (1998) reiterates, qualitative research derives rigour from the researcher's presence through an interactive process between researcher and participants, through triangulation of data.

Data was collected using the procedures and instruments discussed in section 3.7.1 and 3.7.2 over a period of 2 months to allow for representative data collection and sufficient time to enable the pupils to participate in the project without interrupting their normal school routine as well as to get as much independent and original information from the participants.

3.7.1. Data Collection Procedures

The main procedures used in collecting data were interviews (open-ended written interviews, face to face and focus group interviews) and observations, using the data collection instruments outlined in 3.7.2. All the participants involved in the data collection process were given the informed consent forms (Appendix F) at the beginning of the study and before the actual data gathering process asking them to consider participating in the research study. The informed consent forms clearly indicated the purpose of the research as well as the important role of the participants as required by research ethics involving human subjects and were signed by the appropriate and competent authority as indicated on each form.

The data collection procedures are further highlighted under each research instrument.

3.7.2. Research Instruments

These are research tools which serve as the means by which data for a study is collected (Kumar, 1996). The instruments used in this study to collect data were the interview guides and observation schedule.

3.7.2.1. Interview guide for semi-structured open-ended written interviews with Pupils.

The interview guides for semi-structured open-ended interviews were designed by the researcher in which open-ended questions were asked to provide introductory information to be used as the basis for the follow-up observations and focus group interviews (Bell, 1999). The use of open questions allow participants to define, report, interpret and describe a situation or event from their point of view since open questions encourage the interviewee to reply as they wish and in their own terms, hence expressing their view points of reality (Saunders, Lewis, & Thornhill, 2007; Bryman, 2008). Bryman (2008, p. 232) sees open questions as having the advantage in that "the questions do not suggest certain kinds of answers to respondents, therefore, respondents' levels of knowledge and understanding of the issues can be tapped".

A set of semi-structured open-ended written interviews (Appendix A and Appendix B), consisting of the introductory request portion, part for the personal particulars and open-ended questions framed in statements with spaces for writing responses were designed by the researcher and piloted with similar pupils (taken the same classes as the ones used in the main study) before being used for this study. The open-ended written interviews were self-administered to a captive audience at a coeducation school in Lusaka in two phases (as semi-structured open-ended written interview 1 and semi-structured open-ended written interview 2) when pupils where on study time (prep). According to Cohen, Manion, and Morrison (2007, p. 321) "open-ended questions are exploratory and enable participants to write a free account in their own terms, to explain and qualify their responses and avoid the limitations of pre-set categories of response". However, Cohen et al. (2007), notes the disadvantage of open questions in as far as they could generate not only irrelevant but also redundant information, if left too open-ended to such an extent that the respondent does not know what kind of information is being sought. Through the open-ended questions, the extent of understanding achieved on the specific content of interest (saponification content in this case) was measured to enable choice of a purposive sample of only those knowledgeable (See Cohen, Manion, & Morrison, 2007).

The two semi-structured open-ended written interviews were used to explore and gain entry into pupils' knowledge and contemporary understanding of saponification and their possible link to its everyday life phenomena. Each pupil, while seated individually, answered the same sets of predetermined questions in each open-ended written interview by actually recording their individual responses in the spaces provided on the semi-structured open-ended written interview guide while the researcher looked on and answered any queries seeking clarification. Such presence of the researcher when administering the semi-structured open-ended written interview had the advantage of instantly allowing the researcher to attend to and address any queries related to the design of the open-ended written interview and ensured high accuracy, completion of questions and response rate (Cohen, Manion, & Morrison, 2007).

The first semi-structured open-ended written interview (Appendix A) was administered to all the 28 participants of the study and solicited general particulars of the participants, their background and their initial ideas on saponification concepts in a written form in order to establish further contacts as well as their possible participation in further, more demanding tasks as purposively selected information rich sources. The open-ended written interview took about 50 minutes for the pupils to complete. The first semi-structured open-ended written interview also provided space at the end for pupils to write their general comments or some additional information on saponification they may have wanted to share. Through this additional information and comments, pupils provided very important insights mainly on their learning process of saponification as was taught in the previous grade.

The pupils who had some ideas of saponification were later followed up for more data gathering procedures. Sometime of about three weeks was allowed before administering the second semi-structured open-ended written interview to give a breather to the pupils as well as to make other logistical arrangements for access to the pupils.

The second semi-structured open-ended written interview (Appendix B), structured in a more or less similar manner as the first, was a follow-up to the first semi-structured open-ended written interview and was administered to the 18 successful participants of the first semi-structured open-ended written interview. The semi-structured open-ended written interview sought general particulars of the pupils, their knowledge of saponification as it relates to scientific concepts and its link to everyday phenomena in soap-making. This semi-structured open-ended written interview took about 90 minutes for the pupils to complete. The successful participants were later followed-up to demonstrate their practical knowledge with understanding of saponification in an authentic practice of soap-making as demonstration of their written outlines of process and procedure of the second semi-structured open-ended written interview. During this project involving a practical activity and practice the pupils were observed using an observation schedule.

3.7.2.2. Observation Schedule

An observation schedule or protocol is a tool planned for recording observational data during an activity involving participants in qualitative research (Creswell, 2003). In its basic and simplest structure the observation schedule is a form consisting a table divided into two columns by a line in the middle, with one side for descriptive notes of what was observed and the other side for reflections (personal thoughts; impressions, hunches and ideas) of the researcher about what was observed (Creswell, 2003; Nieuwenhuis, 2007).

In this research an observation schedule (Appendix C) was used to guide the focus of observation, collect data and provide insight into the pupils' authentic soap-making process (extent to which pupils applied saponification in soap-making phenomenon) as well as to enrich that data from the interviews (semi-structured open-ended written interview and verbal, face to face conversations). As underscored by Saunders, Lewis, and Thornhill (2007), observation adds richness to the research data. To ensure the full benefit of the responsiveness strength offered by this method (Saunders, Lewis, & Thornhill, 2007) space for further comments was provided at the bottom of the observation schedule to record other observation details that may not have been highlighted in the schedule.

During participant observation, the type of observation in which the researcher is as well immersed in activities of the participants, actual behaviour, activities and attitudes were noted to help put behaviour in context (Kombo & Tromp, 2006). Apart from looking closely and taking notes during observation of the major stages and activities in their engagement, the pupils were photographed to provide valuable insights to help understand pupils' link of saponification to everyday life. Observation was restricted to those knowledgeable pupils who showed a clear outline of how a simple product could be made from simple locally available materials using saponification as outlined in their semi-structured open-ended written interview 2. Based on their clear outline, each pupil was later asked to provide a separate requirements' write up of the simple, locally available materials needed for them to make a simple product of saponification. The material requirements were made available by the researcher and a weekend was set for the empirical saponification project to be done by the pupils.

Due to the school's busy teaching schedule and the limited school laboratories during school days as well as the weekends it was decided that the seven pupils who reached the empirical stage of the research project, work in groups of three and four respectively so as to cut down on the total time of occupying the laboratory. While conducting the empirical project the pupils were observed by the researcher who was assisted by another chemistry teacher during their demonstration of the process and procedure of making a simple product using saponification, in which all the pupils attempted to make crude or simple soap. Bell (1999, p. 158) suggest that, "if possible, it is a good idea to ask a colleague, preferably who is not a participant, to observe with you in order to compare notes and provide some check on the interpretation of events". In terms of the main parts of the activities, the observations captured the local materials used, the scientific processes and procedures engaged in as well as their conversations and interactions.

3.7.2.3. Interview Guide for open-ended focus group interviews with pupils involved in the soap-making project.

An interview guide or protocol of a semi-structured nature (Appendix D) was designed by the researcher to record pupils' actions, reflections and facilitate the direction and flow of the focus group interview or discussion with some degree of flexibility. Basically, the interview guide consists of a heading, opening statements by the interviewer, key research questions which may be followed-up by probe questions during the actual interview and space for interviewer to record comments and other reflective notes during the discussion (Creswell, 2003). A focus group interview focused on the discussion and the interaction among participants who were considered similarly knowledgeable and discussed a topic initiated by the researcher (Cohen et al., 2007). Notably, a focus group encourages an interchange of different viewpoints and does not seek consensus or solutions on the topic or issues under discussion (Kvale & Brinkmann, 2009), through promoting the role of interaction in the construction of meaning (Bryman, 2008).

A focus group interview of 7 pupils (boys only reached this stage) was done at the end of the open-ended written interview answering process as a way of gaining more insight into pupils' understanding of the saponification concept and phenomenon that they linked to everyday life experiences. The focus group interview was used to get the participants' reflections, ideas, opinions, perceptions in order to gain insight into their experiences, understandings and views about saponification. According to Kombo and Tromp (2006), focus group discussions are useful for obtaining information on the participants' beliefs and perceptions on an area of interest, hence can be used to identify and explore beliefs, ideas or opinions of a group of homogeneous members. Focus groups provide a more open setting for discussion in which respondents raise issues which they can justify and elaborate but also provide time for individual reflection within the group than individual interviews, hence a richer and detailed source of qualitative data (Osborne & Collins, 2000). This was where the other advantages of the focus group interview also lay in generating a wide range of cross-checked as well as complemented responses, hence provided a reliable record than an individual could give, apart from the obvious practical and organisational timeserving advantages (Cohen, Manion, & Morrison, 2007).

The focus group discussion/interview was conducted in the evening just after the pupils had their supper in one of the main laboratories that was mainly used as a base room for teaching purposes. The pupils sat in two rows and directly facing the researcher on the next row in front of them. Pseudo names were assigned to them before the interview and then the researcher introduced the topic of discussion as being saponification. The pupils were all encouraged to participate in the interview freely. The focus group enriched the other data collection procedures in which the pupils played a central role and was intended to capture their deeper and practical understanding on saponification. The discussion took about two hours and was recorded on a digital voice recorder and then transcribed verbatim.

3.7.2.4. Interview Guide for semi-structured interviews with teachers

The interview guide (Appendix E) was designed by the researcher in which topics and issues to be addressed by the interview were specified and outlined in advance (Cohen, Manion, & Morrison, 2007). However, depending on the responses given during the interview, the order of the questions in the interview guide could be changed from one interviewee to the other. The major strength of the interview guide is that data collected is systematic for each respondent as the comprehensiveness is increased by the outline (Cohen, Manion, & Morrison, 2007).

The interview guide for semi-structured interviews was used to collect data from two teachers of chemistry (each with 20 years of teaching experience) and two teachers of environmental science (four and seven years of teaching experience, respectively) from some selected nearby junior secondary schools on how each one of them approached the topic on saponification during their lessons. The interviews were tape recorded and transcribed verbatim. This was done in order to consolidate, corroborate, augment and compare the findings from the pupils. The environmental science teachers were drawn at random from the nearby schools in town which offered environmental science to gain insight of the teachers' general approach to the teaching of saponification since, as a high school, the school where the research was conducted did not offer junior subjects but received pupils in grade 10 from any of these junior secondary schools (as is the case with all high schools).

Though the main focus of the study was pupils 4 teachers were thus interviewed in order to get their general views and ideas on saponification as taught, what links or applications the teachers made and also what links, if any, the pupils made to everyday life experiences during the lessons, all done in a bid to consolidate, corroborate, augment and compare the findings from the pupils. According to Østergaard et al. (2008, p. 97), "phenomenological culture analysis provides an understanding of both teacher and pupils as embedded in specific cultural relations, which cannot be reduced or neglected prior to investigation". Furthermore, Nieuwenhuis (2007) observes the multi-perspective analysis that allows the researcher not only the voice and perspective of one or two participants but also the views of other groups of actors in a situation as well as the interaction between them as a vital approach to case studies. This, according to Nieuwenhuis (2007), is essential as it helps the researcher to come to a deeper understanding of the situation under study, a salient feature of many case studies.

The following chapter represents the analysis of data and the interpretations thereof.

CHAPTER FOUR: DATA ANALYSIS AND INTERPRETATIONS

4.0. Overview

This chapter presents data analysis, which, according to Berg (2007) could also be taken as interpretations when undertaken in content analysis. The data analysis strategies are highlighted first to show the specific areas where they will be considered and then the analysis are interwoven with some findings. Berg (2007) has observed that findings from some qualitative approaches such as reporting observations from content analysis can be presented by giving the findings separately or by interweaving findings and analysis. Also, from the case study point of view, "data analysis consists of examining, categorising, tabulating, testing, or otherwise recombining both quantitative and qualitative evidence to address the initial propositions of the study" (Yin, 2003, p. 109). The analysis is also related to the literature, the broader understanding of saponification by pupils and to the original research questions.

4.1. Data Analysis Strategies

The inductive data analysis strategy with its interpretive (naturalistic) paradigm (Maree & Westhuizen, 2007) was preferred for this study in order to get the in-depth understanding of the pupils' responses, actions and how they linked the saponification phenomenon to everyday lived experiences. In addition to the usual context of everyday lived experience, Merriam (1998, p. 4) also notes that "in interpretive research, education is considered to be a process and school is a lived experience".

Data collected was thus analysed by both content analysis and interpretive phenomenological analysis during and immediately after data collection. According to Cohen et al. (2007), content analysis is simply the process of summarising and reporting the main contents and message of written data. Content analysis identifies and summarises message content systematically (Nieuwenhuis, 2007). Merriam (1998) asserts that content analysis of qualitative data involves analysis of the content of interviews, field notes, and documents. In this research, content analysis involved examining the contents of the open-ended written interviews, focus group interviews and observation notes, for, according to Merriam(1998, p.160), "themes and recurring patterns of meaning in which the focus was the communication of meaning" as well as misconceptions in the responses given by the pupils. A particular advantage of content analysis, according to Berg (2007, p. 328) when content analysis is undertaken "to analyse interview data or responses to open-ended questions on open-ended written interviews, the weakness of content analysis in locating unobstrusive messages relevant to the particular research questions is virtually nonexistent". Merriam (1998) sees content analysis as being inductive though categories initially guide the analysis. On the other hand, phenomenological analysis was used to see the experience of the saponification phenomenon for itself articulated by the pupils through analysis of their learning process revealed in the written interviews, the focus group and during the empirical project. Phenomenology was thus used to analyse and establish how the pupils made meaning of saponification through their knowledge and understanding. As remarked by Kvale and Brinkmann (2009), a phenomenological approach is useful in providing understanding of meanings of phenomena in everyday life as perceived by the pupils themselves since reality can only be from them. Berg (2007, p. 304), Miles and

Huberman (1994, p. 8) similarly see a phenomenological approach as one that captures “the practical understandings of meanings and actions”. Thus the meanings attached by pupils to scientific concept of saponification and actions emanating from their understanding of the scientific concept of saponification were important in bringing out the essence of the phenomenon. From such an analysis, the pupils would be seen to display different levels of knowledge; first- and second-order knowledge (Merriam, 1998, p. 158) on saponification.

Hence, pupils’ knowledge and understanding of the concept of saponification was analysed by content analysis whereas the application or link of saponification to everyday life was analysed by phenomenological analysis using the data collected in the interviews and observation notes as was appropriate for each empirical data collection process on saponification. According to Merriam (1998, p. 162), “data that have been analysed while being collected are both parsimonious and illuminating”, hence provide information of interest “which is more likely to help identify the multiple realities potentially present in the data” (Maree & Westhuizen, p. 37). “Multiple realities are constructed socially by individuals” (Merriam, 1998, p. 4) as “there are multiple realities that pupils have in their minds on their understanding about a phenomenon” (Maree & Westhuizen, 2007, p. 81). Nieuwenhuis agrees further and adds that human behaviour is affected by knowledge of the social world, as such there are multiple and not single realities of phenomena. Thus, depending on their individualised familiar social context, pupils can hold or create different meanings, understandings as well as misconceptions about the scientific concepts which in turn affect their creative and logical reasoning of the associated phenomenon. As a result, teaching and learning of scientific concepts through description of the process and procedure of a practical activity assumes the unlikely possibility of two different minds with different daily social contexts achieving a single interpretation.

4.2. Data Analysis and Interpretations

Data analysis in qualitative research is the process of making sense out of the data obtained from the participants' point of view (Cohen, Manion, & Morrison, 2007). Creswell (2003), similarly views the process of data analysis as making sense out of text and image data (meaning interpretations) for deeper understanding of the data.

Content analysis and interpretive phenomenological analysis were seen as appropriate approaches to portray the different ways in which the pupils understood saponification both theoretically and practically as a scientific concept and its link to soap-making phenomenon. Similarly, in another study assessing students' understanding of cell division in biology, Cossa, Holtman, Ogunniyi and Mikalsen (2008) used descriptive and the phenomenological analytical approaches "to demonstrate the different ways in which the students qualitatively described or understood the biological phenomena studied" (p. 20). Bauer (2000, cited in Nampota, 2008, p. 22) also contends that "content analysis is the only method of text analysis that has been developed within the empirical social sciences that bridges the statistical formalism inherent in quantitative studies with the qualitative analysis of the materials". Hence, according to Nampota (2008, p. 22), the statistics may only be used in reporting the findings only after the 'kinds', 'qualities', and 'distinctions' in the text have been analysed. Hsieh and Shannon (2005, p. 1278) and Downe-Wamboldt (1992, p.34, cited in Hsieh and Shannon, 2005) further argue that the goal of content analysis in its application to analysing content of text data is "to provide knowledge (based on participants' perspectives and grounded in the actual data) and understanding of the phenomenon under study".

4.2.1. Criteria for Data Analysis

The pupils' knowledge and understanding of the saponification concept as related to their meaning-making and actions were seen as portraying three major themes (basic knowledge, knowledge with understanding of the related concepts and application to everyday life). The information from the data gathering procedures and research instruments and was used in the framework of analysis to depict the different levels of understanding of the pupils. Data analysis was then done research question by research question.

4.2.1.1. Framework for Data Analysis

According to Gibbs (2009), framework analysis is an approach for qualitative data analysis in which data is classified and organised into hierarchical key themes, concepts and emergent categories.

Table 1 that follows shows the analytical frame work that was used to analyse data (See Nampota, 2008; Cossa, Holtman, Ogunniyi & Mikalsen, 2008; Abrahams & Millar, 2008):

Table 1. Analytical framework for considering pupils' understanding of saponification and its application to everyday life.

Level	Themes/concepts	Observables/objectives/criteria
1.	Basic knowledge of saponification scientific ideas/terms. **(Addressed by Research Question 1 : Questions 5 and 6 of Open-ended written interview 1)**	.....pupils - recall and state what they understand by the term saponification - recall scientific terms/ideas related to saponification.
2	Knowledge of important use of saponification in everyday life. **(Addressed by Research Question 2 : Questions 1 and 2 of open-ended written interview 2).**	…..pupils - mention an important, familiar product of saponification in everyday life (soap) and give simple locally available materials that they would use to make a simple or crude product.
3	Application of saponification life world. **(Addressed by Research Question 3 : Question 3 of open-ended written interview 2 and soap-making empirical project).**	…..pupils - demonstrate in practice, their deeper understanding of saponification in an outline of process and procedure for making a simple product and engagement in the empirical project to make a saponification product.

More specifically content analysis was used to examine the pupils' responses from the semi-structured open-ended written interview items on their understanding based on their knowledge on saponification. The responses from the two semi-structured open-ended written interviews where used to categorise the pupils into emergent levels of understanding of saponification (Table 4), with level 0 (an equivalent of complete lack of understanding) being reflected by failure to state what one understood by the term saponification, while level 1 (an equivalent of poor) was for being able to barely state what the pupil understood by saponification including giving some terms related to saponification (though in certain cases some responses were partly distorted or had misconceptions about saponification), whereas level 2 (an equivalent of fair) was for further ability to link saponification to a familiar saponification product and some local materials which could be used to make a simple saponification product (though some associated concepts would be distorted).

Phenomenological analysis examined the deep understanding of pupils through their outline of the process and procedure and engagement with soap-making phenomenon during the empirical project with the view to capture the pupils' "practical understanding of meanings and actions" (Miles & Huberman, 1994, p. 8; Berg, 2007, p.304). This was placed on level 3 of understanding (an equivalent of good) and signified the ability of the pupils to relate saponification concepts to its essence in everyday life such as soap and soap-making phenomenon.

In certain instances content analysis and phenomenological analysis proceeded hand in hand to understand the meanings and actions of the pupils in their written outlines of process and procedure, during observations made for the empirical project and the focus group interviews made with pupils after the soap-making empirical project, with the teacher interviews being used to enrich the understanding of the pupil responses. Since content analysis was applied to this study which had a phenomenological inclination, condensing data through coding operations was avoided (Berg, 2007) in order to discover the practical understanding of the meanings and actions or essence (Berg, 2007; Miles & Huberman, 1994) of saponification by the pupils.

4.2.2. Analysis of the Pupils' Understanding of Saponification

The pupils' knowledge and understanding on saponification as evidenced in the pupils' responses was analysed to uncover their meaning-making and actions on saponification from their open-ended written interview items, observation of the empirical soap-making project and the focus group interview at the end of the soap-making project.

Data was presented throughout the analysis so as to document as well as demonstrate different themes and observations uncovered from each particular data gathering procedure (Berg, 2007). The following sections present the analysis of the data, research question by research question.

4.2.2.1. Research Question 1

Research question one sought to find out what pupils knew about saponification as a way of getting their initial written information through semi-structured open-ended written interview 1. Thus, recall of what saponification was, such as in terms of definition and some scientific terms or ideas related to saponification sufficed here and were seen as demonstration of basic knowledge.

4.2.2.1.1. Semi-structured open-ended written interview 1

Open-ended written interview 1 (Appendix A) addressed the first research question. The meaningful content of the open-ended written interview items were analysed and teased out into three major responses in relation to the various responses the pupils gave. The responses were initially categorised into meaningful content (MC), mixed-up content (MixC), and for those who either left blank spaces in the open-ended written interview or indicated (in writing or verbally) that they didn't know or had forgotten or never learnt were categorised as non-meaningful content (NMC).

Since participants in the research were sampled purposively so as to offer meaningful perspective of meaning and actions on the concepts of saponification, those who lacked appropriate knowledge and understanding of saponification in their responses to open-ended written interview number one, were considered not information rich sources, hence did not proceed to the second open-ended written interview. However, the pupils who did not proceed to the second open-ended written interview were provided with the opportunity to say something on saponification on the last part of open-ended written interview number one.

The following transcripts were some of the responses from the pupils who did not proceed to the second open-ended written interview but were provided with the opportunity to say something on saponification on the last part of semi-structured open-ended written interview 1. For anonymity reasons, the pupils were given different identity code numbers derived from a combination of their class, date of birth and their initials as obtained from general information on personal particulars.

10715FM: Saponification is a topic that I was never taught but I just studied it on my own.

10317JM: Too hard to remember any term from the saponification related ideas.

10715SSL: Our science teacher did not teach us the topic, so I just studied it on my own but I did not fully understand it.

10316BM: I couldn't manage to answer any question on saponification simply because I have never come across it due to lack of materials in grade 9 and we didn't finish up the Junior Secondary School syllabus, neither did we cover half of it (syllabus) with our science teacher.

10716KC: No idea.

10715RI: Our science teacher never taught us this topic (saponification). He was concerned more about teaching us specific topics which would come in the examination and paid no attention at all to saponification. I just heard of it in grade 10 but I haven't had the chance to get into details.

10716RM: I am not sure about saponification because I knew this through personal study as teacher did not explain. This was because he was out for a funeral somewhere. So we did not finish the syllabus to cover saponification. I cannot remember most of the things I studied about saponification.

10716TM: Never learnt saponification. All I know is what I heard at the Junior Engineers, Technicians and Scientists (JETS) Fair that when making detergents, animal fat is used and is mixed with some chemicals. After all chemicals are added, either soaps or detergents are made. To make soap, the mixture is taken into a process of solidification.

From these transcripts the pupils brought out a wide range of issues such as not having learnt saponification in grade 9, non-completion of the grade 9 syllabus to the effect that they couldn't cover saponification completely (which was also attributed to a number of factors such as teacher transfer, sickness, going on leave or non-availability of teachers altogether in term three when the topic could have been taught and many others), covering concepts on saponification through own study or reading, teacher not teaching concepts on saponification as they had not appeared in any final year examinations previously, hence could be neglected. For example, pupil 10715RI wrote that their science teacher never taught the topic on saponification as he was concerned more about learning specific topics which frequently come in the examinations and paid no attention to saponification. The same pupil 10715RI said he just heard about saponification in grade 9 but didn't have the chance to get into details. The other pupil (10715SSL) said that their science teacher did not teach them the topic on saponification but studied on his own though didn't understand it fully.

From the responses the pupils gave to part III of open-ended written interview 1 (Q5 and Q6), the following categories of knowledge and content were established on saponification.

Table 2. Categories of Pupils' Responses from open-ended written interview 1.

Q.n	MC	MixC	NMC	TOTAL RESPONDENTS
Q.5	18	2	8	28
Q.6	13	2	13	28

From Table 2, a more general picture about the pupils' initial understanding of saponification in relation to research question 1 was obtained. The table shows that 18 out of 28 pupils were able to recall the definition of saponification, of which 13 out of the 28 pupils also gave some terms associated to saponification, as an indication of the basic knowledge of saponification from their previous grade. The definition of saponification and its associated terms were considered as the barest knowledge level that pupils would show on saponification and was used as the criteria of selecting them for further participation in the subsequent follow-up part of the study (semi-structured open-ended written interview 2) which demanded for more saponification related ideas. Clearly, as the demand for recall increased to include that of some scientific terms or concepts that fell directly under saponification, fewer pupils (13 out of 28) showed further ability of recall of knowledge with the understanding of the related terms to the concept of saponification.

The following transcripts were some of the pupils' responses to question five (5) and six (6) of the first semi-structured open-ended written interview. The question on what they understood by the term 'saponification' (Q.5) and the follow-up question on associated terms to saponification (Q.6) were used to gain entry into saponification concepts using the pupils' basic recall and was used in Table 4 (Analytical framework of pupils' emergent levels of understanding) as criteria for level 1 of pupils' understanding.

To keep the pupils anonymous, they were given different identity code numbers that were derived from a combination of their class, date of birth and their initials as obtained from the general information on personal particulars. After each pupil's identity code, the number in brackets indicated the question number to which the pupil was responding.

10715WM (5): This is the process of using sodium hydroxide plus bleached animal fats or oils to produce soap and glycerol.

10715WM (6): Bleached fats, sodium hydroxide, drying agents and compression compression chamber.

10515FM (5): Saponification is the general term which refers to the process of soap manufacture from animal fats.

10515FM (6): Flotation, bleaching

According to the two pupils, 10715WM and 10515FM, in addition to saponification being a process, they also gave what may be considered a practical definition of saponification, capturing the materials required in the saponification process, with the other pupil, 10715WM giving the products of the process as well. Such a practical definition revealed that pupil, 10715WM had also clear knowledge with understanding as the response brought out even some of the scientific terms related to saponification that were solicited by question 6.

The following pupil revealed similar knowledge on saponification but with additional mention of another material used in the process of saponification.

10618KM (5): This is the formation of soap and glycerol by the combination of fats and potassium hydroxide or sodium hydroxide.

10618KM (6): detergent, carbonisation, bleaching, drying agent.

As with the previous response from pupil10715WM, the above definition by pupil 10618KM reflected practical definition and which was linked to the materials and products, with an additional alternative of potassium hydroxide to sodium hydroxide.

Other pupils also gave their definitions of saponification and terms associated to saponification to capture their understanding as was evidenced in the following:

10415MS (5): Saponification is the process of forming soap using glycerol and sodium carbonate which are added together.

10415MS (6): Sodium carbonate, glycerol, heating, drying.

Pupil 10415MS, also said that saponification was a process of forming soap. From the pupil's perspective this was the meaningful content about what the pupil knew about saponification. However, this pupil could not recall appropriately that glycerol was not one of the starting or raw materials used to make soap but rather one of the products of saponification, whereas sodium hydroxide should have been infact, the appropriate material added as opposed to sodium carbonate, which the pupil mentioned. At the level of entry into pupils' understanding of saponification, however, the meaningful content was enough recognition of the pupil's knowledge that saponification was a process of forming soap. Thus, the pupil's inclusion of sodium carbonate on the ideas or terms that fell under saponification was the odd one out as earlier pointed out, hence a mix-up of the associated factual knowledge to saponification.

Other transcripts also gave a wide range of pupils' ideas:

10217MT (5): The process which is involved in the manufacture of soap.

10217MT (5):Sodium hydroxide, salting, filtering, sodium chloride or common salt, solidification, perfume, fats, colourings or colourants.

Pupil 10217MT clearly and concisely demonstrated the knowledge of saponification with the understanding of some related terms.

Also pupil 10215RM below gave a further dimension of detergent in addition to the soap in the definition of saponification.

10215RM (5): Saponification mainly deals with the making of soaps, detergents and it also talks about industrial use of saponification.

10215RM (6): Stages and ways of using saponification, uses and places where saponification is used.

This pupil 10215RM brought out the meaningful process of soap-making while the aspect of the detergent is a different process from saponification which however was appreciated as being a closely related aspect in term of usage of both products for removing grease and dirty.

The other pupils also gave their varied responses on their understanding of the term saponification and related terms, for example:

10515DN (5): This is something to do with the manufacture of soap. It is one of the stages which the process undergoes.

10515DN (6): Bleaching

The above response from pupil 10515DN was less definitive and may have indicated lack of confidence in the answer that the pupil gave. As if to support this assertion further, this same pupil only managed to give barely one term related to saponification where as many more terms or ideas could have been given. Further, this response by pupil 10515DN(5) pointing to stages in soap-making or the flowchart on soap manufacture was similar to the two environmental science teachers' general approaches revealed in this study (See verbatim excerpts, under 4.2.3.1 from Teacher ES1 and Teacher ES2 on how, in general they laid out or presented their lesson on saponification, in which both teachers said that they looked at the stages involved in soap-making, which are as outlined in Figure 2 and Figure 3). Hence, it was apparent that the teaching of saponification in grade 9 involved more descriptive and diagrammatic approaches from which some pupils like 10317JM, 10615YK(6) as well as 10715MT(6) could have acquired what they exhibited as lack of knowledge retention or may have found it difficult to single out scientific or grasp scientific terms or ideas from such diagrams as the flowchart. One reason for this could have been that the pupils may have opted to temporarily memorise the flowchart when they were in grade 9 and which was thereafter soon forgotten.

The following were also given by other pupils as responses to question 5 and 6 of the same open-ended written interview and revealed a close range of pupils' understanding on saponification. The other pupils who participated in the open-ended written interview but their responses were not specifically transcribed here, gave more or less similar ideas to either those reflected above or the ones that follow.

10214GK(5): This is the manufacture of soap and detergents using fats and proteins in the presence of sodium hydroxide.

10214GK(6): Manufacturing of detergent pastes and soap using fats.

10615YK(5): This is the process or manufacturing of soap from the animal fats combined with sodium hydroxide.

10615YK(6): I forgot some of the terms.

10515FD(5): Saponification is a separation technique which is used for the production and purification of soap.

10515FD(6): Residue, filtrate, results, and reactions (chemical).

10715MT(5): This is the process of separating the soap from the mixture of fats and salts during the process of making soap.

10715MT(6): ……………………………………………..… (left blank)

10715JMM(5): Saponification is a process by which fat is turned into soap by solidification.

10715JMM(6): Fats, amino acids, glycerol, enzymes, hydrochloric acid, oxygen, lava, wax.

Whereas more pupils were able to state what they understood by the term saponification than those who could show knowledge of scientific terms or ideas related to saponification, it was not uncommon to find some mixed up ideas, in terms of the combination of reactants and products as well as mention of unrelated ideas altogether, as was with pupil 10715JMM(6). To some extent the mixed up or distorted ideas looked more like guesswork, an indication of misconceptions and/or lack of correct understanding of saponification. However, some pupils for example pupil 10716TM, 10716RM and 10715FM, as already transcribed under those who made additional comments as to why they could not write meaningful perspectives on saponification in open-ended written interview 1 said that they had not completed covering the syllabus to learn all aspects of saponification in grade 9.

From Table 2 (Categories of Pupils' Responses from open-ended written interview 1) and the actual excerpts from pupils' responses to part III (Q.5 and Q.6 on saponification concepts) it was still not emphatic as to whether the pupils could further relate saponification knowledge meaningfully to its practical value in everyday life. The second semi-structured open-ended written interview was thus a follow-up to those pupils who demonstrated the knowledge on saponification in the first open-ended written interview based on research question 1 and was intended to address research question 2 which follows.

4.2.2.2. Research Question 2

The second research question elicited how pupils linked saponification to everyday life through demonstrating theoretical knowledge with understanding by associating a familiar product of saponification to simple, locally available materials in their local contextual world. Mentioning of products such as soap as a product of saponification and/or relating saponification to soap-making using animal fats and sodium hydroxide, for example, was seen as appropriate to the task here.

4.2.2.2.1. Semi-structured open-ended written interview 2

Semi-structured open-ended written interview 2 (Appendix B) addressed research question 2.

Questions 1 and 2 (part IV) of open-ended written interview 2 was used to address research question 2. The meaning-making content from the pupils' perspectives as provided in their responses to the semi-structured open-ended written interview items were analysed into categories of understanding: meaningful content (MC), mixed-up content (MixC), and for those who either left blank spaces in the semi-structured open-ended written interview or indicated (in writing or verbally) that they didn't know or had forgotten or never learnt, were categorised as non-meaningful content (NMC).

Meaningful content from Q.1 and Q.2 (semi-structured open-ended written interview 2) was intended to reveal the next level of pupils' understanding of saponification concept (level 2- depicting knowledge with understanding or comprehension, which was used in Table 4 to show the emergent level of pupils' understanding of saponification).

From the responses the pupils gave to part IV of semi-structured open-ended written interview 2 (Q.1 and Q.2), the following pupils' meaning-making categories on familiar product of saponification and locally available simple materials that could be used to make the familiar product of saponification were established:

Table 3. Categories of Pupils' Responses.

Q.n	MC	MixC	NMC	TOTAL RESPONDENTS
Q.1	15	2	11	28
Q.2	12	11	5	28

The ability to remember that soap was an important product of saponification and also to suggest simple locally available materials that could be used to make this important product of saponification in real life was considered as knowledge with understanding of the link of saponification to everyday life. From Table 3, 15 out of 28 pupils in this study linked saponification to soap or soap-making while 12 out of 28 suggested simple locally available materials that they could use to make simple or crude soap. However, it was also observed that the proportion of the pupils who had mixed-up (or distorted ideas) and those who had completely no idea on a familiar saponification product such as soap or realisation that saponification was related to soap or was used in soap-making (2 out of 28 and 11 out of 28, respectively, adding to up to 13) was considerably high than in Table 2 in which only basic understanding of the term saponification was sought in the first question in the table (for which MixC and NMC added up to 10). Furthermore, it can be seen from Table 3 (Q.2) that as the demand for knowledge with understanding increased to include materials that could be used from the local environment to make a simple or crude product of saponification, the meaningful content decreased while the mixed-up responses together with the non-meaningful content increased to sum up to 16 out of 28 (11 out of 28 for MixC and 5 out of 28 for NMC).

The following excerpts represent some of the responses given by pupils to question 1 and 2 of the semi-structured open-ended written interview 2. Pupils were assigned identity code numbers for anonymity as described in the earlier excerpts.

10715WM (1):It can be used in the production of bathing soap, washing detergents (although sulphonation is usually used for detergents) and glycerol.

10715WM (2): Animal fats, vegetable oils, carbon dioxide, sodium hydroxide, enzymes, perfumes and colourants.

10618KM (1): Soap and glycerol

10618KM (2): Vegatable oil (palm oil or olive oil), animal fats.

10415MS (1): Soap and to obtain glycerine from glycerol, which is also a life necessity.

10415MS(2): Sodium, carbon, biological proteins, glycerol.

10217MT(1): Soap (lifebuoy, protex, lux etc).

10217MT(2): Sodium hydroxide, fats (cooking oil, butter), colourants, perfume for the scent to the soap, water, oranges etc.

10215RMM(1): Soap (bathing soap), washing paste, tooth paste, body lotion.

10215RMM(2): Honey, honey wax, plants such as trees, snail fluid or liquid.

10515DN(1): Detergent pastes for washing, bathing soap, bar washing soap.

10515DN(2): Animal fats and vegetable oil.

10214GK (1): Soap and glycerol.

10214GK(2): Butter, vegetable oil, sodium hydroxide, water, pot, fire.

10615YK (1): Geisha soap, romeo soap, detol soap.

10615YK (2): Soda.

10515FD (1): Bathing soaps, candles, washing paste, washing powder.

10515FD (2): Oils, animal fats

10715MT (1): Making of soft and hard soaps and glycerol.

10715MT (2): Animal fats.

10715JMM (1): -It is used in business once the process is completed.

-Brings income to the country or forex once processed and exported.

-Source of government revenue.

-Brings profit to the manufacturing company

-Brings employment to the people

-lead to economic development and lessens imports but promotes exports.

10715JMM (2): Cosmetics (such as fair and lovely, clear essence, epidermal), soap (lifebuoy), vaseline (petroleum jelly), animal fats, some simple apparatus such as smelters and solidifiers or purifiers, some apparatus to clean or remove bacteria, wax may also be used and candle obtained from beehives.

10715JK (1): Soap and detergent paste. I have forgotten others.

10715JK (2): Heat from a stove, a base which can be used for making shape of soap, colouring agent.

While some pupils like 10715WM, 10618KM and 10217MT were able to suggest both the simple products and simple locally available materials that could be used in saponification, other pupils like 10415MS and 10715JMM found it difficult for them to even differentiate between a product of saponification and the materials that could be used to make this product. One pupil (10715JMM) showed a total mix-up of ideas on materials for making a saponification product and wrote that it is used in business and it is used as a source of government revenue (as a saponification product) and wrote soap and cosmetics as materials required to make a product of saponification.

Furthermore, some pupils (10415MS) could not give the appropriate set of local materials that would be used for saponification (proteins were mentioned in place of fats, while sodium was given in place of sodium hydroxide) and glycerol, one of the products of saponification was instead given as a local material which could be used to make soap. It was also evident that some pupils, for example 10618KM, diverted from simple locally available materials which could be used to make the simple product to materials which were not familiar or locally available in the Zambian local context (such as palm oil and olive oil, economically regarded as expensive and more valuable as food). This could possibly suggest the likely indication of the pupils only having theoretical knowledge which they could not use fully to make meaning of their own local environment, later on everyday life.

At the knowledge level of the pupils and in accordance with the approved environmental science and chemistry textbooks for secondary schools, the link of saponification to everyday life prominent in pupils' responses was soap manufacture. Glycerol was also an important link of saponification which some pupils (10715WM, 10618KM, 10214DK) also realised. However, the mention of candles, tooth paste as well as body lotion showed some degree of lack of meaningful understanding of saponification as defined by the pupils (such as 10515FD, 10215RMM). Similarly, for pupils like 10215RMM, whose proposed simple materials were honey and honey wax, with saponification products such as toothpaste, were seen as more of mere guess work or misconceptions. The basic definition of saponification at the grade 9 environmental science level from the approved textbooks suggest fats and sodium hydroxide as the main materials and soap as the product of saponification.

Also, in the scientific context of saponification in this research, the argument to link saponification to marketing and its related economics was viewed as having little or no recognition of the scientific understanding of saponification. As may be seen from 10715JMM(1), the pupil departed from the process of saponification as it related to the useful products such as soap and glycerine (glycerol) found in everyday life but instead dwelled on aspects that did not build on the deeper and practical understanding of saponification and its link to everyday life. Because of time wasted in such avenues during science teaching, one teacher of chemistry involved in this research and base at the high school were the research was conducted observed that ‘‘science needed a practical approach connected to the things the pupils meet in day to day life if it was to make sense to these pupils…, it must be full of skill acquisition where pupils coming out of school are equipped-for example can make soap" (Personal communication with chemistry teacher 1, 7 January, 2010). The teacher went further to say that "the only problem in this syllabus, the children are taught a lot about nothing because when they come out of the school, they know nothing about science, so it may be necessary to re-visit the content-loaded syllabus’’ (Personal communication with chemistry teacher 1).

4.2.2.3. Research Question 3

Research question 3 elicited the pupils' extent to which they applied saponification knowledge in everyday life. This was through a practical application of saponification concepts using the pupils' outline of the process and procedure and the empirical project on the soap-making phenomenon.

Question 3 of the semi-structured open-ended written interview 2 (Appendix B) and observations during the empirical project on soap-making addressed research question 3.

4.2.2.3.1. Semi-structured open-ended written interview 2

The last part of the semi-structured open-ended written interview 2 (Q.3) solicited an outline of the process and procedure for making a simple or crude saponification product as a way of pupils demonstrating knowledge of practical application of saponification phenomenon and ultimately, to pave way for the empirical project.

The following excerpts represent some of the pupils' outlines or main steps for making simple or crude soap using locally available materials:

10715WM: You first put animal fats in a chamber or tube containing carbon dioxide to remove the pigments that it contains. After this the animal fats become bleached. You add sodium hydroxide to the bleached fats. The products of these two will be soap and glycerol. You can add some perfumes of your choice to the soap. The perfumes and colourants added must not have a wide range of allergic reactions to people. The glycerol, I have no idea what it is used for but as for the soap it is used for bathing and washing. You could also add some enzymes if you require the soap to be a biological detergent or soap. By adding the enzymes, they would help in hydrolysing stains of biological origin like blood, chlorophyll and fats.

The pupil's (10715WM) general outline of process and procedure for soap-making was more theoretically anchored and non-practical. This was further supported by the pupil's additional comment made at the end of semi-structured open-ended written interview 1 that "even though we learnt everything in grade 9 Zambian syllabus, we are only good at the theory part and not experimental part because of rare visits paid to the laboratories, therefore, somehow we are handicapped in practicising some of the things we learnt in grade 9 science" (10715WM).

The following was another excerpt from another pupil.

10515FM: During the process of saponification, the soap is made or manufactured by using sodium hydroxide from animal fats.

Finally, after all processes and procedures are done, the last step is where you are required to separate the soap and glycerol since they are mixed in animal fats. After separating the soap and the glycerol you can even spray some perfume to the product inorder to make it attractive and improve its quality.

The pupil's outline of the process and procedure of saponification was sketchy, superficial, and inadequate. The pupil's outline was more theoretical and lacked much practical detail. However, the skeleton of ideas of what the pupil thought would be put to practice was there and the pupil participated in the empirical project. Other pupils as well gave their own perspective of saponification in terms of process and procedure outline.

10615YK: Animal fats are the most important and other substances which contains oils. When they are combined with sodium hydroxide they produce glycerol which in turn forms soap. During this process substances like soda may be used to speed up the chemical reaction and enzyme amylase is used to hydrolyse protein in animal fat to leave free fat so as to combine them with sodium hydroxide to produce glycerol (soap).

Call me again please!!

10618KM: Saponification is the process of producing soap and glycerol from a combination of animal fats or vegetable oil or palm oil or olive oil and potassium hydroxide. The animal fats or vegetable oil are put together with potassium hydroxide or sodium hydroxide in a pan. They are then heated by steam heat. The hard substance which forms floats on a liquid. There after soap and glycerol are formed. The two are formed by adding salt (sodium chloride) to the mixture to separate the soap and glycerol. This process is called salting out. There after some materials such as perfume, colour are added to make the soap look and smell attractive like toilet soap. At first in the process animal fats or vegetable oil is bleached. Bleaching is the process of removing coloured materials or pigments from fat. During detergent formation sulphuric acid is used to neutralise the sodium sulphate.

10515DN: The raw materials used in the manufacture of soap are animal fats or vegetable oils and sodium or potassium hydroxide. However, the fats and the oils contain pigments which must be removed. The first stage is thus bleaching which is the removal of the yellow pigment which is naturally found in the fats or vegetable oil. The second stage is saponification, which is actually the mixing of the fats or vegetable oil with potassium hydroxide or caustic soda which helps in removing stains on clothes. Carbonisation, which is the addition of carbon dioxide to the fats or vegetable oil, is another stage involved. It also involves the putting of perfume to the fats. The second last stage is the removing of the fluid from the fats and oils. It is the one which determines whether the product you want to make will be a bar soap, detergent paste or powder soap. This process can also be referred to as evaporation. Finally, the last stage is the packing of the finished soap product.

Pupil 10615YK had a fairly good grasp on the material requirements for making a saponification product. However, the actual process and procedure lacks a concise method of what could be actually done in terms of the physical processes. Carelessness was also evident in the manner the starting materials and products were jumbled up in the presentation. For example, this pupil wrote that when animal fats are combined with sodium hydroxide, they produce glycerol which in turn forms soap, yet both glycerol and soap are formed when the heated animal fats react with sodium hydroxide. Pupil 10618KM on the other hand gave a clear outline of a saponification process. In his further attempt to address the formation of detergents, he mentioned that sulphuric acid is used to neutralise the sodium sulphate, though it should have been the sulphuric acid is neutralised by sodium hydroxide. Pupil 10515DN equally gave a good attempt of the materials required to make the saponification product though the thrust of the actual process and procedure must have pointed to heating the animal fat to melt them first and not just mixing or adding them to sodium hydroxide, before any mention of the heating. Pupil 10515DN also simply made a mere mention of bleaching but how the bleaching was to be achieved in practice was silent just like how the carbonisation was going to be achieved in practice was as well silent. These 3 pupils were however, among the 7 who later proceeded to participate in the empirical project on soap-making using the simple, locally available materials to demonstrate deep and practical, authentic link of saponification to everyday life.

While some pupils such as 10618KM gave relatively clear outlines of saponification (process and procedure), hence showed potential that they could participate further in the empirical project on soap-making to demonstrate a practical link (use) of saponification to everyday life, others such as 10715JMM were not even able to differentiate between a product of saponification and the materials that could be used to make this product to start with. Generally, some of the pupils' (such as 10715WM, 10515FM and 10515DN) outline of the saponification steps in terms of process and procedure in soap-making was non-practical and inadequate to be used to demonstrate the link of saponification to everyday life. Some pupils' outlines were also unclear, lacked procedural reality and materials were mentioned anyhow whenever they were remembered within the steps outlined, whether they had any link to saponification or not. In certain instances it was evident that the outlines of the process and procedure were not precise enough as a lot of procedural undertakings required for the actual empirical saponification project were left hanging in suspense. For example, the pupil wrote the following as first step for the outline:

> "Using industrial or high standard qualities, take water either in a tank or anything that can be used to hold the water. Heat the water. Mix it with materials such as sodium, biological proteins, if possible and other products such as glycerol. Take something like a separating funnel after having mixed the mixture uniformly…" (10415MS).

For the above pupil, precisely, the fats were the materials to be heated in a metal container and not the water; after which addition of sodium hydroxide and sodium chloride would follow in order to produce soap and glycerol on further heating.

The general feature of most of the pupils' outline of process and procedure was more like the same with scanty articulation of process and procedure, mixing-up of scientific terms, inability to be concise and in certain cases, was more or less guesswork. Additionally, the outline of the process and procedure of saponification for some pupils was mainly characterised with use of incorrect scientific terms such as "make the fats soluble by heating" (10217MT) which would have been, better still, "melt the fats".

Examination of the meaningful content of the pupils' outline of process and procedure revealed that, either pupils made reference to some industrial process whose soap-making conditions were not easily attainable in the laboratory for them to show link of saponification to everyday life or the outline left much process and procedure hanging, hence lacked practicality. Of the 28 pupils who were initially involved in the main research, 7 of them only (all boys) reached the soap-making empirical project to demonstrate their understanding of saponification and its link to everyday life.

Hence, for those pupils whose procedure had adequate steps to follow, they went on to participate in the empirical saponification project, though not as an individual but as groups of 3 so that that they could share their ideas and reinforce each other's strength. It was also noted that there was great interest shown by the pupils to want to participate in the soap-making project as seen, for example, from the plea made at the end of the outline of process and procedure by pupil 10615YK, "call me again please".

4.2.2.3.2. Empirical Project on soap-making

The last and final part to elicit the extent to which pupils applied saponification concepts sought deep understanding and meaning-making actions from the pupils' perspective using the empirical project of soap-making phenomenon in which the pupils followed their outlines of the process and procedure (question 3 of the semi-structured open-ended written interview 2).

Seven pupils gave a clear outline of saponification (process and procedure), hence participated further in the empirical project on soap-making to demonstrate a practical link (use) of saponification to everyday life. During the soap-making project, the pupils were observed and pictures of some of the important different stages of their actions were taken and are now presented in the following sections.

4.2.2.3.2.1. Observation of pupils during soap-making

The observation of the pupils during the empirical saponification project on soap-making provided greater insight into their understanding of saponification and its link to their everyday life.

The 7 pupils who exhibited some knowledge and understanding (on all the 3 levels of understanding as described in Table 1 of the framework of analysis) on saponification as reflected in the responses of the open-ended written interview items in the 2 open-ended written interviews, further participated in simple soap-making to demonstrate their deeper understanding of saponification and its link to everyday life. The observation provided authentic pupils' knowledge and understanding on how they linked saponification to everyday life during the soap-making phenomenon. Procedural challenges, which were not anticipated or taken for granted by the pupils in the written outlines of the process and procedure of soap-making, became evident as observed during the soap-making project. The main characteristics of the observations, in terms of the physical setting and what was observed are now highlighted and presented below:

4.2.2.3.2.1.1. Local materials used

The materials used by the pupils during the soap-making project included animal fats, wood ash, flowers, leaves, table salt (sodium chloride), and animal charcoal.

Figure 5.1, 5.2, 5.3 and 5.4 below show the materials and process of filtering alkali used by the pupils in the empirical project.

Figure 5: The local materials required for making crude soap and the filtration process for alkali.

Pupils gathered some of the materials required for soap-making from their local environment while the animal fats and animal charcoal were provided by the researcher. Through this engagement with the empirical project, the pupils were meaningfully able to make sense of the science knowledge and understanding in real life as they now related it to the environment. In addition, pupils showed responsibility for their environment and sustainability by choosing to pick and use empty bottles of plastic drinks and water thrown all over the school premises from the school tuck shop as some of their vessels for their empirical project.

4.2.2.3.2.1.2. How did they start the process?

The pupils collected the flowers, soaked them in water, crushed them and then filtered off the coloured solution (for colouring the final soap product). A concentrated salt solution was also made by dissolving sodium chloride in water while the melted fat was decanted.

Figure 6.1, 6.2, 6.3 and 6.4 below show the processes of crushing flowers, soaking the flowers, filtering the flower solution, making a concentrated salt solution and decanting the melted fat.

Figure 6: Starting the process

The fats were melted in a pot and then decanted from the unmelted solid fat. The hot liquid fat was decanted into a separate beaker and animal charcoal added to decolourise it (i.e. remove the yellow pigment in the fat). A major challenge faced by the pupils at this stage was the removal of the animal charcoal from the liquid fat as attempts to filter off the animal charcoal saw the fat solidifying in the funnel and blocking it in the process. It thus seemed so easy in theory for the pupils to write about how to remove coloured pigments from the fats but not so in practice.

Figure 7.1 and 7.2 below show the filtration of the melted fat to remove the animal charcoal and the emerging challenge faced by the pupils during the filtration process, respectively.

Fig 7. 1: Filtering the melted fat

Fig 7. 2:The melted fat solidifying in the filter funnel

Figure 7: Filtering the melted fat and the challenge of filtering.

The pupils in the second group to perform the soap-making empirical project didn't remove the animal charcoal altogether, making the soap they made to acquire the black colour of the charcoal as opposed to the soap which was made by the first group.

Figure 8.1 and 8.2 below show the two samples of crude soap made by the two groups of pupils during their empirical project.

Fig. 8. 1: Sample 1 soap

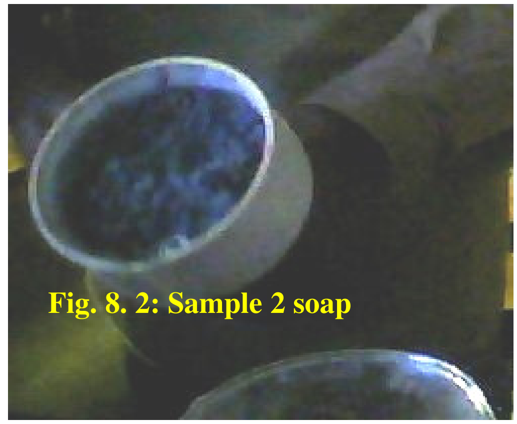

Fig. 8. 2: Sample 2 soap

Figure 8: Samples of the soaps made by the two different groups

4.2.2.3.2.1.3. Experimental/scientific procedures used

The main scientific procedure that the pupils used in soap-making was saponification as they reacted the animal fats with the alkali solution (by definition). However, to accomplish the whole process and procedure so as to achieve the final soap product, several related scientific processes were also involved practically. For, instance, filtration was used for different separation activities in the empirical project. Furthermore, as could be seen in the visual observations made, pupils performed many other scientific processes such as dissolving, melting, decanting, bleaching, and so on. The pupils were thus applying the scientific knowledge which they may have learnt as unrelated and discrete pockets of information under other topics in science but now coordinated in a more authentic way. Notable was the fact that pupils found difficulties and challenges in practice to do what they had suggested in their written outlines. Thus, the ambiguities in the outline became real obstacles in the authentic practical activity during soap-making as they posed technical challenges not anticipated in theory.

4.2.2.3.2.1.4. Collaboration between and among pupils

A great deal of collaboration occurred among the pupils working in the same group during the empirical project. They put the required materials and/or apparatus for soap-making together and agreed on the various activities to follow as well as the sequence for setting up the preliminaries such as having the flowers crashed, making the concentrated salt solution and melting the fats. Whilst conducting the activities involved in and leading to soap-making they used a wide range of scientific terms related to the many processes that they performed, some appropriately while some scientific terms were not applicable to whatever they were doing. However it was not uncommon to find the pupils discussing some of their various steps or activities and their challenges using their vernacular language. This collaboration to some extent allowed pupils to interact and share opinions and ideas with each other.

4.2.2.3.2.1.5. Scientific/local terminology or vocabulary used

A blend of both English and local language terms were used during their conversations, for the materials that they gathered and the activities they performed during the soap-making. The terms such as filtering, soluble, colouring, melting, decanting were also commonly mentioned in the local languages. Some scientific terms were also mentioned randomly with little or no connection to what they were doing and one such term was capillary action which was mentioned during the filtration process.

4.2.2.3.2.1.6. Connection of soap-making (phenomenon) to the scientific concept (saponification).

Through their participation in the soap-making process the pupils made clear connection of everyday life phenomenon (soap-making) to the scientific concept (saponification) as the two, directly or indirectly implied each other. The kind of mix up some pupils showed in the written interview between useful saponification product (soap) and locally available materials (fats and alkali) that could be used to make a simple saponification product was not experienced anymore in the focus group discussion after the empirical project. It became certain, especially after making the soap and testing it on their hands that, as the name implied, saponification was used for making soap.

4.2.2.3.2.2. Focus Group Interview for seven pupils after the Empirical Project

Since the third research question was concerned with the pupils' practical ability and concrete understanding of saponification in relation to the soap-making phenomenon, after the soap-making empirical project, the pupils who participated were then engaged in a focus group interview which provided them a more open platform for expressing themselves, their experiences, ideas, feelings, thoughts, views, challenges and understandings on saponification as a way of concluding. The 7 boys who reached the empirical project stage participated in the focus group interview.

For purposes of the interview so that the pupils were addressed by name during the focus group interview and not the earlier identity codes, the pupils were given pseudo names; John (for 10515DN), James (for 10214GK), Jimmy (for 10615YK), Jack (10217MT), Mark (for 10618KM), David (for 10415MS), Dennis (for 10715WM), before starting the interview.

4. 2.2.3.2.1. Pupils' understanding of saponification and practical application of phenomenon in everyday life.

Pupils' understanding and practical application of saponification were examined from the pupils' perspective on saponification from the soap-making phenomenon; common characteristics or rather commonalities, meanings and actions which they demonstrated in the empirical project (the expectation of level 3 category of understanding in Table 1: Framework of analysis).

The following verbatim transcripts show the interview with the pupils on their practical understanding of meanings and action on saponification as related to soap-making from their perspective:

Researcher: What are some of the things that you learnt under saponification topic in grade 9? That is, before the empirical project that you did as part of this research.

Mark: I learnt that animal fats contain fatty acids and animal fats and what...aaaah...animal fats and sodium hydroxide will make soap and the fats must be bleached- then it must be bleached in what... in a vacuum. Then at that point we couldn't really finish the syllabus. But it must be bleached in a vacuum before adding sodium hydroxide.

Researcher: What do others say? Didn't all of you learn saponification in grade 9?

Jack: I just read on my own

David: Even me I just read on my own.

Jimmy: I also just read on my own

James: I also just read on my own from books.

Researcher: And, yourself (John) what did you learn on saponification in grade 9?

John: Ok, maybe I will start from- ok, when you have these...the requirements...may be the animal fats or vegetable oil; first before....before adding sodium hydroxide- to do saponification you need to bleach those fats in order to remove the yellow pigment which is found in those fats... because I don't know...I don't know what this yellow pigment is so called but what I know is that you just

need to bleach them so that you removed that yellow pigment and then from there that's when you can add sodium hydroxide...is it or potassium hydroxide?

David: Sodium hydroxide or potassium hydroxide…either.

John: -continues: yaah...sodium hydroxide, that is for saponification.

Dennis: Also that you need to heat the fats in a vacuum at $190^{O}C$ for 30 minutes.

Researcher: Any more ideas on saponification as learnt in grade 9?

Jimmy: Just as he has said...that you need sodium hydroxide, animal fats and also charcoal which supplies carbon dioxide (such as the activated carbon)...and that before sodium hydroxide is reacted with fats, charcoal is added to bleach the fats...and if you want to add perfume to the soap and colour, you have to add the perfume before the soap is in the solid state and then cut or mould it into appropriate sizes and shapes so that as it is gets dry it already has the perfume.; that is the soap itself.

John: And there are those soaps; the…what...the...what...the detergent pastes like boom; for them...as in...ok, according to what I read, they don't do saponification but they do this process called sulphonation....something like that. I don't know the name of the mineral that they add...

James: …adds...sulphuric acid.

John: Yaah, that is the chemical that is involved in sulphonation, that's if you want to obtain a detergent paste not these other soaps.

Researcher: After learning saponification in grade 9, was any experiment done by yourselves or a demonstration by the teacher? If that was so, what was the experiment or demonstration all about?

Mark: We were just taught about saponification but no demonstration nor practical was done.

Dennis: None.

John: We were taught about the manufacturing of soaps in industry but there was no practical nor demonstration that was performed.

The main ingredients required for soap-making which the pupils also used in the empirical project were either actually learnt in class or pupils had to read from the science textbook on their own. However, pupils raised their main concern that most of them had either to read the concepts on their own as they had no teacher or they couldn't finish covering the topic on saponification in class, for various reasons, including were the teacher advised that these concepts on saponification were not examined in the final grade 9 examinations. Equally evident from the excerpts was that certain practical requirements, as outlined in the pupils' textbook, for saponification were specifically for the industrial neat process. For instance, bleaching the fats in a vacuum was practically not easily attainable during the empirical project. However, the bleaching procedure could still be done in simple demonstrations. Perhaps, this requirement of what seemed not easily practicable may have led some teachers to avoid demonstrating the soap-making process in class and instead justified to the pupils that other materials required were beyond the reach of the schools. For example, one environmental science teacher (Teacher, ES1) did allude to the lack of resources, both material and financial as well as the level of complexity of procedure described in the environmental science textbook as the huddles making them to fail to do experiments or demonstrations on saponification. The following verbatim excerpt was part of the interview:

Researcher: Have you ever performed the actual experiment to show the pupils pupils how to use these fats and oils to produce a product which they can see and lay their hands on?

Teacher ES1: As I said earlier that if you are a rich school, it is so easy to do practicals in science but as we are here I don't think I can manage to do the practical part showing them these are the steps and these are the products of the process.

Researcher: What requirements complicate the demonstration? Or what material requirements seem to be lacking for you to do a demonstration?

Teacher ES1: I think...aaah…with this topic we lack apparatus...ok...you know it mentions of the vacuum chambers where you should heat the fats at 190^{o} C. Quite alright one can use the others (improvised) but I think it is more complicated; I would need complex materials also to use to do the experiment which we are not having as of now.

However, the same teacher said she opted to bring the already made or factory made soap to the class to show the link of saponification with everyday life:

Researcher: In the process of facilitating the learning process, what sorts of links or connections do you make to everyday life on saponification?

Teacher ES1: Although other things may be required, I usually bring soaps-soft soap and hard soap and I show them this is soft soap and this is hard soap. I tell them that soft soap is made with potassium hydroxide and hard soap is made with sodium hydroxide.

The following is the continuation of the focus group interview with the seven pupils on their experiences:

Researcher: Coming to the project you have just completed this time, what have you learnt from it? Is there anything that you may have learnt on top of what you learnt in grade 9?

Mark: I have learnt the use of animal charcoal in bleaching the fats.

Dennis: In grade 9 we learnt that it is carbon dioxide that is used for bleaching, but after doing the project, I have learnt that it is actually through the use of charcoal.

Mark: In grade 9 we also learnt that when heating the fats you must do it in a vacuum but in this project we did it just in a pot. So it was good to learn that it was ok if you heat just like that.

The pupils pointed to the fact that what was considered as complex or not easily achievable or misunderstood in theory, might be provided a second chance for the pupils to redress it during actual practice. Indeed, theory alone might make scientific concepts or procedures appear as if they were so complex and could only be done using the state-of–the art equipment and not attainable under ordinary class room conditions. This, the pupils observed, might further switch them off or make them lose interest.

The focus group interview with the 7 pupils continued as follows:

Researcher: Any challenges that you faced in the project?

Jimmy: During the filtration...because according to what I read in books you need to filter the...fats...is it the fat, at high temperature or pressure? ...something like that. So when we were doing the project (I believe you guys will agree with me) we had a problem in doing filtration as it was very slow.

Mark: We were also waiting for so long and the fats were solidifying quickly in the process. So we had to reorganise our approach to add spirit to the melted fats to avoid solidifying during filtration since fats are soluble in organic solvents such as spirit.

In addition to dealing with saponification, pupils extended their application of science knowledge as they began to use practically other scientific processes such as filtration, which also allowed them to come across such terms as organic solvent (which was used to filter the fats without solidifying).

Researcher: How do you compare the learning and understanding that took place in grade 9 and the project you had just done this time trying to follow the actual process of saponification by doing it to obtain your simple or crude soap?

Mark: Apart from the time required to put the materials together, the actual experiment also takes a lot of time to do it. It is more demanding as well as difficult to do than just the theory. Practically, filtration of the fats to remove the animal charcoal was very challenging.

John: I don't know what they do in industry to obtain the filtrate quickly because...we saw here that…that…

Dennis: (chips-in); the process is slow.

Researcher: Jimmy, you want to say something?

Jimmy: Yes...these companies or industries that make soap, I think there is a certain process may be that they use to do the filtration and not the way, maybe, we did…because it was very slow and I doubt if they can manage at the rate the filtration was going in our project.

Mark: The experiment we did showed that the theory much easier than practical in terms of the effort put in.

The pupils seemed to acknowledge the aspects of time required, the demand in terms of effort involved in planning the process and procedure to do the actual experiment as well as the challenges of doing the activity in practice. Indeed these were challenges that affected even the teaching and learning of science and consequently the understanding of scientific concepts achieved by the pupils. From the engagement that pupils had with the materials, it was anticipated that more internalisation of scientific concepts would as well have taken place.

The pupils also pointed to the fact that theory was much easier than practical. Evidently, as the demand for deeper understanding involving practical activity increased the proportion of pupils involved in the study drastically reduced from 28 to seven only. This demonstrated that most pupils achieved very low levels of understanding which mainly involved memorisation of scientific concepts that they only used to define and gave some concepts associated with saponification.

Researcher: Anything more?

Dennis: The other thing is that the explanation on saponification, the materials mentioned and the procedure in the grade 9 science textbooks is just too summarised and one cannot follow those books to do a practical and make the soap. Much of the steps that one would need to follow to make soap in a practical task is actually missing. The information in the book is too inadequate and is just aimed for the purpose or sake of examination but certainly is not enough for a practical.

John: As for me what I now know about saponification on manufacturing of soap is not what I learnt in grade 9 because now I can gather some materials together and at least make soap. As he (Dennis) has said, those science textbooks we used in grade 9 are too summarised and a lot of steps are missing as one would not make anything reasonable out of those steps to do saponification.

From what the pupils said, it was clear that the science textbook used in grade 9 at environmental science level did not, in the first place, provide the approach where pupils engaged with the actual materials for them to gain the life experience of the phenomenon of saponification. Thus, in order to engage with the saponification phenomenon, pupils needed more understanding of the concept of saponification and also the practical method to follow for the process and procedure to make soap, which they could only get through reading different literature sources.

The following was the continuation of the focus group interview with the 7 pupils:

Researcher: Which approach of learning science would you prefer; one using theory or both theory and practical?

Group answer: Theory followed by the actual practical.

Researcher: What could be the main problem in junior school that may have hampered you from doing the actual practical?

Jimmy: Lack of apparatus, interest of teachers...they know that most exam papers mainly have obvious topics like electricity so that is what they concentrate on.

Mark: And also lack of chemicals.

Jack: And also lack of laboratories in junior secondary schools.

Researcher: Any further reflections on the topic of saponification and the soap-making project in your final thoughts?

John: If we had not only done theory in grade 9, our experiment could have been even better and more successful as we could have had more confidence.

Jimmy: The teachers in junior schools may be, know that the manufacture of soap is done already in industries so maybe they just want to give us an idea.

Dennis: There are a lot of diagrams in the grade 9 book which are not easy to follow. The method of soap manufacture should have been outlined step by step even in terms of what to do in practice and the approximate timing required for each step.

James: The experiment gives a lot more or involves a lot more science ideas that can help one in understanding other topics in science. It took us over 3 hours to complete the experiment on soap-making yet in class the lesson on saponification was done in about 30 minute or so.

Jack: The science textbook in grade 9 does not really capture what really is to be done in practice, how the product will look like or the appearance, so that as you are doing it in an experiment you are able to compare and then progress confidently. The information is very scanty and lacks a practical procedure.

The pupils did recognise and appreciated the essence of doing the practical from the actual materials other than mere theory. The phenomenological scientific method of using the senses was here mentioned by the pupil as an important element to acquiring a rich picture in the learning process, which the environmental science textbook seemed not to have related to the appearance the pupils had earlier talked about.

The focus group interview ended with the following observation:

Jimmy: there is a lot more science involved in saponification if you did the actual saponification project. There are terms like filtration, melting, bleaching, solubility, soluble, filter funnel, colouration and I think many other things that came up during the process of doing the experiment to make soap.

From the pupils' voices it was clear that most pupils learnt science through talking about and mere mention of scientific concepts from which most of them could not form a rich picture about science. Indeed learning as a lifelong process would cease to be so if the process of learning is only examination centred as it is a fact that not all who sit for the examinations pass these examinations. Hence, ability to be able to use science or the related scientific ideas not only in examinations but to make useful links of scientific concepts to everyday life outside school would be useful in the pupils' lives.

4.2.3. Analysis of Teachers' views about making links to pupils' life world experience.

In order to get the teachers' views on their general approach when teaching saponification and link to saponification-related phenomenon during their science lessons, 4 teachers (4 to 20 years of experience) were interviewed using a semi-structured interview guide. The interview was recorded on a digital voice recorder and was transcribed verbatim. The teachers' input was also used to corroborate the responses from the pupils as well as to enrich the discussion, conclusion and implications on the pupils' understanding and meaning-making of saponification. Research question 4 addressed the teachers' perspectives on saponification as taught or ought to be taught.

4.2.3.1. Research Question 4

Research question 4 sought to find out how environmental science and chemistry teachers facilitated for pupils to link saponification concepts to everyday life during the science lessons. Though the main focus of the research was on the pupils, teachers however provided rich insights related to the pupils' understanding as related to everyday life.

The following verbatim transcripts were interviews with the environmental science and chemistry teachers on their general approach and facilitation role to saponification. Though during interviews the teachers were interviewed individually, the data will be presented together. According to Cohen, Manion and Morrison (2007) presenting data this way amalgamates key issues emerging across the individuals and captures major themes.

The two environmental science teachers were identified by the code ES1 and ES2 respectively while the two chemistry teachers were identified as CT1 and CT2 respectively.

Depending on the insights sought and level of teaching (whether at junior or senior secondary), some questions were answered by both the environmental science and chemistry teachers while certain questions and thoughtful perspectives were represented by one of the two groups of teachers, as such questions might had applied more to the particular grade level.

Researcher: Under which topic does saponification fall in your syllabus (for the appropriate level/grade)?

Teacher CT1: Ok, in the syllabus we talk about saponification when you are dealing with bases, i.e. under acids, bases and salts...and the way we teach it, it is just mentioned as one of the uses of bases…that they are used in soap-formation- when the bases are reacted with fats...animal fats, the salt of the organic acid in the fats is what is called soap, but beyond that, nothing is added- it will only appear may be in esterification or hydrolysis of fats in organic chemistry- that when fats are broken down by bases we form soap- so again mentioned…just a mere mention!

Teacher CT2: At senior secondary school level, saponification is covered more fully under organic chemistry. Also, just as a mere introduction when introducing chemistry for the first time in grade 10 we tell or mention to the pupils that the soap they use in everyday life in their homes is as a result of chemistry- but the details then will be covered under organic chemistry.

Teacher ES1: Saponification is a continuous sub- topic on the topic of separation techniques. We introduce it by telling the pupils that we will look at the separation techniques which are still going on in the formation of soap in industries.

Teacher ES2: Saponification falls under matter, specifically separation techniques.

Researcher: At the level you teach, what is the best suited definition that you use to define saponification?

Teacher ES1: At junior level we define it to say, saponification is the formation of soap together with an important product called glycerol when sodium hydroxide or potassium hydroxide is added to fats or oils.

Teacher ES2: Saponification is the process through which soap is made.

Teacher CT1: We define saponification as a process by which soap is made when fats are reacted with bases.

Teacher CT2: The word saponification comes from the word soap, so its actually formation of soap by breaking down of fat using sodium hydroxide solution.

The teachers in this study acknowledged the fact that concepts on saponification were covered at both senior and junior level, with the general agreement that at senior level the concept came under organic chemistry while at junior level they were covered under separation techniques. In addition, some chemistry teachers did also handle aspects of saponification under the introduction to chemistry and its applications in society, while others also brought in aspects of saponification under acids, bases and salts. So far, at whatever point saponification was covered, the teachers simply made mention of it as being used in soap-formation and the definition pointed to the process used in soap-making.

Researcher: In general, how do you layout your lesson, i.e. presentation of the lesson when teaching saponification (major themes in the topic).

Teacher ES1: The lay out of the topic should be in stages, starting from the reactants which are involved in the formation of soap, that is, the fats and oils, then you talk about what should happen to them (the fats or the oils). Then what should be added to the oils or the melted fats- all the stages should be put clearly the way they are followed even in the industries. In short, the lay out should be stage by stage. That is why you should have a flowchart showing the stages as melting the fats, bleaching the melted fats, saponification reaction, salting out and then drying the soap.

Teacher ES2: We look at the stages which are involved in soap-making:

(1) Bleaching stage (2) Filtering

(3) Saponification –as a stage (4) Salting out

(5) Drying

(6) Marketing- as a final stage which involves the selling of the soap.

> To begin with, I must admit that the very first time I taught saponification, it was challenging but I had no way of avoiding it as the syllabus demands that I teach it... it was almost complicated. In my second time and year of teaching it, I then thought of involving the pupils in groups to discuss each of the stages as laid out in the science textbook. This was with the intent to act as just exposition; teacher-based question and answer- marshalled by children left on their own. A group was assigned a given stage involved in soap-making to discuss and then report the group findings. For example, the filtration stage- the group were to discuss what they thought was happening at this stage and then reported the group findings. The best thing I discovered from this approach was that the pupils read and discussed on their own first and the questions the pupils asked thereafter were more objective and focussed.

The teachers articulated the processes that were covered under saponification, most of which, indeed involved the practical aspect of science which the pupils could use to develop and show their skills during the actual process of soap-making, thereby building on and complementing their understanding of the concepts under saponification and the link to soap-making phenomenon. However, the marketing aspect, being not much of a scientific concept related to saponification, might just have been mentioned as all pupils might have bought soap before or might have heard or seen an advert on radio and television on soaps, hence they were aware of the marketing aspect of soap with certainty. The real scientific phenomena that the pupils needed to link to their everyday life were inherent in the remaining stages outlined by the teachers (ES1 and ES2) as melting the fats, bleaching the melted fats, filtering, saponification reaction, salting out and drying the soap product. These processes, once followed through an actual experiment could have been used to build a rich picture of saponification and help pupils develop long term learning experience which the pupils would not easily forget by tangibly relating classroom science to everyday life. Indeed, the learning experience that would be practically acquired by the pupils would be beyond what theory or words only could have developed in pupils.

The interview with the 4 teachers continued:

Researcher: What are the key words that you usually use when you are teaching saponification in class?

Teacher ES1: For saponification? Ok, to simplify the word itself we just say soap manufacture or soap-formation in industries.

Teacher ES2: The key words fall under the major themes covered under saponification; being soaps (types- soft and hard soaps), chemicals used to make the different soaps (sodium hydroxide and potassium hydroxide) and processes involved in soap-making.

Teacher CT1: The key words are neutralisation, acid, base, salt (soap), water of course, if you are looking at saponification from the point of view of uses of bases under acids, bases and salts.

Teacher CT2: The word soap, the hydrolysis of fat (and then the backward reaction of esterification).

$$\text{Fatty acid} + \text{sodium hydroxide} \rightarrow \text{soap} + \text{glycerol}$$

From the teachers' responses it was evident that the word that could not be avoided by any teacher in their efforts to give the key words that fell under saponification was soap.

The interview was continued as shown by the following transcripts:

Researcher: Is there any practical or demonstration that you do with the class or you give to the pupils to do when teaching saponification?

Teacher ES1: So far the only practical part of it I have given the pupils before is to research on what other things can be added in the process of saponification which we haven't very much dwelt on during the topic. That is so far what I have done.

Teacher ES2: I am hoping to do so in future as I am hoping to improve my previous approach every year. I will try to follow the outlined stages and try to see if we can make materials close to or similar to soap.

Teacher CT1: Nothing. The way we teach science these days, if you include the practical work, the time will not be enough to cover even half the syllabus, although it is the best way to teach science that you have to teach it with practicals- it is a practical subject you have to include some practicals but it is because of time...the syllabus is so vast that if you have to include practicals as you are teaching, you will never finish the syllabus...and we have accepted it that way! To make matters worse, is when you are in a school where there is no trained laboratory technician where if you think of a practical, you need to have time to arrange everything, demonstrate, remove them for safe keeping after use, so you find you have no time for a practical, hence we have accepted to teach it (chemistry) theoretical.

Teacher CT2: Not always but I have done it once since I started teaching some twenty years or so ago. In fact, it was my laboratory assistant who did it…he boiled the fat and vegetable oil with sodium hydroxide and then allowed it to cool down for some day. Then later, it crystallised, so what was coming out was a solid that was soapy…just to demonstrate all this…so what I needed were just the other ingredients to make it attractive.

The teachers showed some common agreements to the teaching approach which they employed during their lessons on saponification in which a little, if not no practicals at all, were done by the pupils to practice and concretise what the pupils learnt in theory. There was equally no demonstration done by the teachers too, to show the pupils the science involved in saponification. The process of saponification, as earlier alluded to by teacher ES1, was taken to be purely an industrial process and not what could easily be done by the pupils themselves.

Thus, saponification was taught more descriptively, as emphasised by Teacher CT1, than practically with reliance on the pupils to visualise what the teacher was always able to 'see' because of the long teaching experience, even when it was not vivid for the pupils. However, during the interviews the approaches the teachers described about teaching saponification seemed to reflect or entail something that the pupils and the teacher, could do themselves in a practical experiment or demonstration- to let the process and procedure develop authentically and be part and parcel of the pupils' appreciation of the lifeworld of science, hence leave a permanent skill, creativity and memory in them. If the process is practiced authentically, not only will it be confidence building and allow pupils to develop ownership of the knowledge, but will also make the pupils develop more trust in the teacher by authenticating the theory, which when brought out only through abstract as the lesson progresses, would make it hard for the pupils to cement the scientific concepts involved together. It was probable from the theoretical point of view that the pupils were left with more doubts or had very little confidence to put what they learnt together in practice on their own. The best explanations that teachers tended to give to pupils in trying to be practical were word equations which might not equally convince the pupils to see what the teacher saw either. As considered by Teacher CT2 the key aspect on saponification was the equation:

Fatty acid + sodium hydroxide $\rightarrow$ soap + glycerol

The interview with the teachers continued in the following excerpts:

Researcher: How do you facilitate for the learning process during the lesson on saponification?

Teacher ES1: As a teacher you should have the teaching aids such as a chart showing the flow or the stages in the formation of soap so that when you are at a particular stage the pupils are even sure that we are talking about this particular stage or the second stage and the methods used in the separation techniques in production of soap. I also bring to class the actual soaps and when it comes to soft soap we use it with water to show the scum that it produces because of some glycerol left during the process of making it and I show them that the laundry soaps do not leave much of the scum because much of the glycerol was removed during the process of salting out of the soap.

Teacher CT1**:** I usually start with saying fats when reacted with bases they form soap. I then connect the local materials, fats and ash (as base)…the base in ash will always dissolve in water, no wonder when cooking say, beans or okra at home they get that solution from ash- a base. By so doing we are trying to show them that even at home in their villages they can make soap…then you connect it to, of course, the school laboratory where the base would be sodium hydroxide or potassium hydroxide- which are used industrially- but just by merely mentioning…so to them it is just part of something which they are learning and they are being taught, hence cant see it or does not really touch their lives, unless it is done practically.

Teacher CT2: First it is the background- that they have to know the reaction of fat, that is an ester, when hydrolysed, what is formed- that is the first step…so it is the opposite of esterification. So when a fat which is an ester, i.e. a lipid…when it is hydrolysed, essentially will form an acid and water, ok…so that's the first step but if during the hydrolysis process there is already sodium hydroxide then that hydrolysis process, instead of forming the acid, you are going to form the salt. So the pre-requisite there is how the ester link is broken to produce the necessary alcohol and the acid and then the acid should form now subsequent salt, so they will be able to tell the formula of the salt from the structure of the acid …because they are just going to replace the hydrogen of the acidic group by sodium…so first, they must know esterification and then the reverse reaction, then you go to saponification.

The teachers' facilitation role, to some extent suggested the authentic practical approach of using the actual materials that could let the pupils to link the process of saponification to everyday life but due to the constraints and challenges the teachers faced, in most cases the abstract approach was used more during their facilitation.

Researcher: What can you say/tell them; in your view, if a pupil asked you why do they have to learn saponification, (such a tongue-twisting word) or rather; why should this topic be taught to pupils?

Teacher ES1: Yes, in science there are terms which we should know, although we have simpler words in plain English, science has got its own terms, so it is important for pupils to know the terms used when you are talking about something. So I would say it is very important to know that soap-formation is saponification, so that when they come across such a term they are not confused that it is something so strange but they straightforward know that saponification is soap-formation for the manufacture of soap. Pupils should also know that it is not just relevant to talk about the soap but they should know that the soap they use can be made even by themselves using the process of saponification. So it is important because it will make them to relate the topic to day to day life.

Teacher ES2: It brings the science of the things we use everyday. In ddition, in this dynamic world one may even get employment in future in a soap-making industry, hence this understanding from school science, during interviews, would make such a candidate better than the way without some understanding on saponification. The concepts in saponification also form the foundation of the senior level for the pupils. It is actually very important that the pupils have such a foundation.

Teacher CT1: Yaaah, that will be a very good question, though under certain topics, also a very hard question to tell them an answer. Generally, in chemistry, the way we look at the subject, it is abstract because the way I am looking at saponification it is like, you look at the particulate nature of matter…infact we are even luck that the pupils do not ask us such questions; because if a pupil was to ask what is the relevance of that topic and why should I be learning the particulate nature of matter, why not teach me, may be formation of lotion so that if I don't get employed in future I can be making lotion? Firstly, saponification is an important topic to our daily lives such that acquisition of such knowledge goes beyond the classroom and could be applied in our villages, whenever the situation dictates. It is not justifiable for a learned somebody in the villages to look dirty when they can access animal fats and ash is all over. So I can say, this is to equip you in case you are in a problem- you can make soap in the village and you would see what you learnt comes out to be beneficial, more so in a rural set up -problem-solving, where you have no laboratory.

Teacher CT2: Of course, it's a thing that they apply everyday, it's like part of their lives. Without saponification ideas applied in the industry, the pupils cannot look clean and it also prevents germs from entering their skins…so we need soap just like we need food; in the same manner we learn how these foods are prepared and processed, the same manner we have chosen to learn about soap…it is a domestic commodity that is very important to our lives.

The teachers saw the concept of saponification as being useful in everyday life and in such areas as in problem-solving as well as for pupils' academic foundation that could be laid at junior secondary level so that they could have a better understanding when they meet similar concepts at the senior secondary level.

The continuation of the interview with the 4 teachers follows:

Researcher: So at the end of day when teaching this topic what connection or link of saponification do pupils make to their everyday life?

Teacher ES1: They will always think or remember of the soap when they are bathing that this is the soap we learnt that it is made using the process of saponification.

Researcher: What could you do to better ensure that pupils link saponification to their everyday life in your facilitation process?

Teacher CT1: When teaching, the way I bring the topic…I tell them that this soap is a product of fats- which fats they know…They know glycerine- which they mix with lotions and which others apply directly on their bodies , they have also been sent to buy the commodities before and are all products of saponification, hence they can link or connect saponification to the soap and glycerine- the things they use everyday. But, it may be that the pupils do not see or make any connection because we don't teach saponification properly and the pupils are also just reading to pass examinations – the science is not taught to make it useful for later life and pupils have also got used to it just that way.

Teacher CT2: Chemistry is a practical subject. After they have handled some chemicals and so on in the laboratory then they are told to rinse or wash hands…always…what they are using that is soap itself, so they are applying saponification for safety measures. So its one thing that they will always use in the laboratory and so on. Because soap is a bit alkalinic it also neutralises acidic burns that might be on the hands. So to some extent it is highly applicable.

The teachers were in complete agreement that there was a lot more potential that could link saponification to everyday life if planned properly in the facilitation of environmental and chemistry lessons and could help make the scientific concept less abstract and less theoretical.

The following transcripts were recorded as the end of the interview:

Researcher: Finally, any reflections/comments you may want to make on the topic.

Teacher ES1: I think the best way to teach saponification is to have the apparatus and materials which should be used to do a demonstration or group work or even a project to make simple soap sample using the same process as a way of making pupil see how theory can be employed in practice.

Teacher ES2: The interview has made me to think of revisiting my approach to the way I teach this topic to my pupils. I have realised that the topic is interesting as it makes pupils see how simple science could be and which they can relate to their day to day lives since they use soap everyday. The pupils also see the things they touch and use everyday are also the things in science and which can be even made by themselves, therefore simplify the understanding of science as a whole.

Teacher CT1: The syllabus should be encouraging practical- for example to make soap from fats. Because, in this case, if pupils make soap, they don't only become very confident but also develop confidence in the teacher, too. Other topics also would be approached in a similar manner as they may also involve the things we meet in day to day life. In this syllabus the children are taught a lot about nothing because when they come out of the school, they know nothing, so it may be necessary to re-visit the content- loaded syllabus.

There was a further general view and realisation by the teachers in their reflections that for meaningful learning which helps to develop pupils' deeper understanding of science to take place, both scientific concepts and well-planned practical activities that engaged the pupils in varied but tangible practices found in everyday life should be used. Though the teachers acknowledged some major challenges that derailed their desire for such an effective teaching process, mostly hinging on policy, curriculum and poor funding, they nevertheless pledged to reposition their approaches to teaching in order to involve the things that pupils met in everyday life whenever this would be possible. Teachers saw the potential of improving pupils' understanding of scientific knowledge if pupils could attach their own experiential meaning to scientific concepts as a result of active or tangible engagement with the materials that defined the phenomena they dealt with in science lessons. The teachers argued that it would be very difficult for a pupil to forget an experience in which the pupil was actively engaged, such as say soap-making, hence such an activity linked to a scientific concept was bound to leave a permanent mark of understanding as opposed to memorisation of scientific facts and principles geared for the examinations only and beyond which learning would end.

4.3. Ethical Considerations

When conducting the research, necessary steps, care and behaviours were followed to ensure moral and responsible defensible behaviour towards the participants or indeed any other human subjects involved (Bell, 1999; Saunders, Lewis, & Thornhill, 2007). The main considerations with respect to ethics included the participant's right to privacy, safety, informed consent, right to withdraw, confidentiality of participants and of the results in reporting and disseminating findings of the study (Bell, 1999; Berg, 2007; Saunders, Lewis, & Thornhill, 2007). These considerations were taken to ensure that no harm was inflicted on the participants while caution was equally exercised to ensure that there was no bias introduced on the part of the researcher (Kumar, 1999; Maree & Westhuizen, 2007). In ensuring that there was no bias introduced by the reseacher, another teacher who was not a participant in this study was invited to also observe and then in the end compared notes of the interpretation of events made during the observation of the empirical project on soap-making with those of the researcher (Bell, 1999).

Pupils who participated in the data gathering process where sincerely thanked and also as way of appreciating their valuable time, some material appreciation (such as past examination papers, pens and refreshments) were given to them at the end of the data gathering period. The research was also beneficial to the pupils at large as it made them reflect on, apply and engage with many other scientific concepts of current and future study in their school science curriculum. Meeting the concept of saponification and indeed other scientific concepts in future grades would probably make the pupils to have a more refined and positive approach in terms of understanding from the emanating experience and interpretation.

CHAPTER FIVE: DISCUSSION OF THE FINDINGS

5.0. Overview

The chapter presents the discussion of the findings of the study on the pupils' understanding of saponification and the link to everyday life from the pupils' perspective of meaning-making and actions exhibited. The structure and presentation of the discussion of findings start with the actual pupils' meaning-making process and actions on linking saponification concept to everyday life and is then corroborated by the general teachers' facilitation role during the saponification topic to help provide more insights into pupils' understanding on saponification and enrich the discussion. The discussion of the findings are presented research question by research question, using elements from the theoretical framework, with the analytic generalisation at the end.

5.1. Pupils' Understanding of Saponification and Link to Everyday Life.

The main focus of the study was the understanding of saponification and its link to everyday life from the pupils' own perspective of interpretation, meaning-making and actions on saponification. The link of saponification to everyday life has further entailing consequences on the pupils' knowledge retention and deeper understanding. In the following sections the findings are discussed in relation to the research questions addressed in the study. The analytical framework in Table 4 was used to help structure the discussion.

The following were the research questions addressed in the study (as guided by the purpose and intent in the research objectives of this study):

1. What do pupils know about saponification?
2. How do pupils link saponification knowledge to everyday life?
3. To what extent do pupils apply saponification knowledge in everyday life?
4. How do science teachers (environmental and chemistry) facilitate for pupils to link saponification phenomenon to everyday life?

Pupils' understanding of saponification and its application to everyday life was structured into 3 different levels of understanding based on the content of pupils' knowledge from the written text and the practical interpretation of meanings and actions from their own perspective. According to Yandila (n.d) the term understanding may indeed be ambiguous unless operationally defined, for instance through defining different levels of understanding as outlined in the taxonomy or hierarchy of educational objectives (Muzumara, 2007, p. 111, 112; Yandila, n.d, p. 87).

In this study, the research questions themselves were arranged in order of the first three levels (hierarchy) to reveal the different level of pupils' understanding. The following section describes the emergent levels or categories of understanding the pupils showed on saponification in addressing the 3 different research questions in relation to their interpretations of meanings.

5.1.1. Categories of Pupils' Understanding of Saponification

From the pupils' meaning-making processes and actions based on the first three research questions addressing pupils, four levels of pupils' understanding of saponification and its link to everyday life emerged (Table 4: The Analytical

Framework for the emergent categories of pupils' understanding and application of saponification). Of these different levels of understanding, level zero reflected complete inability to state or show the barest understanding of what saponification was, hence was not in Table 1 (Analytical framework for considering pupils' understanding of saponification and its application to everyday life) as it was assumed that all pupils in grade 10 had basic ideas having studied and qualified to grade 10 using the same curriculum content which contains saponification aspects in grade 9.

In Table 4, which follows, the meaningful content of the pupils' ideas solicited by research question 1 were placed at level 1 of understanding while the meaningful content of the pupils' ideas on research question 2 were at level 2 of understanding as shown in the analytical framework for the emergent categories. The third and highest emergent level of understanding was based on the deeper understanding of meaning-making and actions addressed by research question 3 on the soap-making project.

Table 4. Analytical framework for the emergent categories of pupils' understanding of saponification and link to everyday life.

Level of pupils' understanding established	Criteria demonstrating level/competences demonstrated
0 (Lack of basic knowledge)	…pupils gave wrong definition or left the space blank or indicated in writing that they had no idea of saponification or didn't learn about saponification or had forgotten.
1 (Poor)	…pupils stated what they understood by the term saponification and gave terms/ideas related to saponification.
2 (Fair)	In addition to level 1, …pupils singled soap as an important, familiar product of saponification in everyday life and gave simple locally available materials that would be used to make simple or crude soap.
3 (Good)	In addition to level 2, …pupils, suggested simple materials to use to make soap, outlined a process and procedure to make soap in practice and demonstrated their practical understanding of saponification in simple soap-making (empirical project).

The lower categories or levels of pupils' understanding (levels 0, 1 and 2) were derived from their written responses to the semi-structured open-ended written interview items and displayed mainly their basic theoretical knowledge and understanding while the last and highest level (level 3) of understanding measured the practical application of knowledge and understanding (to capture the deeper understanding by the pupils). The hierarchy of these levels of pupils' understanding was consistent with Bloom's Taxonomy of educational objectives in the Cognitive Domain. According to Muzumara (2008, p. 116), "Bloom's Taxonomy has provided a basis for the ideas of developing the analysis of the hierarchy of levels of pupils' understanding of scientific phenomena".

The emergent hierarchy or order of the levels of pupils' understanding and application were on the basis of the following criteria (as adapted from Muzumara, p. 2008, p. 119):

- Knowledge competence (lowest or level 1) – demonstrated by "recall of information for the definition of concept of saponification.
- Knowledge with understanding or comprehension competence (second or level 2) – demonstrated by "understanding information and translating knowledge into new context".
- Application competence (third or level 3) – demonstrated by "use of information, methods, concepts and theories in new situations, demonstrate an activity and put theory into practice".

The emergent levels or categories of understanding were used for discussing the data on the pupils' understanding of saponification knowledge and link to phenomenon of soap-making. Since each level of understanding, progressively saw fewer and fewer pupils exhibiting it in comparison to the total number of pupils that were involved in the research at the beginning, it was evident that pupils gained scanty understanding on saponification which they could not use to demonstrate deeper understanding in further tasks. Studies have shown that among the many problems faced by pupils in chemistry education, teaching and learning of isolated facts to which pupils do not attach meaning and lack of appropriate knowledge transfer by pupils to real life or its uses in everyday life has been persistent and prominent (Gilbert, 2006; Osborne & Collins, 2000). Furthermore, other concerned scholars have noted that much of the pupils' knowledge was leading them to misconceptions and/or partially adequate ideas, and attributed this as the main reason why the pupils found it difficult to apply such knowledge to show understanding of simple phenomenon (African Forum for Children's Literacy In Science and Technology [AFCLIST], 1993).

In the following subsection the findings of the study are further discussed in relation to the four research questions using the elements of the analytic and the theoretical frameworks.

5.1.2. Research question 1 (What do pupils know about saponification?)

From Table 2, 18 out of 28 pupils were able to state meaningfully what they understood by saponification while 13 out of 28 also gave some meaningful terms associated with saponification. These pupils rather showed basic knowledge and understanding of saponification. However, other pupils (8 out of 28) also showed complete lack of understanding of what saponification was, hence could hardly define or state what they understood by saponification while 13 out of 28 pupils could not give any meaningful terms associated with saponification. 2 out the 28 pupils showed a great deal of mixed-up ideas both on what they understood by saponification and also in terms of the terms associated with saponification. The proportion of pupils with mixed-up scientific ideas and understanding could be seen as a sign of partial or lack of understanding of saponification. As the first research question was considered to serve as the entry point to pupils' scientific knowledge and understanding of saponification, most pupils showed weakness on understanding of saponification concepts. This, to some extent, was in conformity with the pupils' claims that most of them were never taught saponification in grade 9; they simply read on their own (for example pupil 10715RI and 10715SSL), hence one could infer that memorisation of concepts without understanding was central during their own studies. Thus, the pupils were driven and influenced by the fact that they were still going to sit for an examination, hence had to read at least something on saponification on their own but whose content, however, left them with more uncertainties and guesswork. The African Forum for Children's Literacy In Science and Technology [AFCLIST] (1993) remarks that teaching science through activities with a focus on linking local activities that relate to the local environment allows pupils to acquire a better understanding of scientific concepts and avoids promotion of rote learning. In the same vein, other studies have lamented that when pupils memorise scientific ideas and concepts which have no justification of the scientific world-view, their knowledge is largely portrayed as bare and of little more than superficial value since it cannot be applied to understanding simple phenomena in real life (for example, Osborne & Collins, 2000, AFCLIST, 1993). Of course one obvious consequence of such knowledge, as also pointed out by Gilbert (2006) is that pupils easily forget the subject material learnt.

5.1.3. Research question 2 (How do pupils link saponification knowledge to everyday life?)

For the second research question, according to the categories of understanding in Table 3, 15 out of 28 pupils gave meaningful content of a prevalent saponification product in everyday life while 12 out of the 28 pupils did as well suggest meaningfully some materials that could be used authentically to make a saponification product as a way of pupils demonstrating theoretical link of saponification to their everyday life. 2 out of the 28 pupils showed mixed-up ideas while 11 out of the 28 pupils showed complete lack of understanding on a familiar saponification product. There was also a significant increase in the proportion of pupils who showed mixed-up ideas (11 out of 28) in terms of their suggested materials to make a saponification product while 5 out of 28 pupils showed complete lack of understanding of the simple materials that could be used to make a simple saponification product.

These findings seemed to be an indication of increasing uncertainty in the pupils' responses as well as a sign of more and more guesswork by the pupils to an extent of conflicting even with their own earlier definition of saponification provided in the first research question (a complete departure from the product of saponification pointing to soap). As less and less pupils (seen from the decline in the meaningful content in the pupils' responses in Table 3 in comparison to Table 2) were able to link saponification in theory to everyday life world of the materials and products around them, it was clear that the findings were pointing to a superficial and theoretical acquisition of scientific concepts where pupils themselves did not participate in the knowledge creation process hence their learning was more mechanical and left no permanent impression. Noticeably, there was a further decline in terms of pupils who made a theoretical link of saponification to a useful product as well as mere mention of simple materials which could be used to demonstrate making such a simple product. Again, this seemed to be pointing to the fact that acquisition of scientific concepts was more theoretical as pupils themselves did not participate in the knowledge creation process hence their learning was more mechanical and left no permanent impression. Other research findings in support of these findings have found that most pupils do not participate with their hands and eyes in science classes since teachers quickly rush into theorising science concepts and abstract activities (such as scientific jargon, chemical equations and flowcharts) which then dominate these science classrooms at the expense of the pupils meaningfully mapping their own learning (For example, Dahlin, Østergaard, & Hugo, 2009).

5.1.4. Research question 3 (To what extent do pupils apply saponification knowledge in everyday life?)

The findings from research question three on the extent to which pupils applied saponification knowledge in everyday life indicated some major limitations in the pupils' deep understanding of meanings and actions on soap-making phenomenon. To some pupils, saponification was an abstract concept dealt with in industries only but which had little to do with them. Very few pupils showed a meaningful and reasonably clear, straight to the point outline of the process and procedure of soap-making that would be used to link to or show application of saponification in soap-making phenomenon. Evidently, most of the pupils' outlines of the process and procedure of soap-making lacked coherent steps and procedural reality that could have allowed them to use the outlines to demonstrate authentic simple soap-making. At the level of deep understanding of phenomenon the pupils thus provided the procedure of simple soap-making that was seen as hanging more in the air than could be realised as meaningful steps. For example, it was common for the pupils not to mention specific materials but simply talk of adding the required materials together to make soap or alternatively, the pupils would mention one of the required materials and then say that this was then combined with a certain substance. The high degree of uncertainty and sometimes even wrong order of facts were common in the pupils' outline of the process and procedure such as giving the product of saponification as fats, again. The pupils showed lack of confidence, an indication that little authentic practice, if not nothing at all was acquired from the classes at the time of learning saponification, to put theory into practice. The pupils actually attested to this during the focus group interview with four out of the seven indicating that most of what they knew on saponification was largely due to own study and all the seven pupils indicated no practical or demonstration on soap-making was done in grade 9 or in their current grade. The pupils further remarked on their failure to see how meaningful the many diagrams such as the flowchart on soap-making in the textbooks were as they found the diagrams not easy to follow. It can thus be argued that pupils develop more understanding and appreciation for science if they experience science in practice through actual engagement that further allows collaboration and opportunity to explain, clarify and justify certain concepts to one another in the process. Other findings on understanding of the concept of alcohol (Uamusse, Mutimucuio, & Bonga, 2008) show agreement with these findings as they also observed that pupils had the opportunity to express their ideas during the sessions and moments of their activities. Other studies have shown that pupil engagement with practical science improves their understanding as the content is made more accessible (Osborne & Collins, 2000).

5.1.5. Research question 4 (The role of the science teacher as facilitator in science classes to help pupils make links to everyday life)

The teachers mainly played an active role to transfer theory-laden information and partial facts on saponification intended to meet the examination requirements of the curriculum, with very little effort to help with the deep understanding of pupils and link to everyday life. As has been highlighted by Manzini (2000), the teachers are well versed with the inadequacies of the curriculum but are obliged to follow the prescribed syllabi and textbooks as the examinations are inevitable and are used as a measure of teacher competence in schools. Manzini (2000) also found that many pupils were not helped by their teachers to gain actual understanding of science since the teachers could in certain cases cut out parts of the syllabus which was not examined. However, the teachers in this study acknowledged the need for pupils to engage with the saponification concepts in a more practical manner, though they were limited by many other factors such as limited time allocated to science lessons, lack of the laboratory technicians, lack of finances in schools to purchase some sophisticated requirements (as they felt they needed these), lack of apparatus in the laboratories and in certain cases the actual absence of the laboratory itself. As an alternative and final resort the environmental science teachers in this study used the flowchart on the saponification process to show the pupils what was going on in the saponification process, stage by stage.

At the senior level, the approaches by the teachers were not any different as they were also dictated by the examinations that pupils needed to sit for in order to qualify to higher level, dominated by equations and scientific jargon on saponification. Some of these findings are echoed by those of Osborne and Collins (2009, p. 23-59) that most of what the teachers teach is driven by the "rushed curriculum in which the pupils are being frog-marched across the scientific landscape, with no time or opportunity to diverge for pupils to raise their engagement and involvement". Also [AFCLIST], (1993) argues that pupils do not often require the elaborate chemicals or state-of-the-art equipment as the environment can provide familiar materials such as flowers and ashes, hence the teachers' claim of lack of materials in this study might not be a justifiable one. According to [AFCLIST], (1993) teachers need to understand their pupils' conceptual view of the world in order to facilitate bridging their understanding with scientific concepts.

5.2. Analytic generalisation

Though the study involved only saponification as one scientific concept that may easily be linked to everyday phenomenon of soap-making, there is general agreement in the teaching approach to science by the teachers which seem to promote theory of the abstract concepts through mere mention of scientific concepts (for example Teacher ES1, Teacher CT1 on their reflections on saponification during the interview). The teachers in this study attributed their failure to use practical approaches in the teaching of science as mainly due to the fact that "the syllabus is so vast" (Teacher CT1) which in turn posed a severe challenge on finding extra time for practical work (in its varied forms and approaches), lack of trained laboratory technicians in most secondary schools, which compounds the work pressure on the teacher who is expected to prepare, set the practical arrangement, demonstrate, clean up the apparatus after the experiment or demonstration and finally store them away for safe keeping.

The findings of this study may thus be generalised to other similar scientific concepts in which most pupils come out of the science lessons with complete abstract theory, hence see no necessity for learning science as it does not link to their everyday life. Kumar (1996), in support of the analytic generalisation observes that a lot could be learnt from a single case on the assumption that the case studied is typical of cases of a certain type, thus generalisations may be applicable to other cases of the same type (p. 99).

CHAPTER SIX: CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

6.0. Overview

This chapter provides the conclusions, implications and recommendation of this study which investigated grade 10 pupils' understanding of saponification and its application to everyday life.

6.1. Conclusions

The findings discussed in this study seem to provide insights which show that many pupils in environmental science and chemistry gained very low levels of understanding on saponification. The pupils found it difficult to make meaning of saponification concepts and consequently did not link saponification to soap or soap-making phenomenon in everyday life world. The pupils either easily forgot the scientific concepts or harboured a great deal of uncertainties coupled with guesswork or simply lacked confidence. As a result, many of the pupils did not have a concrete meaning of saponification as a scientific concept, let alone link the scientific concept more meaningfully to soap-making phenomenon in their everyday life.

It was noted in the study that the main focus of learning the scientific concept of saponification was to pass examinations and proceed to the next grade, hence only what the teacher viewed as the frequently examinable content on saponification which was mainly at the mere definition level and the associated key terms were studied by pupils through largely rote learning. The study further showed that the pupils' own scientific experience was superficial in which much of their knowledge was reflected as bygone as retention of the scientific concept only mattered at the point of preparing for the examination but after the examination it became irrelevant to remember anything. As reiterated by African Forum for Children's Literacy In Science and Technology [AFCLIST] (1993), rote learning of scientific facts and theories for examinations purposes does not constitute useful knowledge since after the examinations the knowledge varnished as it was acquired temporarily. These findings share common underpinning assumptions with those by Uamusse, Mutimucuio, and Bonga, (2008) who considered integrating pupils' indigenous knowledge (knowledge present and in use in their local communities, mainly without fuller understanding of the science associated with the processes) and technologies in a grade 10 chemistry class, intended to promote the conceptual understanding of the concept of alcohol and the processes of its production. Using concepts of alcohol Uamusse, Mutimucuio, and Bonga, (2008) linked fermentation and distillation processes used in alcohol production in everyday life (using analogies between the indigenous and industrial scientific processes) to enhance conceptual understanding. As their study was interventional as opposed to exploratory, their findings reported significant improvements in pupils' understanding of scientific concepts and processes emanating from pupils' participation in the learning process that enabled them to associate their everyday experiences with the scientific knowledge.

The underpinning assumption in the current study was that if the grade 10 pupils had prior knowledge of saponification, they would in turn show their understanding of the related scientific concepts and further show their deep understanding of saponification through a demonstration of the face value of saponification (the link or application part). Based on this assumption, the three elements (knowledge, understanding and application) relating to how pupils make meaning of the saponification concepts may be seen to be interrelated. Thus knowledge of saponification concepts is a precept used to display understanding whereas understanding is equally a reflection of knowledge. Similarly, deeper knowledge with understanding can further lead to application in which theory is put into practice and that leads into reinforcement of both knowledge and understanding. A rich interplay of concepts existed as pupils were involved in some form of engagement in which they display their abilities and capabilities which in turn lead into consolidation of knowledge, understanding and application of theory into practice. Put another way, "science involves an interplay between ideas and observation" (Abrahams & Millar, 2008, p. 1965).

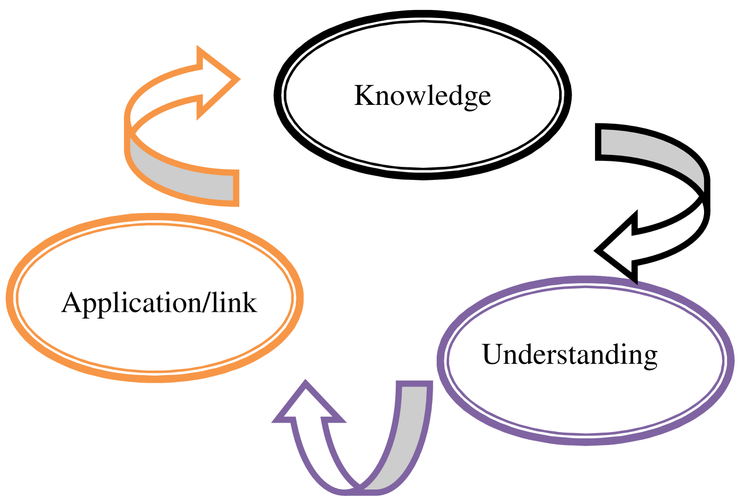

Figure 9: Interrelationships among knowledge, understanding and application of saponification concepts.

Hence, the view here and driven by the phenomenological bend is that acquisition of knowledge, understanding and ability to link to everyday life may begin at one platform through exploration of commonly experienced phenomenon using any of the three platforms shown in Figure 9 and involve interrelated activities in the learning process of the pupils. Through the knowledge, understanding and application interrelated activities, it would then be possible to move to scientific concepts in order to develop the richer understanding, hence generation of an appreciation of learning as not being a simple same way activity. "Learning occurs when the pupil utilises higher order thinking skills by connecting new knowledge to prior knowledge" (Fay, Grove, Towns, & Bretz, 2007). Mahlomaholo, Milton, Khabanyane and Sookdin (2000) argued that pupils need to acquire skills that allow them to believe in themselves in terms of capabilities if learning is to be seen as meaningful and useful. Broks (2007) further argues that science education should act as life experience by providing knowledge, skills and attitudes essential for life. According to Broks (2007, p. 26), "education is a specially organised gaining of life experience for life", inevitably education and life are two fundamentally interconnected phenomena.

In order for the schools in Zambia to provide meaningful, sustainable science education that would allow the pupils to participate holistically with relevant understanding of science beyond school there is need to incorporate different approaches in the teaching and learning of science such as the phenomenological perspective and its partly overlapping elements. Dahlin (2001) contends that if science education is to be realistically harnessed with the perspective of an all-around development of human personality, then complementary theoretical bases to the dominant cognitivism and constructivism must be accommodated too. Whereas, for example, cognitivism focuses mainly on conceptual cognition and concept formation, the phenomenological perspective of science education cultivates a holistic learning approach that makes learning meaningful as life world experiences are easily translated to scientific concepts, enhancing a rich interaction of experience and knowledge (see Dahlin, 2001). Learning, more so meaningful learning must have the perspective of the pupil whose lens should be used to see the extent to which the learning has been accomplished. According to Merleau-Ponty (1962, cited in Kvale & Brinkmann, 2009), all meaningful scientific knowledge is gained from one's own point of view and includes experience of the world around. In this light, the pupil's own presence and active participation through engagement in meaning-making process would be seen as central and crucial to knowledge acquisition and subsequent understanding, let alone application of scientific ideas. It is important to recognise the fact that not all scientific concepts can be taught following one theoretical perspective but rather the different methodological perspectives, some partly overlapping, that capture the enthusiasm of the pupils and form a well-balanced blend in developing sticky scientific concepts and deeper resolute understanding. According to Dahlin, Østergaard, and Hugo (2009), phenomenology is a basic philosophy of knowledge in which human experience is considered significant for our understanding of the world. Hence, the different theoretical perspectives, once selected and employed appropriately should form a working synergy that complements one another. Osborne and Collins (2000) have shown that the lack of variety in the way science is taught with emphasis on rote learning of facts and principles contributes to the notion that science learning is hard.

It is evident from the above arguments that for a sustained understanding of saponification and in general other scientific concepts, in which understanding of scientific concepts is meaningfully related or linked to everyday life, pupils' own meaning-making and actions or better still, pupils' practical understanding through appropriate interpretation of the meaning of phenomena is paramount in learning of science.

6.2. Implications for Policy, Practice and Process.

The findings from this study have implications for the curriculum, science teachers, and also the policy makers.

6.2.1. Curriculum

There is need for both the environmental science and chemistry curricula to be revisited so as to provide clear and practically renewed emphasis on authentic experiments/activities which teachers need to perform with their classes in their facilitation of science lessons so as to help the pupils to link relevant scientific concepts to everyday lives. This would not only enhance their understanding of scientific concepts but also help them to pave way for forming sufficient background and long term familiarity for such concepts as well as stepping stone for future concepts when they recur at higher level, for instance.

In its current form and exacerbated by the emphasis on the use of examination scores for selection and certification, the curriculum provides little or no opportunity for creativity in science, hence pupils experience science as more theoretical or abstract as a result pupils further view science as difficult and irrelevant to their everyday life. In view of this, the curriculum should promote learning which goes beyond the single purpose of passing public examination only. The impact of public examinations on meaningful learning needs to be addressed with possible alternatives including continuous assessment and projects to be considered as a way of attaining a balanced curriculum which offers not only theoretical knowledge but also skill and creativity.

Equally important at the level of curriculum planning, the content-loaded syllabus needs to be revisited both at junior and senior levels so as provide sufficient time for meaningful content coverage which balances both scientific knowledge and related real life phenomena of interest to the student. According to the MoE (1996, p. 27), "some increase is desirable in the number of hours of actual teaching".

6.2.2. School Supervision and Attainment of Curriculum Goals

This routine component of the education system seems to remain unattended to for various reasons, ranging from lack of funding to understaffed standard officers needed to undertake the thorough necessary exercise and ensure quality education and attainment of curriculum objectives. As was evident in the findings of the current study, each teacher decides what to teach and what not to teach as they are accountable to themselves only. In addition, without this supervisory link between the MoE and schools, the current state of affairs of concern in schools may remain uncorrected thus leading to poor delivery of educational experiences. According to the MoE (1996), many factors that contribute to quality in education such as the curriculum, books, teaching aids, laboratories, science equipment, and classroom furniture are all in need of urgent attention, support and improvement in order to promote effective teaching and learning. For example, from my practical experience of being a teacher, schools provide inadequate teaching time and short of the minimum requirement recommended in the syllabus to sciences, hence compounding the problem of non-completion of the syllabus. Also, there are many untimetabled activities and programmes, yet known officially in schools that consume most of the teaching and learning time for the pupils. For instance, the non-examination classes in schools loose over a month of teaching and learning time during the final examination for grade 12 classes due to inadequate movable furniture, classroom space and teachers.

6.2.3. The Role of Science Teachers as Facilitators for the Teaching Process

Science teachers, in their facilitation role during science lessons should provide pupils with adequate opportunities to link authentically, as many scientific concepts as possible to everyday life experiences. Through the teachers' facilitation role the pupils are provided opportunities to manage their own learning by working together, developing willingness to listen to each other's ideas, analyse each other's suggestions and reach consensus (The African Forum for Children's Literacy in Science and Technology [AFCLIST], 2004). Both Science Community Representing Education [SCORE] (2008) and The African Forum for Children's Literacy in Science and Technology [AFCLIST] (2004) support such opportunities of collaboration during practical work among pupils further as they develop and provide pupils with a range of skills, more coherent science knowledge and conceptual understanding as ideas bounce around, discussed more meaningfully, hence retained longer and reduce rote-learning.

During the soap-making process pupils exhibited collaboration among them and reported a better understanding of saponification concepts later during the focus group interviews. To the contrary, the findings in this study on how science teachers facilitated for pupils to link saponification scientific knowledge to everyday phenomenon showed that the teachers' main engagement was in transferring abstract scientific knowledge to pupils mainly theoretically, which inevitably promoted rote learning through pupils studying on their own. Another study by Abrahams and Millar (2008) showed that the teachers' focus in the science lessons was predominantly concerned with developing pupils' scientific knowledge and not understanding of scientific enquiry procedures which has a significant impact on the way pupils learn. Osborne and Collins (2000) have argued that the theoretical emphasis of intangible or invisible scientific concepts coupled with non-pupil active engagement with the actual chemicals and materials of science remove pupils from the important experience of their everyday life concerns. This does not only limit their experiences in science but puts a formidable challenge on their understanding and appreciation of the relevance of science in everyday life.

6.3. Recommendations

The following were the recommendations made:

1. Phenomenon-based science education and the other elements of different, partly overlapping perspectives in science education such as context-based, scientific literacy, inquiry-based and problem solving must be strongly incorporated into the instructional framework of the curriculum to complement the teaching of school science in order to form a formidable and skill oriented foundation for the scientific concepts beyond a single focus of passing public examinations.
2. The secondary science school textbooks should include enough detail to enable both the teacher and pupil carry out possible activities that relate scientific concepts to everyday life phenomenon using phenomenological approaches. Alternatively, this could be in form of a separate course companion material for the teacher.
3. The MoE should take up the full responsibility of providing resources for the meaningful educational process that sets a strong foundation for scientific

concepts with relevance to everyday life, beyond just providing policy guidelines on paper, deficient of laboratories, laboratory technicians and material support to schools to ensure quality education.

6.3.1. Direction for Future Research

The following could be considered as directions for future research:

1. There is still need to conduct more research in future to find out teachers' and pupils' meaning-making and understanding of everyday life phenomenon that are linked to specific scientific concepts. This will in turn make clear their views and beliefs about phenomenon-based science education as well as allow them an opportunity to compare the traditional dominant approaches in science teaching and learning as a way of beginning to see their potential benefits in relation to pupil knowledge retention and understanding. Thus, whereas saponification is one concept with familiar links to everyday life phenomenon; other scientific concepts would be of interest to research on and find out how pupils and to some extent teachers, make meaning of their related applications whose familiar face value could be incorporated into the meaningful teaching of science. Also, it may be necessary to compare pupils' understanding of scientific concepts of those who learn science as physical science and those who learn the so called pure sciences.
2. Teachers' views on the current science curricula and how adequately it meets the intended objectives to allow them teach science meaningfully could equally be considered in future research in view of the fact that since the senior secondary school syllabus was effected at the time of switching from the Cambridge syllabus there has never been a comprehensive review of the

said syllabus involving the teachers themselves to assess its effectiveness, limitations and other challenges.

3. There is also need to investigate teacher competencies in science teaching using specific methodological orientations in general, as it may also be that certain teaching approaches such as chalk and talk, question and answer and lecture are more preferred by teachers as these approaches do not place on them higher demands in terms of detailed content knowledge, accountability of the methodological detail as well as material and apparatus preparedness.

Indeed, as our country walks the path towards the millennium development goals, the educational process will need to play a pivotal role and refocus its research agenda in sciences and science-related fields for this country to attain the envisaged aspirations and goals.

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APPENDICES

APPENDIX A: SEMI-STRUCURED OPEN-ENDED WRITTEN INTERVIEW (1): PUPILS

Dear respondent**,**

I am a masters' student registered with the University of Zambia by full research with the School of Education.

As part of my studies towards a master in science education, I am carrying out a research project to find out **your understanding of saponification** as a scientific concept and **how you would use or apply saponification-related phenomena in everyday life.**

As part of my initial data gathering process, I am kindly asking you to complete this semi-structured open-ended written interview.

Kindly feel as free as you can while answering the semi-structured open-ended written interview. Also be as objective and sincere as you can. Where you feel you don't seem to understand what is meant exactly by the question always feel free to ask me.

The information you are going to give will only be used for academic purposes of this study and will be treated purely as confidential, as your real name will not appear anywhere in my final research report. I may require your help later to participate in further research activities, hence the reason for your identity in the meantime.

If, for some reason, you still strongly feel uncomfortable to give the information requested for, kindly say so and note that you are under no obligation to complete this semi-structured open-ended written interview.

PART I: PERSONAL PARTICULARS

NAME:………………………………………………… CLASS:…………….…

AGE:………………… SEX:………………..…

RESIDENTIAL ADDRESS:…………………………………………………………

………………………………………………………………………………………

NAME OF PREVIOUS SCHOOL WERE YOU ATTENDED GRADE 9:

………………………………………………………………………………………

PART II: JUNIOR/SENIOR SCHOOL BACKGROUND

Q1. (a) Which subjects did you learn at junior secondary?

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(b) Which of these subjects were amongst your best five results in your grade 9 selection Examination?

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Q2. (a) Which subjects are you currently taking in your current senior class?

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…………………………………………………………………………………………

(b) Identify the subjects that were taught together as environmental science in grade 9 but are now taught separately.

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Q3. At the start of your grade 10 chemistry, you may have covered some practical applications of chemistry in everyday life. Mention a few of these everyday applications of chemistry in everyday life (be it in society and/or in industry).

…………………………………………………………………………………………

………………………………………………………………………………………...

………………………………………………………………………………………...

Q4. Now that you know which topics and concepts/terms in the junior environmental science fall directly under chemistry, give some of the everyday uses of chemistry which were covered at junior level (including those that may already have been mentioned in (3) above.

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…………………………………………………………………………………………

PART III: SAPONIFICATION CONCEPT

Q5. Saponification is one of the scientific terms in your junior environmental science syllabus. What do you understand by the term ‘‘saponification?’’

……….……………………………………………………………………………...

Q6. Give some of the ideas/terms/words/concepts that were used or mentioned under saponification in environmental science.

……….……………………………………………………………………………...

……….…………………………………………………………………………..

Any additional information you may have on saponification or saponification-related ideas that you may want to share.

(In case you did not write anything in part II (5), would you give a reason why?)

…………………………………………………………………………………………

…………………………………………………………………………………………

THANK YOU VERY MUCH FOR YOUR COOPERATION AND TIME.

PLEASE DON’T GET FED-UP WHEN I CALL UPON YOU AGAIN FOR SOME MORE INFORMATION.

I VALUE YOUR COOPERATION.

APPENDIX B: SEMI-STRUCTURED OPEN-ENDED WRITTEN INTERVIEW (2): PUPILS

Dear respondent,

This is my second part of the data gathering process that I embarked on last time, and as earlier appealed to you, I wish to ask you to give further information on saponification that you learnt in environmental science in your junior phase.

The first semi-structured open-ended written interview, had parts I, II and III. Based on the successful articulation of your concepts on saponification, you have been selected to continue with the information gathering process on saponification.

Hence, this semi-structured open-ended written interview will form the proceeding parts of semi-structured open-ended written interview 1.

PARTICULARS:

AGE:……………………….. CLASS:……………………….

SEX:…………………………

NAME OF YOUR JUNIOR SCHOOL:……………………………………………

…………………………………………………………………………………………

PART IV: DEMONSTRATING KNOWLEDGE AND USE OF SAPONIFICATION IN EVERYDAY LIFE.

In the previous semi-structured open-ended written interview you explained what you understand by saponification and also mentioned some of the ideas/terms/ words/concepts that were used under saponification in environmental science.

Today we will further consider important applications or uses of saponification in everyday life (in relation to useful products/commodities that are/can be made and/or found in society).

Q1. Name/give a familiar, saponification product that you can make from locally available materials.

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Q2. Suggest simple materials from your local environment set-up that you may have used in environmental science or which you could use to make an important product of saponification or saponification-related ideas.

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Q3. Using the materials mentioned above outline the important steps (process and procedure) that you can use to make a sample of a simple but important product used in everyday life experience using saponification.

Include all the things you can think about and do to make your product as perfect and attractive as you can (starting from the starting materials to the time you obtain/separate the product).

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THANK YOU VERY MUCH FOR YOUR COOPERATION AND TIME.

APPENDIX C: OBSERVATION SCHEDULE FOR THE PUPILS' SOAP-MAKING PROJECT

Group no……..   **Observation schedule**

Focus of observation(what was observed)	**Details of observation**
1. Local materials used	
2. How did they start the process?	
3. What experimental/scientific procedure did they use?	
4. What kinds of collaboration between them?	
5. Scientific/local terminology or vocabularly used	
6. Connection/link of the local process to the scientific one	
7. Product evaluation (a) What did they produced? (brief description of product) (b) How did it work? (c) What did they learn? (d) Did they apply saponification knowledge in everyday life?	

Any other comments:……………………………………………………………………

APPENDIX D: INTERVIEW GUIDE FOR FOCUS GROUP INTERVIEWS WITH PUPILS

Focus group interview with pupils was conducted after their empirical project on soap-making to provide a more open platform for expressing themselves; their experiences, views, challenges and understandings on saponification as a way of concluding the research investigations with the pupils.

Seven boys participated in the focus group interview which was conducted after the empirical saponification project. They used pseudo names; John, James, Jimmy, Jack, Mark, David, Dennis, which were given to them before starting the interview.

The pupils sat next to each other at the back of a biology laboratory occupying two rows and facing each other directly with the researcher on the immediate next bench.

The researcher greeted them and set the ball rolling by introducing the focus of their meeting that evening. The pupils were then asked to collect small folded pieces of paper from a box which had names on them and those were going to be their names for purposes of that discussion.

Introduction by Researcher.

Let's talk about the saponification topic as a way of concluding our project meetings this evening.

Feel as free as possible to express your views, ideas and perceptions on saponification. You may chip in as a way of adding to what your friend is talking about if you have something really important requiring that action but let's be courteous in doing so. We also have to respect each other's views by avoiding interrupting unnecessarily when others are still holding the floor, unless it is really necessary that you would want to support or disagree, but let's remain cordial and warm to each other.

Questions used in the focus group interview.

Q1. What are some of the things that you learnt under saponification topic in grade 9? That is, before we reach the stage of the empirical project that you did last time.

Q2. (Was a follow-up to their responses): What do others say? Did all of you learn saponification in grade 9?

Q3. Any more ideas on saponification as learnt in grade 9?

Q4. After learning saponification in grade 9, was any experiment done by you or demonstration by the teacher on saponification? If that was so, what was the experiment or demonstration all about?

Q5. Coming to the project you have just completed this time, what have you learnt from it? Is there anything that you may have learnt on top of what you learnt in grade 9?

Q6. Any challenges that you faced in the project?

Q7. How do you compare the learning and understanding that took place in grade 9 and the project you had just done this time trying to follow the actual process of saponification by doing it to obtain your simple or crude soap?

Q8. Which approach would you prefer; one using theory or both theory and practical

Q9. What could be the main problem in junior school that may have hampered you from doing the actual practical.

Q10. Any further reflections on the topic of saponification and the soap-making project, in your final thoughts?.

THANK YOU FOR YOUR CO-OPERATION AND TIME.

APPENDIX E: INTERVIEW GUIDE FOR SEMI-STRUCTURED INTERVIEWS WITH TEACHERS

Setting the environment: Start by greeting the teacher and thank him/her for accepting/seeing the necessity to participate in the interview. Explain the purpose of the interview and ask the teacher to be as free, open and honest (may be for lack of a better term). Also mention that the findings and results will be as confidential and no names of specific individuals will be mentioned anywhere in the findings. Ask the teacher to ask any questions in case they would like to clarify certain aspects with regard to the research or interview they are about to embark.

INTERVIEW GUIDE

PERSONAL DETAILS

Qualification:…………………………………………………………………………

Major Subject(s) qualified to teach:……………………………………………….…

Years of teaching (experience) ……………………………………………………….

Other subjects taught:…………………………………………………………………

Years of teaching (experience):………………………………………………………

ENVIRONMENTAL SCIENCE ☐ CHEMISTRY ☐

Grades that you teach: ……………….. Grades that you teach:………….

Years you have taught:……………...… Years you have taught:………….

Goal of interview is to find out what is taught on the concept of saponification as well as to find out the teachers' focus in these lessons.

You may choose to have your latest lesson plan that you have prepared before to teach the subject content.

(Make a photocopy of the lesson plan if the teacher accepts).

Lets now get started on the concepts/issues/topic of saponification:

Q1. Under which topic does saponification fall in your syllabus (for the appropriate level/grade)?

Q2. What is the definition that you use for saponification at this grade level?

Q3. In general, how do you lay out your lesson i.e. presentation of the lesson when teaching saponification (the major themes in the topic, including catching the minds of the pupils).

Q4. What are some of the key words that you use when teaching saponification?

Q5. What can you say/tell them; in your view, if a pupil asked you why do they have to learn saponification,(such a tongue-twisting word) or rather; Why should this topic be taught to pupils?)

Q6. In your own view, is this topic necessary to be taught at this level?

Q7. Is there any practical or demonstration that you do with the class or you give to the pupils to do. (Which is which?)

Q8. Do pupils make any connection/see the applications of saponification in everyday life?

Q9. If yes, which connections do they make?

(a) If no, what is the main reason why you think they don't seem to link saponification to everyday life?

Q10. What could you do to better ensure that pupils link saponification to their everyday life?

Q11. Finally, any reflections/comments you may want to make on the topic.

Thank the interviewee for the valuable time spared.

APPENDIX F: INFORMED CONSENT REQUESTS AND FORMS

APPENDIX F1: INFORMED CONSENT REQUEST TO ALLOW PUPILS AND TEACHERS PARTICIPATE IN RESEARCH STUDY.

The University of Zambia

School of Education

Department of Mathematics and Science Education

P.O. Box 32379

LUSAKA.

11th January, 2010

The Provincial Education Officer

Lusaka Province

P.O. Box 50021E, RW

LUSAKA

Dear Sir, Madam,

REF: REQUEST TO INVOLVE SOME SELECTED LUSAKA SCHOOLS IN A RESEARCH STUDY (MASTERS' DEGREE).

The above captioned subject matter refers.

I am a masters' degree student in Science Education (by full research) at the University of Zambia and a chemistry/physics teacher at David Kaunda Technical High School.

I am hereby asking for permission to conduct a research study involving some pupils and some teachers in some selected Lusaka Schools.

In accordance with the ethical conduct of research involving human participants, I hereby also attach a self-explanatory consent form for your endorsement.

Thanking you in anticipation,

Yours sincerely,

Foster Mwanza.

APPENDIX F2: INFORMED CONSENT FORM TO ALLOW SCHOOL PUPILS AND TEACHERS TO PARTICIPATE IN RESEARCH STUDY.

Dear Sir, Madam,

Subject: Request to involve some selected Lusaka schools in a Research Study.

My name is Foster Mwanza, a masters' degree student in science education (by full research) at the University of Zambia and a chemistry/physics teacher at David Kaunda Technical High School.

I wish to ask for permission to carry out a research study involving grade 10 pupils from one high school in Lusaka and some teachers of chemistry from the same school as well as a few teachers from some selected secondary schools teaching environmental science in Lusaka as part of my data gathering process. The information that will be gathered in this study entitled ''**Pupils' understanding of saponification and its application to everyday life''** is not about assessing pupils or teachers in chemistry but is intended to find out if pupils (as well as teachers; while teaching sciences in class) are able to link scientific concepts (both senior science i.e. chemistry and junior science i.e. environmental science) to everyday life phenomena (experiences). The research topic emanates from the challenge chemistry as a subject possess to pupils at senior level who in turn question the relevance of chemistry as a subject and always think the subject is about invisible concepts and is abstract with no use in their everyday life.

As participants in the study, the pupils will be engaged in answering interviews as well as planning an outline of the process and procedure to demonstrate their understanding of saponification concepts and link to everyday life experiences.

On the other hand, a few teachers will be interviewed to give their views, ideas and approach on saponification as taught and/or ought to be taught, in a bid to consolidate, corroborate, compare and augment the findings from the pupils.

The information synthesised and the findings of the study will be used for academic purposes only and may also be presented at academic conferences and published in national and international journals as a contribution to research. **Clear steps will, however, be taken to ensure confidentiality of all the participants.**

Once the study is completed, the dissertation will subsequently be available in the special collection of the University of Zambia Library.

If you agree and are satisfied with the aims of the study and role the school pupils and teachers will play in the study, as has been explained, kindly sign below.

NAME OF EDUCATIONAL AUTHORITY……………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

______________________________ ____________________

Signature **Date**

N.B. Also note that the participation of the school pupils and teachers in the study is voluntary and they could withdraw from the study at any time, if they strongly feel, for example, uncomfortable or insecure with the research.

Should you require any further information about the study, please do not hesitate to contact me or my Supervisors at the following contacts:

Mr. Foster Mwanza
(Masters' student and researcher)
Phone no. +260977784187
Email: foster.mwanza@yahoo.com

Mr. Christopher Haambokoma
(Project Supervisor)
School of Education
The University of Zambia
Phone no. +260977713219
Email: christopherhaambokoma@yahoo.com

Associate Professor Edvin ∅stergaard
(Project Co-supervisor)
Phone: +47 64 96 61 71 (office)
Norwegian University of Life Sciences
Email: edvin.ostergaard@umb.no

Professor William C. Kyle, Jr.
(Project Co-supervisor)
University of Missouri, St. Louis
USA.
Email: bill_kyle@umsl.edu

Thanking you in anticipation.

Yours sincerely,

____

Foster Mwanza

APPENDIX F3: INFORMED CONSENT FORM TO ALLOW PUPILS AND TEACHERS PARTICIPATE IN RESEARCH STUDY (FOR THE STUDY SITE).

Dear Sir, Madam,

Subject: Permission to involve school pupils and teachers of science in a research study.

My name is Foster Mwanza, a masters' degree student in science education by research at the University of Zambia.

I wish to ask for permission to carry out a research study involving school pupils and teachers in my study as part of my data gathering process. The study entitled ''**Pupils' understanding of saponification and its application to everyday life**'' is not about assessing pupils or teachers in chemistry but is intended to find out if pupils (as well as teachers; while teaching sciences in class) are able to link science concepts (both senior science i.e. chemistry and junior science i.e. environmental science) to everyday life phenomena (experiences). The research topic emanates from the challenge chemistry as a subject possess to pupils at senior level who in turn question the relevance of chemistry as a subject and always think the subject is about invisible concepts and is abstract with no use in their everyday life.

As participants in the study, the pupils will be engaged in answering interviews, which in part will include planning an outline of the process and procedure to demonstrate their understanding of saponification concepts and link to everyday life experiences. On the other hand, a few teachers will be interviewed to give their views and approach on saponification as taught and/or ought to be taught, in a bid to augment, corroborate, consolidate and compare the findings from the pupils.

The information synthesised and the findings of the study will be used for academic purposes only and may also be presented at academic conferences and published in national and international journals as a contribution to research. **Clear steps will, however, be taken to ensure confidentiality of all the participants.**

Once the study is completed, the dissertation will subsequently be available in the special collection of the University of Zambia Library.

If you agree and are satisfied with the aims of the study and role your child/ ward/ school pupils will play in the study, as explained earlier, kindly sign below.

NAME OF PARENT/GUARDIAN/EDUCATIONAL AUTHORITY……………………………

………………………………………………………………………………………………

___________________________________ ________________________

Signature **Date**

N.B. Also note that the participation of the child/ward/ school pupils/teachers in the study is voluntary and they may withdraw from the study at any time, if they strongly feel, for example, uncomfortable or insecure with the research. Should you require any further information about the study, please do not hesitate to contact me or my Supervisors at the following contacts:

Mr. Foster Mwanza
(Masters' student and researcher)
Phone no. +260977784187
Email: foster.mwanza@yahoo.com

Mr. Christopher Haambokoma
(Project Supervisor)
School of Education
The University of Zambia
Phone no. +260977713219
Email: christopherhaambokoma@yahoo.com

Associate Professor Edvin ∅stergaard

(Project Co-supervisor)

Phone: +47 64 96 61 71 (office)

Norwegian University of Life Sciences

Email: edvin.ostergaard@umb.no

Professor William C. Kyle, Jr.

(Project Co-supervisor)

University of Missouri, St. Louis

USA.

Email: bill_kyle@umsl.edu

Thanking you in anticipation.

Yours sincerely,

____

Foster Mwanza

APPENDIX F4: INFORMED CONSENT FORM (TEACHERS) TO PARTICIPATE IN RESEARCH STUDY.

Dear Sir, Madam,

Subject: Request to participate in a Research Study.

My name is Foster Mwanza, a masters' degree student in science education (by full research) at the University of Zambia and a chemistry/physics teacher at David Kaunda Technical High School.

I have selected your school to be one of those to participate in my research study and I am therefore further kindly asking you as a teacher of ……………………………(subject taught) to participate in the interview as part of my data gathering process. I regard your participation in this interview as highly important and informative because as a teacher you play a key role in facilitating the process of knowledge delivery and therefore, information collected from the pupils may as well be consolidated, corroborated, augmented and compared with that from the teacher in the specific subject area. The information that will be gathered in this study entitled ''**Pupils' understanding of saponification and its application to everyday life''** is not about assessing pupils or teachers in chemistry/ environmental science but is intended to find out if pupils are able to link scientific concepts (in chemistry/environmental science) to everyday life phenomena (experiences). The research topic emanates from the challenge chemistry as a subject possess to pupils at senior level who in turn question the relevance of chemistry as a subject and always think the subject is about invisible concepts and is abstract with no use in their everyday life.

Therefore, kindly feel free to share your experiences, ideas, views and approach on saponification as taught or ought to be taught.

The information synthesised and the findings of the study will be used for academic purposes only and may also be presented at academic conferences and published in national and international journals as a contribution to research. **Clear steps will, however, be taken to ensure confidentiality of all the participants.**

Once the study is completed, the dissertation will subsequently be available in the special collection of the University of Zambia Library.

If you agree and are satisfied with the aims of the study and your role as a teacher in the study, as has been explained, kindly sign below.

NAME OF TEACHER……………………………..……………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

______________________________________ ______________________

Signature **Date**

N.B. Also note that your participation in the study is voluntary and you may withdraw from the study at any time, if you strongly feel, for example, uncomfortable or insecure with the research.

Should you require any further information about the study, please do not hesitate to contact me or my Supervisors at the following contacts:

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(Masters' student and researcher)
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Phone: +47 64 96 61 71 (office)
Norwegian University of Life Sciences
Email: edvin.ostergaard@umb.no

Professor William C. Kyle, Jr.
(Project Co-supervisor)
University of Missouri, St. Louis
USA.
Email: bill_kyle@umsl.edu

Thanking you in anticipation.

Yours sincerely,

____

Foster Mwanza