Exploring and expanding situated cognition in teaching science concepts: The nexus of indigenous knowledge and Western modern science

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By

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Declaration

I declare that this thesis work which thrives to show how cultural practices, artefacts and social science terms can be used in situated cognition is a product of my own effort. All the other sources used or cited have been fully acknowledged and referenced. It is being submitted for the Degree of Philosophy at Rhodes University. It has not been submitted elsewhere in any format for a degree or examination at any other university.

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Abstract

Certain teaching and learning strategies are appropriate in the context of exposing learners to modern science in situated cognition (SC) - the theory that posits that knowing is inseparable from doing - during, for example, visits to industrial operations. The distance and cost of travel, however, excludes most rural teachers and their learners from such SC exposure to Science and technology in industrial settings. To fill this gap between knowledge and practice in the curriculum experience for rural schools, this research investigated the extent to which a SC approach could be used in relation to indigenous knowledge practices (IKP) that have relevance to science teaching for rural science teachers. The study was conducted in three schools in the Zambezi Region of Namibia whereby six science teachers participated in the study. Also, to generate data from the community, the study included Indigenous community members as participants. Only three selected members from the community participated as representatives of the whole community.

Essentially, the study explored and expanded possibilities for rural school teachers to use IKP as sites of SC in relation to concepts of pressure in particular and other science concepts. The research thus studied teaching practices as activity systems related to concepts in the school curriculum and the activity system of Indigenous community members. The patterns, regularities and irregularities provided the framing which was used to view SC through the lens of IKP. This framing of SC within the school curriculum was explored using cultural historical activity theory (CHAT) and Engeström's expansive learning cycle (ELC).

The study was organized into two phases; exploration and the expansive phase. In the exploration phase, interviews, community analysis, document analysis, brainstorming, reflections and audio-visual evidence were used to generate data. The expansive stage used brainstorming, reflections, and interviews, an experimental test, audio-visual evidence, and interviews. Inductive and abductive modes of inference were used to come up with explanations of the research questions. Explanations proceeded using the frameworks of socio-cultural theory and social realism.

Some findings from the data generated from the exploration phase revealed that science teachers in the schools studied do not always engage in a SC approach on account of a lack of Western modern science (WMS) resources and factors related to economic marginalization of the learners. Data generated in the same phase revealed that science teachers can engage the SC approach

through embracing indigenous knowledge practices (IKP) reflecting Science whereby they can apprentice learners. Some of the other findings from the expansive learning phase show that science teachers in under-resourced schools can engage the SC approach if IK practices are used as mediational tools which can be used as models, icons/symbols, vocabulary, patterns, case studies and practical activities anchored in IKP.

From the findings obtained the contribution which the study made was to come up with some methods of infusing indigenous knowledge systems in science teaching. The trend in research related to IK is more aligned to policies rather than how IK can be usefully used for the benefit of science teaching. As the study only looked into the IKP reflecting Science which the participating teachers brainstormed, it provides an insight into how and which other IK practices can be woven into WMS to encourage social transformation accommodative of Afrocentric world views which allows scientific literacy to be achieved.

Acknowledgements

In this study that is guided by socio-cultural theory and social realism where Cultural Historical Activity Theory was used as an analytical tool, it is proper to acknowledge social and cultural structures and activity systems that backed the formation, shaping and development of this study.

A journey of such nature cannot be realized alone as is said in a Shona proverb that one finger cannot crush a lice (*Chikunwe chimwe hachitswanyi inda*). This understanding propels me to thank some friends I encountered during the process of conceiving and compiling this thesis.

Firstly, I want to thank my colleagues in the Mathematics and Science department at University of Namibia-Katima Mulilo Campus for the support they gave me each time I requested permission from them to attend PhD weeks in Grahamstown or visiting Okahandja to see my supervisor. Mr. Denuga Desalu, a colleague working with me went to boost my morale to compile this study when I saw him joining me in an effort to also bring a study which might address challenges and their solutions which can be implemented in the Namibian Education system.

I am grateful to Prof. K. Ngcoza and Dr. C. Chikunda who did not only serve as supervisors for this thesis but they mentored me into the community of practice where today I can interact with other members. Before I was only equipped with subject content knowledge and pedagogical content knowledge without knowing how I can share it with others and bring expertise in science and maths teaching practices. It was through them that I learnt how to compile book chapters and conference papers and have them published to serve the purpose of sharing ideas to others in the science education field in particular. It was then through these activities I conceived an idea of how science teachers in under-resourced schools can be assisted to engage situated cognition since currently some are unable on account of absence of materials which facilitate engagement of situated cognition.

I would also like to thank Professor O'Donoghue for giving me encouragement when this thesis was still in its infancy phase. When he detected that my thesis aimed at addressing absence using indigenous practices he was quick to support me with literature related to this study. He also assisted me in pointing out some relationships of theories I could use to support my data and also had indicated to me that the study would close the gap currently experienced by under-resourced school teachers.

To Professor Heila Lotz-Sisitka I say thank you for being those PhD weeks you arrange. Even though I am from afar there was always a feeling and interest in attending the PhD week programs with the hope of having the mind sharpened after the encounter. The social theories you introduced in particular social realism to me were helpful in a way that I reconnected theories learnt before with what you meant with social theory. To you Tich Pesanayi and Caleb Mandikonza you were so helpful during my PhD journey. Pesanayi you went to clarify to me the concepts of cultural historical activity theory in a way that today I understand it better and this has enable me to point out contradiction which prevents indigenous knowledge to be used in schools as it competes for a market with Western modern science. This also applies to Caleb Mandikonza who made me understand better the levels of reality.

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I thank the three principals who allowed me to conduct this research at their schools. To the six science teachers who participated in this research I say thank you and hope the ideas gained can be implemented to address science teaching practices whereby there is a lack of Western modern science social and cultural structures to conduct situated cognition. I also thank the community members who assisted the teachers when they were tasked to find Science in their communities useful in engaging situated cognition.

Finally, I say thank you to my daughters Milagra, Dorcas-Thiyadora and my two sons Taiziveyi-Stephen and Takuona-Gerald. You were patient and behaved well each time I went to Okahandja to see my supervisor or to Grahamstown to attend PhD week programs.

Dedication

This thesis is dedicated to all those who might want to engage situated cognition in schools whose nearby surroundings lack Western Modern science infrastructure but have indigenous social and cultural structures which can be used.

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Acronyms and/or abbreviations

ASARECA	association for strengthening agricultural research and central Africa
CA	cultural artefacts
CAT	contiguity argumentation theory
CCK	curriculum content knowledge
CHAT	cultural historical activity theory
CK	content knowledge
CP	cultural practice
COP	Community of practice
CT	cultural translation
CTL	contextual teaching and learning
DAFOR	dominant, abundant, frequent, occasional and rare
DWR	development work research
ELC	expansive learning cycle
ICK	indigenous content knowledge
IK	indigenous knowledge
IPCK	indigenous pedagogical content knowledge
ITCK	indigenous technical content knowledge
LCE	learner-centered education
LTSMs	learning and teaching support materials
M/M	morphogenesis/morphostasis
MEC	ministry of education, sports and culture
NIED	National institute of educational development
NMEC	Namibian ministry of education, sports and culture

NSSC	Namibian senior secondary school certificate
PCK	pedagogical content knowledge
PPCT	person-process context and time
PTCK	pedagogical technical content knowledge
PICK	Pedagogical indigenous content knowledge
SADC	southern African development community
SBS	School based studies
SC	situated cognition
S-C	Socio-cultural
SJ	social jargon (terms)
SPCK	specific pedagogical content knowledge
TCK	Technical content knowledge
TICK	Technical indigenous content knowledge
TK	traditional knowledge
UNAMKMC	University of Namibia Katima Mulilo Campus
UNICEF	United Nations International Children Educational Fund
WMS	western modern science
ZFM	zone of free movement
ZPA	zone of promoted action
ZPD	zone of proximal development

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CHAPTER 1: SITUATING THE STUDY

> *People coming from different walks of life, watching the same event, are likely to come up with different interpretations of that event. Certainly, depending on "the spectacles" each one of them is "wearing" in viewing the event, they would each have a different "view" of the event* (Imenda, 2014, p. 1).

1.1 Introduction

As suggested in the epigraph above, people from different walks of life will not interpret events in the same way. The environments that they have encountered in the past will influence their analysis and interpretation of an event. I present the following short account of my personal history so that the readers understand the lens through which I view the world. This may enable them to appreciate my analysis. I start from the time I was a small boy up to the time I began this study. In addition, the context, curriculum issues, research problem and questions of the research are discussed in this chapter. Each section will be supported by reference to my autobiography and will reveal how I interacted with indigenous ways of knowing nature. My story is reflected in the literature and the conceptual and theoretical frameworks I have selected and explored.

1.2 My personal history

I grew up in a rural area and attended a rural primary school. When the school day was over I was expected to assist with various household chores such as herding cows, ploughing the field during the rainy season, and gardening during the dry season. Engaging in these activities equipped me with a home-grown understanding of nature which subsequently informed my professional development, initially as a high school Physics teacher and, eventually as a Science and Mathematics educator.

My experiences were pragmatic and rooted in reality (Bhaskar, 1978). Elder-Vaas (2008) supports this as he suggests that experiences are empirical and are a subset of the other levels of reality; this is further elaborated in Section 3.2.2 in this thesis. From my interactions with my environment, I observed that schools in rural settings are under-resourced and do not engage in situated cognition (SC) where knowledge is situated in activity bound social, cultural and physical contexts during science teaching and learning in the same way as schools in urban areas. This is exacerbated by the fact that the environs of rural schools lack infrastructure, such as industries or factories where learners can be apprenticed in order to apply science concepts and theories learnt in the classroom. Consequently, teachers in such schools cannot engage SC approaches. Tjipueja (2001) supports this suggestion, as he states that a lack of resources hinders the attainment of the universal educational goals, namely, *access*, *equity*, *quality* and *democracy*. Itibari and Zulu (2006) concur, when they say:

> Currently, there are many challenges facing education in Africa: lack of funds, teachers, classrooms, learning materials, and transparency. Considering this challenge, contemporary African education needs a critical examination of its mission, goals and objectives that moves beyond the questions of select donor agencies and narrow national issues. Hence, an African centered critical theory is needed to extract the best of indigenous African thought and practice to present research-based alternatives and solutions to current educational challenges in Africa. (p. 41)

These challenges pose major problems to the goals of education mentioned above. This is not only a problem found in Zimbabwe, where I was born, raised and attended school, but it is a phenomenon common to all Southern African Development Community (SADC) countries as (Elmore, 2001) suggests. However, to narrow this study, I have collected and analysed data in a region in one of the SADC countries to share how we can come up with a solution to this problem. The context and curriculum issues I discuss in this chapter relate to schools in the Zambezi Region of Namibia, where I focused my research. Despite focusing on only a small region of the SADC, the problem I discuss is common to all SADC countries, as they are all developing countries whose economies are still figuring out how to make all schools function at the same level. My short autobiography reveals how I interacted with indigenous ways of knowing nature, which is also known as traditional knowledge (TK) or indigenous knowledge (IK).

My two older sisters were pillars of support. I interacted with my two older brothers only during school holidays when they returned from a missionary boarding school. My sisters and I walked fourteen kilometres to and from school every day. I remember that, at a very early age, I was introduced to a subject referred to as Nature Study (Jackman, 1891; Comstock, 2010). I remember that I liked the subject as I could easily relate the basic concepts to my environment. Itibari and Zulu (2006) view science instruction and learning as starting from a particular area as evidenced from the quote below:

> Science instruction and learning begins with a social issue, and then related technological and science concepts are drawn in. With the knowledge acquired, the social issues are revisited. This approach can make learning happen in a meaningful context. (p. 51)

The Nature Study curriculum emphasized the study of fauna and flora in the environment (Kass, 2014). It is noteworthy that all animals and plants which featured in the curriculum were familiar to me and to the community as a whole. In that respect the concepts were contextualized and situated. Nature study placed me in a position of 'sympathy' with nature. Concepts I learnt were in the dominant category of Ogunniyi and Hewson's (2008) five categories in the contiguity argumentation theory (CAT) where the other four are, equipollent, assimilated, emergent and suppressed.

Following Ogunniyi and Hewson's (2008) theory, my world view based on indigenous ways of knowing nature was not suppressed by, or assimilated into a Eurocentric world view. Neither was my learning of Nature Study concepts of the emergent conception type, which arises when an individual has no previous knowledge of a given phenomenon (Ogunniyi & Hewson, 2008). Emergent conception occurs when concepts taught are abstract; that is, one's community does not have cultural practices [that can be] linked to learning in community activities. Had the indigenous ways of knowing nature and Eurocentric conceptions of Nature Study co-occurred in such a way that they exerted comparably equal intellectual force on the process of my conceptual learning, then that learning would have been located in the equipollent category. Collateral learning could have taken place as the experience would be enduring (Aikenhead & Jegede, 1999). In that case, according to Ogunniyi and Hewson (2008), the ideas or world views would have co-existed in my mind without necessarily resulting in a conflict. So, the Western modern science (WMS) I confronted fell into the dominant category, since concepts taught in Nature Study were adaptable to my context.

I think this is why I enjoyed the subject. Each time the teacher introduced or mentioned a concept, I related it to what I saw when I walked to or from school, when I tilled the soil, or herded father's cattle. For me, the inclusion of Nature Study was one of the better ideas in the colonial curriculum, supporting the fact that not all structures in the colonial system were bad (Enosi, 2010). However, to my disappointment, that subject was phased out a few years down the line. In hindsight, this was probably because curriculum planners at that time found that Nature Study promoted African ideas, which previous education systems in SADC regions had aimed at eradicating in order to promote Western world views. Sadly, no other subject was taught using the approach that was used in Nature Study.

Conceptual learning was also influenced by some household tasks and cultural practices as illustrated by the following personal experience from my childhood. My sisters were responsible for the ironing and one day a hot iron accidentally fell on my foot and I was severely burnt. I would have had to wait until the following Sunday to catch the weekly bus to the clinic, fifty kilometres away. Fortunately, the following morning, my paternal grandmother arrived at our homestead.

When she noticed that I was in agony, with the burnt area becoming infected, she took me into the veld and instructed me to dig up the roots of a shrub. "*Crush the roots into a paste substance*", she instructed me. Thereafter, she told me to smear the paste on my wound and dress it. The following day the wound was dry and I had no pain. I knew the shrub as *chibayamadhongi* in the Shona language, but I was not aware of its use before that day. In Nature Study, I had studied how the same shrub reproduces, but not how the community benefits from it. Thus, my teacher had failed to show me how my community used traditional knowledge in cultural practices. Had this connection been made, learning would have been contextualized and situated in relation to cultural practices.

Another example of conceptual knowledge building gained from household tasks related to fetching water. Many rural communities in the SADC region source water from boreholes, springs or wells. My mother used to wake us before sunrise to fetch water for domestic use. I later learned that this cultural practice observed by communities in my area meant that we procured the water before atmospheric pressure affected the water levels of the water source. Surface tension determines capillary action, and "decreases with rise in temperature" (Dudeja, 2009, p. 325). Before the sun rises, surface tension causes a manifestation of pressure and by the principle of capillary action pushing water up in the capillary, water is also pushed up into the well, spring or borehole, making it easier to collect. In Section 2.4.3 a detailed discussion of surface tension triggering capillary action is provided.

I learnt concepts related to capillary action and surface tension when I was in secondary school. I related this cultural practice to vapour pressure and atmospheric pressure when my teacher was teaching concepts related to capillarity action and pressure. Although the teachers used examples where these concepts are applied, the examples were not related to what I mentioned earlier. The teachers' examples were located in other cultures, and in so doing they ignored the use of everyday examples in the community reflecting Science. Yet, communities like mine are indigenous knowledge archives. There are other examples that reveal how such communities prevent water from evaporating excessively which I witnessed when I was growing up (see Section 2.4).

Another example relating to fetching water is that members of my community were discouraged from using containers contaminated with soot. The fundamental understanding was that soot causes water to evaporate. The idea of discouraging community members from using soot contaminated containers to fetch water from wells or springs, I linked to heat absorption by black bodies. Black carbon from the container falls into the water and darkens that source of water which then acts as a black body. Western science became aware of the adverse effects of soot on the environment quite recently. For example, the understanding that soot causes ice to melt faster (see results of experiment conducted with participating teachers in Figure 28), thus depriving those who depend on melted ice to irrigate farms, is a comparatively recent discovery. Ramanathan and Carmichael (2008), Pravetton (2009), and Chen (2012) have also recently revealed how soot contributes to global warming.

Indigenous communities, however, have been aware of these effects for some time. Such knowledge has been and is still used by Indigenous communities to curb the effects of global warming. Mukwambo and Ngcoza (2015) suggest that Indigenous communities use cultural practices based on understanding how the contamination of water bodies by soot can be avoided in order to reduce excess evaporation of water, as well as preventing the accumulation of large amounts of energy from the sun. This is also known as the Albedo Effect, which informs one of the cultural practices that were investigated in this study. As one of the cultural practices in which pressure concepts are used as tools by Indigenous communities a thorough description of the Albedo Effect is in Chapter Two (Sections 2.1, 2.3 and 2.4.2). Its suitability for use in under–resourced schools to enable engagement of SC was investigated (ibid.).

I observed another phenomenon involving pressure that I related to modern science concepts when I was channelling water from a river using a canal to irrigate my garden. I chose an area situated at a higher level so that water could flow into my garden using gravitational force. If a gorge was along the route, I would bypass that gorge using a cylindrical piece of bark. The cylindrical structures were supported by poles allowing water to be directed to the next section of the canal and then into the garden.

Phenomena related to pressure were also noted when I was fetching cows, and during swimming. When fetching cows from the mountains, I found that I suffered from nose bleeds. The treatment for nosebleeds in my community is to pour cold water over the head. The effect of pouring cold water is to reduce interior nasal vasodilation. Up on a mountain, atmospheric pressure is less than blood pressure (Bond & Hughes, 2014); that is, blood pressure and atmospheric pressure are not in equilibrium. This causes the blood vessels to burst causing a nose bleed (McConnell, 1917).

Also when I was in the mountains my ears became blocked resulting in temporary deafness. A friend advised me to swallow hard when my ears were blocked. I made use of this experience when I was doing secondary education. A science teacher told me that people in an aeroplane are given sweets to suck in order to avoid the effects of atmospheric pressure reduction as altitude increases from sea level. Although at that time I had not been on a plane a similar situation of being on a mountain allowed me to understand the concepts of pressure.

The same experience occurred when I was swimming in the river with my sisters. After diving into the pool I found that my ears were blocked. They also suggested that I swallow to offset the adverse effects of pressure. Under the water, pressure is high and it forces its way into the ears and disturbs the pressure equilibrium between blood pressure and atmospheric pressure. We did not go to the river for the purpose of swimming only. Our main duty at the river was to do laundry.

Laundry was done in accordance with the cultural practices of my community. Even though the river had many rocky areas along its banks, we were encouraged to ensure that the soapy water did not go directly into the river. We fetched the water with buckets and other utensils and would find a suitable rock away from the river and do the laundry there. My understanding of this practice is that some communities understand the Marangoni Effect. This is an effect in which fluids move from regions of lower vapour pressure to regions of higher vapour pressure on account of the vapour pressure gradient that exists between liquids (Gonzalez, 1987). This effect is further explained in detail in Sections 2.1, 2.3, 2.3.1 and 2.4.2 since it is a good example of how communities facilitate SC in under-resourced schools.

My experiences with indigenous ways of knowing nature were not only used when I was a science learner, and are not confined to pressure. My focus however in this study is on how concepts of pressure and other science concepts can be taught using SC approaches in under-resourced schools. I have also used indigenous ways of knowing nature while teaching, as I illustrate below.

As a student teacher, I was taught that a teacher needs to contextualize science concepts s/he teaches. Rivet and Krajcik (2008) support this practice as they suggest that contextualizing entails "utilizing students' prior knowledge and everyday experiences as a catalyst for understanding challenging science concepts" (p. 1). In order to contextualize science concepts, I did mention areas where these ideas were applied in daily life. However, a void still remained since the school was in a remote area and the learners could not relate the notions I was teaching to what they experienced in their own community situation. This experience of teaching in a rural school was short lived. After working for three and a half months, I transferred to a school in an urban setting.

I found that at the new school I had access to more educational resources. Unlike the rural school, here I was able to take learners to places where science concepts are applied in industries. Learners also had the opportunity to interact with workers involved in the use of science concepts as tools, and learners were able to serve as apprentices for a few hours. However, not all science concepts could be taught using the SC approach.

For example, when I was teaching the idea of child spacing or family planning, I resorted to first discussing how it is done in the community. Culturally, the withdrawal method, or abstaining from sex (also known as the rhythm method) (Ngalangi, 2016), are used for child spacing or family planning. Thereafter, I discussed how family planning is done following the inventions of Western science; that is, the use of condoms, injections, pills and other methods was discussed and linked to the concept of child spacing applied in their community. The aim of this was to situate and contextualize the concept.

However, the use of such an approach was short lived when the head of the school heard that I was using local knowledge as an explanation, I was reprimanded and had to appear before a disciplinary committee. The disciplinary committee said, "*We charge you of bringing non-scientific knowledge into the classroom. We give you the first warning and once we hear the* *incident recurring we will serve you with a suspension letter so that you do not practice in this profession*". I stopped using that approach.

I then decided to be very cautious each time I engaged the use of IK in my practices. In most cases I smuggled it in when I explained a topic to small groups of learners who I felt would not report me to the school administration.

Fears of using IK as prior knowledge were removed when I started attending some classes offered by Rhodes University staff at the National Institute of Educational Development (NIED) in Namibia. The lecturer sanctioned the use of IK and I read widely on the topic. I was influenced by Mukuka (2010) who views IK as a body of knowledge with value that also can be taken as a commodity. Being value-driven, it can be also used in SC approaches. Gorjestani (2000) also considers IK as a body of knowledge which is an asset. Having noted the valuable properties of IK in my experiences, I concluded that IK can be used in SC approaches. This came about when I saw that trainee teachers that I was supervising in rural schools were grappling to engage the SC approach. Schools in rural settings do not have Western science structures supporting the use of the SC approach.

I now discuss the context that located the problem I observed and issues related to the Namibian curriculum are discussed. Also, the research problem, as I have stated above, reflects what is happening in relation to the curriculum in the region where this study was conducted.

1.3 Context of the Study

This study sought to find out how grade 11 Physical Science teachers in under-resourced rural schools of Namibia might make greater use of the SC approach when teaching science, and in particular the concepts of pressure. As stated in the Namibian National Curriculum for Basic Education (NNCBE) [Namibia. Ministry of Basic Education and Culture] (2010), SC creates opportunities to contextualize subject knowledge. Moreover, in the implementation of the official NNCBE sanctioned by the Namibian government, it is stipulated that teachers are to be guided by socio-cultural theory (Sleeter & Grant, 1991).

Yet, despite the fact that the NNCBE emphasizes contextualizing science concepts taught in schools, and that the SC approach is compatible with the socio-cultural theory informing the curriculum (NNCBE, 2010), Namibian rural science teachers continue to grapple with how to engage with the SC approach using locally available resources. It is postulated that important linkages between IK and SC can be meaningfully utilised in teaching Western modern science (WMS). This is based on the assumption that school science learning may be more effective if familiar scientific principles associated within IK practices in the learners' own socio-cultural environment are used as prior knowledge (Matang, 2006).

Furnham (1992) states that IK as prior knowledge provide the cultural and social context in which SC can be used as an approach to teaching and learning. This study thus aimed to explore how SC pedagogy can be engaged using IK practices that reflect concepts within the Namibian national education curriculum.

1.4 Namibian curriculum issues

One of the issues that Namibia's Vision 2030 addresses is the challenge of making Namibia a knowledge-based society. To this end, teachers are encouraged to make innovative use of knowledge systems (IK being one of these), as advocated in the NNCBE (2010). The intention is to improve education in terms of *equity*, *quality*, *democracy* and *access* (Namibia. Ministry of Education, Sport and Culture [MEC], 1993). Such an endeavour requires equipping teachers with the approaches advocated by the NNCBE, namely, learner-centred education (LCE) and SC, both of which are compatible with socio-cultural theory.

The basic application of SC involves the elicitation and integration of local examples of learners' IK in their learning of scientific concepts, an obvious way of contextualizing teaching and learning. Even though the NNCBE (2010) encourages teachers to take cognizance of the learners' IK to address educational goals, research shows that some teachers struggle to engage with SC in their practices (Mukwambo, Ngcoza & Chikunda, 2013). Tjipueja (2001) believes that a lack of resources is a factor that hampers the achievement of this goal.

To address this knowledge-practice gap, characterized by teachers' failure to use local examples in science teaching, this study aimed to find out how well science teachers were equipped with IK to use in applying the SC approach. Brown, Collins, and Duguid (1989) as well as Lave and Wenger (1991) view a SC approach as allowing learners to be in contact with community members who are applying theories as practical tools. The knowledge-practice gap is explained in the research problem.

1.5 Statement of the problem

Over the years working as a teacher-educator in the Zambezi Region, I have observed trainee science teachers teaching in under-resourced schools. I have concluded that despite opportunities to do things differently, many concepts are taught in abstract ways, without the inclusion of local examples which engage a SC approach. In their reflections, many trainees raised the point that the environment of the schools lacks an infrastructure supportive of a SC approach. I made it a habit to then ask trainee teachers whether they could see any value in arranging encounters with community members to help to contextualize the concepts taught. Only factors related to contextualization were explored to narrow it, of which further evidence of the lack of contextualizing learning is perhaps provided by the statistical data, shown in Table 1.

Table 1: Percentage marks obtained in Physical Science by learners in schools in the Zambezi Region (Extract from the Directorate of Namibian National Examination, 2011, 2012 and 2014)

Symbol	A^{+}	A	B	C	D	E	F	G	U	Year
% obtained in each symbol	1,11	2,78	6,67	18,89	26,68	16,67	17,23	8,3	1,67	2011
	0,22	1,35	2,7	13,93	12,81	23,37	30,11	13,26	2,25	2012
	0	0,56	2,25	5,06	17,87	24,72	30,34	14,61	4,49	2014

Table 1 shows that the percentage of learners who were awarded the symbols A^{+}, A and B is low; this starts to change from level C. Most learners earned symbols D, E, F and G, with some even getting a U symbol. The 15% ungraded in Physical Science and other high ungraded percentages in preceding years could be due to the absence of contextualized learning (Namibia. [NMEC], 2011). The MEC is quoted as saying: "In the following subjects, Physical Science and Mathematics, more than 15% of candidates were ungraded" (NMEC, 2011). This situation triggered my interest in investigating how teachers might use local situations embedded with IK as alternative SC environments to offset the knowledge-practice gap.

1.6 Significance of the Study

The significance of this study lies in strengthening teachers' understanding of how IK can be used in SC in schools in rural communities in order to change their practices. That is, it may shift the trend in which research has concentrated on "documentation of IK, neglecting its implementation in the classroom" (O'Donoghue, & Neluvhalani, 2002; Mokuku, 2004; Shava, 2005). Aikenhead (1999) revealed the relevance of bringing Aboriginal adults into the science classroom to talk about Aboriginal Science as this demonstrably crosses knowledge practice boundaries from the everyday to mesh with the knowledge embedded in WMS. This cross-border move has been termed 'cultural border crossing' (Aikenhead & Jegede, 1999) and raises questions about how teachers can mediate this transformative learning process where the students have a worldview whose epistemology and ontology differs from that of WMS as taught in the school system. Another significance which all the above authors support and did not mention is the epistemological transfer which Breidlid (2013) points out explicitly.

The skills to epistemologically transfer in this research may thus have implications for teachers' knowledge types as advocated by Shulman (1987). Even though Shulman advocated eight types, only four will be discussed and linked to the SC approach in this study. These are; content knowledge (CK), pedagogical content knowledge (PCK), pedagogical technical content knowledge (PTCK) and curriculum content knowledge (CCK). That is, the ability displayed by teachers to create a learning experience using SC is likely to be enhanced as content is contextualized. This ultimately helps teachers relate to and apply science knowledge in their everyday activities and in doing so *access, equity, quality and democracy* are addressed.

The current scenario is that in schools, with all the necessary infrastructures such as those in urban areas the above-mentioned goals are addressed. How can the same goals be achieved in schools in rural settings that have no sanctioned activities where science concepts are applied and can be used to apprentice learners or to contextualize science concepts. The learner-centred approach thrives if learning and teaching support materials (LTSMs) are available (Czerniewicz, Murray & Probyn, 2000). Thompson (2013), Chisholm and Leyendecker (2008) support the need to have LTSMs as they say the learner-centred approach is a failure in Namibia as teachers in the schools do not engage in it on account of a lack of resources. Thompson's remedy for this is Bhabha's (1994) cultural translation which is discussed in Section 2.5

My experience is some schools located in different communities do not apply a pedagogy incorporated with indigenous ways of knowing that learners use during informal learning of

Science when they are in IK apprenticeship programs. So, an understanding of how the SC approach can be engaged using IK might allow schools faced by a scarcity of LTSMs, to contextualize science concepts thereby level the uneven teaching and learning terrain. A case study below is analogous to what is happening in terms of achieving the Namibian educational goals while using the learner-centred approach.

In an African setting a group of people made up of the 'haves' and the 'have nots' discussing an imminent famine in their community will all say 'we are suffering'. The 'haves' because they want to echo the 'have nots' will also say that hunger has devastated the community even though they are not hungry.

This resonates with what is happening with the implementation of the learner-centred approach. On account of wanting to identify with those who make it, as occurs in schools situated in communities with facilities to support the SC approach - all teachers maintain that they are achieving the required goals using a learner-centred approach. However, the national examinations reveal that many schools fail to achieve the required symbols as reflected in Table 1.

As this study strives to understand how cultural practices, cultural artefacts and social science terminology can be used in the SC approach, the benefit might be that science teachers in rural settings will also be in a position to address the goals thereby making the teaching and learning environment equal for all schools. What follows are the goal, objectives and the research questions which guided this study.

1.7 Goal of the Study

The main goal of this study was to explore and expand the use of the SC approach by Physical Science teachers in rural under-resourced schools in the Zambezi Region of Namibia. To this end, the objectives of the study were:

- To explore how science teachers in rural schools use the SC approach in teaching pressure and other science concepts; and
- To develop meaning-making skills in Science with reference to how pressure and other science concepts can be taught using SC in under-resourced schools through incorporating appropriate examples of IK.

1.7.1 Main question

How do Physical Science teachers engage SC in teaching pressure and other science concepts at the nexus of indigenous knowledge and Western modern science?

The study strove to provide responses to the following research sub-questions:

1.7.2 Sub-questions

- How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching pressure and other science concepts? [Interviews, community analysis, document analysis, brainstorming and reflections were used to answer this question].

- What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts? [Brainstorming, audio-visual evidence, reflections, and interviews were used to answer this question].

- What expansive learning and mediation tools can the study develop to support the use of SC in the teaching of science concepts through the use of IK and other science practices? [Brainstorming, reflections, and interviews were used to answer this question].
- What insights can be obtained from a SC-driven pedagogy? [Experimental test; audio-visual evidence, reflections, and interviews were used to answer this question].

To investigate the above research sub-questions, the understanding of some fundamental conceptual terms and frameworks is required. These are found in various chapters of this study. Below, I clarify some which have been used in this study.

1.8 Clarification of concepts

Clarification of concepts involves the explanation of ideas and/or terms, supported by describing essential meaning, different meaning and appropriate use of a concept (McMillan & Schumacher, 2006). Three types of concept analysis exist: generic analysis, differential analysis, and condition analysis.

Generic clarification of concepts entails separating the elements that distinguish the particular concept from others. Differential analysis reveals the basic meanings of a concept, and suggests the logical domain that it covers. This type of concept clarification is engaged when a concept has more than one definition. Condition analysis identifies areas where a concept can be used, and it begins by giving examples that meet the necessary condition of the concept. In this section, I will use any of the above-mentioned types of concept clarification to show how I understand each concept in relation to my study.

Situated cognition

Situated cognition (SC) is also known as situated learning (Lave, 1988, 1996; Rogoff, 1995; Wertsch, 1991). As a learning theory, situated cognition proposes that learning does not take place in a vacuum (isolation). Instead, for learning to take place one must ensure that there are tools to use for learning to occur as well as a context. The context must be based on the culture of a person who is engaged in the learning activities.

Indicators of situated cognition include people learning in interactive activities and engaging with a community of practice (Lave & Wenger, 1991; Wenger, 1998). In these communities of practice, people who are learning and gaining experiences that shape their understanding while participating in the activity. In doing so, the learners acquire the cultural values and rules of their communities and, ultimately, shape history. Therefore, social interaction within a community of practice is of paramount importance in situated cognition.

Community of practice

Learning theorists behind the concept of community of practice include Brown and Duguid (1996), Lave and Wenger (1991) as well as Wenger (1998). These learning theorists understand communities of practice as groups of people who are self-organized. The selected group of people constituting a community of practice has a common sense of purpose and a desire to share ideas.

Even though communities of practice appear to be somewhat informal in character, they manifest mutual engagement, joint enterprise and a shared repertoire (Wenger, 1998). To Wenger, mutual engagement enables participants to engage in activities that finally bind them as one social entity. Joint enterprise comes as a result of collectively engaging in activities the community of practice is tasked to undertake. The shared repertoire is seen in the tools which are common within a community of practice. Language, for example, is such a common grouping.

Situated cognition emphasizes the need for social interaction and providing contextualized environments where tools are used to promote learning. This need paves the way for those interested in learning to interact with the community of practice. Interaction with those in the trade enables the learner to construct knowledge and develop cognitively through serving in an apprentice program.

Cognitive apprenticeship

Collins, Brown and Newman (1989) understand cognitive apprenticeship as a process of learning where the learner is guided into the experiences along cognitive and metacognitive levels. Cognitive apprenticeship ways of learning entail immersing learners into contextualized authentic activities. Learning takes place when learners serve as cadets acquiring the language and expertise from knowledgeable people who are already putting the theories learners want to learn into practice. The knowledgeable ones in the community of practice guide the novices. The novices, being in the peripheral area of the knowledge spectrum, are bound to show interest in what they acquire during participation. The way learners learn in a cognitive apprenticeship is similar to how carpenters, builders or other technical skills are acquired by those apprenticed to that specific trade.

Cognitive apprenticeship thrives if learning is situated, legitimate peripheral participation occurs (Lave & Wenger, 1991), and learners are guided to participate in certain activities in which theories or concepts they intend to learn are applied. Finally, learners need to show willingness to be members of a given community of practice.

Indigenous knowledge

According to Warren (1991), indigenous knowledge is a body of knowledge built up by a group of people through generations of living in close contact with nature that local people use to make a living in a particular environment. Indigenous knowledge comes as the result of facts that are known or learned from observations and experiences. The acquired knowledge is handed down from generation to generation (Kibirige & Van Rooyen, 2006), and is an essential part of the identity of a given community. Indigenous knowledge also enables a community to live in harmony with the environment for generations (Shizha, 2007). A variety of terms are used to describe indigenous knowledge: local knowledge, traditional knowledge, indigenous traditional knowledge, indigenous technical knowledge, traditional environmental knowledge, rural knowledge and traditional ecological knowledge. Indigenous knowledge constructed in a community is expressed in cultural practices and construction of cultural artefacts. Cultural practices and cultural artefacts are then used by the community as important tools in environmental conservation and natural disaster management.

Socio-cultural theory

Cultural elements and social elements in a community do not exist in isolation. Interaction exists between different cultural elements, as well as between different social elements. Cultural elements in interaction form a cultural system and social elements in interaction form a social system. Examples of cultural elements can be language, beliefs, values, and artefacts whereas an example of a social element is knowledge. Cultural and social systems also interact with each other. A social system and a cultural system interacting together, is referred to as a socio--cultural system. A socio-cultural system forms the basis of socio-cultural theory. This study is based on a socio--cultural theoretical framework.

A key figure behind this theory is Vygotsky, who introduced concepts such as interpsychological, intrapsychological and the zone of proximal development to educational theory. According to Vygotsky (1978), socio-cultural theory is a perspective on human mental processes as they come into contact with the meaning-making tools available in the cultural and social arena. The presence of social systems dictates the need to incorporate a social theory and, for this study, social realism was found suitable.

Social Realism

Social realism involves the view that theories refer to real features of the world. Case (2013) sees it as involving cultural and structural systems. Unlike socio-cultural theory, which looks in detail at social and cultural systems, social realism is concerned with social structures. Social structures, like customs, traditions, norms and cultural practices/activities, are part of reality.

The reality revealed in social structures is in layers: real, actual and empirical. Some of these layers are a subset of the other layers (Bhaskar, 1993). Even though social realism dwells more on social structures and the socio-cultural on both social and cultural aspects, the historical aspect remains un-addressed. Historical aspects are important elements when dealing with reality, and are addressed in this study through the use of the cultural historical activity theory.

Cultural Historical Activity Theory

An important idea in socio-cultural theory is that knowledge is acquired during social and cultural interaction. During interactions tools such as language are used. Whereas in social realism knowledge gained is used to construct theories. The common ground between the two theories is the emphasis on the necessity to create knowledge in an activity system during interaction. The links between the elements which are in interaction in the two are not explicit. Besides bringing in the aspects of history, the cultural historical theory (CHT) was promoted by Vygotsky (1978) and perfected by Engeström (1987) who explain explicitly the relationship between the participating elements: the mediating tools, subject, rules, community, division of labour and object. All these elements are dialectically related.

Cultural historical activity theory emphasizes how the cognitive development of an individual develops through simultaneously interacting with tools and a community of other people during joint activities (Vygotsky, 1978) and Engeström (1987. Cultural historical activity theory proposes that people engaging in activities are continually shaping and being shaped by social context in the activities (Blunden, 2010).

The clarification of concepts above is aimed at understanding the ideas which are used in this study. What follows is a guideline of how the chapters are structured and where each concept is thoroughly explained.

1.9 Thesis Outline

This thesis consists of nine chapters which are outlined below.

Chapter One introduces the study. I provide an introduction, followed by my personal history. Also discussed is the context of the study, which includes issues related to the Namibian curriculum. The problem statement as well as the research questions is set out. Also, stated in

Chapter One is the significance of the study. The clarification of concepts concludes this chapter.

In **Chapter Two,** the literature reviewed that related to the study is discussed. I introduce the concepts that fall within the conceptual framework. The conceptual framework discusses concepts like situated cognition, cognitive apprenticeship, communities of practice, authentic context, pressure concepts, indigenous knowledge embedded with concepts of pressure, myths that can support the SC approach, indigenous practices reflecting pressure which can be used for teaching conservation, cultural translation and the concluding section.

The theoretical framework which is a requirement for every research study is discussed in **Chapter Three**. The theories discussed are: socio-cultural theory in general and social realism in particular. The tenets of socio-cultural theory discussed are those from Vygotsky (1978); most especially the intrapsychological and interpsychological levels, and the zone of proximal development (ZPD). In social realism, the three levels of reality are discussed. Also in social theory, I examine some views in social theory and how they can bring about some changes in the practices of science teachers. These views are discussed in relation to IK and how they can contribute to facilitating SC in under-resourced schools. Finally, CHAT is discussed as an analytical tool in the study. The ontogenesis of CHAT is outlined, and how concepts in it contribute to this research study.

In **Chapter Four,** the methodology used in the study is discussed. The chapter opens with an introduction, followed by a description of the framework of the methodology and its justification. Developmental work research as the methodology is discussed and its tenet, the expansive learning cycle (ELC) and its stages, is explained. This is followed by a discussion of the two phase process of organizing the instruments used to generate data, the research site, and the use of data gathering instruments under each phase.

Data analysis follows, with an explanation of how data generated from the instruments were analysed. In order to comply with the ethical aspects of doing research, research ethics are discussed in this chapter showing how I worked with the participants as well as the data generated from the study. Before concluding the chapter, trustworthiness, validation and triangulation techniques are explained. Limitations to the study are discussed in the last section before the concluding remarks.

In **Chapter Five,** data generated using exploration instruments is presented. The instruments considered as responsible for generating exploration or data from Phase one were: document analysis, community analysis and brainstorming.

Presentation of data from exploration data generating instruments is done in **Chapter Six**. Instruments used for generating the data were: interviews, brainstorming, experimental test, audio-visual techniques, and reflections.

Analysis of all the data presented in the two preceding chapters is done in **Chapter Seven.** Data analysed first is that from instruments used in Phase one. This is followed by analysing data from the expansive data generating instruments.

Chapter Eight presents the themes that emerged from my data. The themes are analysed by relating them to the concepts in the literature review (Chapter Two), the introduction (Chapter One) where the research questions are stated, and the theoretical frameworks (Chapter Three).

The summary of findings is discussed in the last chapter, **Chapter Nine**. Recommendations and limitations of the study are stated before concluding the research programme.

1.10 Concluding remarks

Chapter One begins with a discussion of my personal experiences, where I show how indigenous knowledge is a key concept in this study and which is further discussed in detail in Chapter Two. Thereafter, the context is explained and which allowed me to discuss issues related to the Namibian curriculum. All curricula are anchored in ~~a~~ theory, and Chapter Three focuses on theories that support my conceptions in the study. These discussions led me to state the research problem and share the research goals and questions that guided the whole research. Finally, a brief outline of each of the chapters in the thesis is presented.

In the next chapter (Chapter Two), the focus is on reviewing literature related to indigenous knowledge and I highlight areas where it can be used to support situated cognition.

CHAPTER 2 : LITERATURE REVIEW

Knowledge is situated, being in part a product of activity, context, and culture in which it is developed and used. (Brown, Collins & Duguid, 1989, p. 32)

2.1 Introduction

The aim of this study was to understand how a situated cognition (SC) approach can be engaged when teaching pressure and other science concepts in schools that lack present-day technological resources. The communities where such schools are situated are rich in cultural practices/activities, artefacts and social terminology, which can be used for contextualizing concepts taught. Brown, Collins and Duguid (1989) in the epigraph point out the fundamental role of activity, context and culture in learning, however, their work excluded the activities, context and culture found in Indigenous communities. Cultural practices contain science knowledge which can be used in science teaching. To explore and expand the use of the SC approach by Physical Science teachers in under-resourced schools in the Zambezi Region of Namibia it was imperative to understand SC, IK in which cultural practices, artefacts and social terminology are embedded and whether the NNCBE accommodates this cultural translation.

2.2 Nature of Namibian curricula

Namibia curricula guidelines reveal that teachers are not technicians whose job is to deliver a "pre-packed curricula" of a prescriptive type (Morris & Adamson, 2010, p. 29). Instead, they are encouraged to act as agents in transforming the curricula. This transformation can be fuelled by using learners' experiences. Bass (2012) considers experience as part of the informal curriculum which can be used to implement the formal curriculum discussed above.

Learners process new science concepts in a way that makes sense to them in their own frameworks of reference, their own world views which they would have used to build up their experiences. This view of learning and teaching considers that the mind naturally strives for meaning in context. The hope of a learner is to establish a relationship between what the teacher imparts and similar concepts observed in their environment. To achieve this, a learner searches for relationships that make sense and appear useful.

The Namibian curriculum planners understand this and for this reason encourages that all knowledge sources in a learners' environment should be used when teaching science concepts. Through this understanding, the Namibian curriculum encourages a learner-centred approach which goes hand in hand with a SC approach. SC is advocated in the NNCBE (2010, p. 29) as it suggests the "ability to create new knowledge and acquire new skills do not happen in isolation. We are situated in a natural and cultural context with which we interact". These approaches enable learners to see concepts taught not as abstract but as concepts they know and use in their daily activities. However, with learners whose schools are in areas where natural resources are extracted and transported to other areas for processing they are at a disadvantage when the experiences which teachers select are not part of their culture. Several factors determine the experience which a learner brings to the science classroom.

Some of these factors are socioeconomic status, gender, ethnicity, culture and native language which play a key role in the experiences of learners. So, where the practices recommended in the curriculum are for learners of a different social class or socioeconomic status this becomes an obstacle to the learner's understanding. The practises cannot be related to the ideas already in his schema which he can accommodate or assimilate (Piaget & Cook, 1952). Wadsworth (2004) refers to this as a process of adaptation and this can occur if the right factors which have influenced the formation of experiences are used. Adaptation can be understood as a way of adjusting to the context which the situation requires or to "translate" a practice or situation (Hambleton, 1996, p. 3). This is where the teachers acting as agents can transform the curricula through engaging in cultural translation (to be discussed in Section 2.5). Similarly, in the SC approach, learners use materials and experiences from familiar cultural practices in classroom discussions.

Recommendations of experiences which learners found useful in the Namibian school curriculum indicate that it is not a top-down or centralized but rather more of bottom-up approach. The bottom-up approach in science teaching allows science teachers and their learners to bring on board practices of Science done in the community and also involves community members around the school to participate in the education of their children. This approach allows other stakeholders namely; the community and their infrastructure, the learners and their experiences, the teachers and the government to participate in advancing transformation and enhancing learning. On the other hand, the top-down also known as the centralized approach to curriculum emphasizes that decision making in matters related to curriculum involves only people and agencies close to the government. Morris and Adamson (2010) reveal extracts from the Hong Kong Education Department (1971) showing this type of curriculum which is essentially characterized as follows:

> *No instruction maybe given by school except in accordance with a syllabus approved by the Director (Education Regulations, 1971, S92 [1].*
>
> *No person shall use any document for instruction in a class in any school unless particulars of the title, author and publisher of the document and such other particulars of the document as the Director may require have been furnished to the Directorate not less than fourteen days previously (Education Regulation, 1971, S92[1])*

In contrast, the Namibian curriculum does not have such restrictions in its curriculum. It encourages teachers to incorporate as much material as they wish to promote learner-centred approach. That is, it allows science teachers to adapt the curriculum to meet the needs of diverse learners. In the discourse of this research study, this is to culturally translate the curriculum. Cultural translation can be achieved through the use of learners' IK which reflects the learners' experiences. When teachers use the IK of learners they accomplish the Africanisation goals that Mbeki (1998), Makgoba (1998) and Mukwambo, Ngcoza and Chikunda (2014) advocate.

Avoiding the use of IK where relevant cultural practices, artefacts and social terminology are found when teaching in an under-resourced rural school is analogous to a thirsty person ignoring a pool of water. LTSMs are scarce in schools in rural settings but it must be made clear that the same schools that lack infrastructure to support the SC approach have abundant indigenous resources which can be used as an alternative. Such schools are set within Indigenous communities with practices which reflect science concepts that can be used for the SC approach. Some examples are explained in the section which follows.

2.2.1 Knowledge that the NNCBE suggests for inclusion

There are, however, many activities reflecting Science which Indigenous communities practice in various parts of the world. For instance, in sub-Saharan Africa, some Indigenous community members in the Zambezi Region of Namibia apply the principle of Bernoulli (a theory about pressure) to cross the Zambezi River (Mukwambo, 2013). The science knowledge the Indigenous communities apply is situated in this activity, and involves understanding how best to cross the Zambezi River without encountering dangers or difficulties. However, when teaching Bernoulli's principle, science teachers use instances where a pedestrian is likely to be pulled under a truck or a train if s/he is near the area where the pressure variation occurs. To learners in rural schools, such examples are abstract and make it difficult for them to understand the concepts of pressure. Non recognition of local encounters and resorting to unfamiliar examples renders it difficult for Science teachers to engage the SC approach in their teaching repertoires.

Another example refers to the principles of the Albedo Effect. This is a cultural practice applied by Indigenous communities when they discourage the use of a soot contaminated container to fetch water from a water source. The soot dust darkens the substrate and fosters increased heating and evaporation. Similarly, the Capillary Effect (Marangoni Effect) and how soap affects the vapour pressure of water represents the cultural practices of Indigenous communities to curb global warming. The Albedo Effect and Marangoni Effect, as concepts in Science, as well as cultural practices, cultural and structural systems as Case (2013) suggests, are some of the elements that will be examined to achieve the objectives of this study:

(i) To understand how science teachers in rural schools use the SC approach in teaching pressure and other science concepts; and
(ii) To develop meaning-making skills in Science with reference to how pressure and other science concepts can be taught using SC in under-resourced schools through incorporating appropriate examples of IK.

The exclusion of cultural practices from the learners' environment by teachers makes inadequate use of the acquired concepts. This is similar to the formerly misunderstood rare gases (helium, neon, argon, krypton, xenon and radon), which were assumed to be inert (Hale, 2013). It is now accepted knowledge that they can be activated by energizing them to participate in reactions. Pressure or other science concepts acquired without engaging in the SC approaches are inert and useless as learners have no idea of where they can be applied in their community. To understand how such knowledge about pressure can be energized, the study sought to understand how grade 11 Physical Science teachers in rural schools within the Zambezi Region of Namibia facilitate learners' interaction with peers using IK when they engage with SC in their learning, specifically, when taught the topic of pressure.

Brown, et al. (1989), as well as Lave and Wenger (1991) propose the SC approach as a pedagogical style that can allow teachers to facilitate learners' knowledge construction. The focus of the study is to explore the value of SC as the conceptual framework. Other conceptual frameworks mentioned in Chapter One are also discussed in detail in this chapter, including IK and cultural translation.

2.3 Conceptual frameworks

A conceptual framework is a synthesis of the existing views in the literature concerning a given situation (Imenda, 2014). Liehr and Smith (1999) suggest that a conceptual framework is a model or integrated way of looking at a problem. In this study, the conceptual frameworks are situated cognition, pressure, and indigenous knowledge. Conceptual frameworks embrace ideas that are specific to a study and form a springboard for the theoretical framework I have chosen (Imenda, 2014).

2.3.1 Situated cognition

Situated learning or situated cognition is an instructional approach first developed by Brown, et al. (1989). Lave and Wenger, in the early 1990s, considered the SC approach as a social activity, in which a teacher relates activities to daily experiences. SC theorists posit that knowledge is generated as one interacts with the environment (context) and further see learning as a situated process (Bodner & Orgil, 2007). These theorists used the work of Dewey, Vygotsky, and Bronfenbrenner, among others as a foundation.

Dewey (1859) suggested that for teaching to accomplish its end, the actual life-experience of the learners needs to be incorporated into the learning activities. Furthermore, Dewey (1934) suggested that, "unless there has been experience in some degree analogous, which may now be represented in imagination, confusion remains more confusion" (p. 25). His suggestions for teachers to ensure that learning takes place, was to make certain that learners are immersed in real-world, practical situations in which they can demonstrate their knowledge through creativity and collaboration.

Vygotsky (1978), on the other hand, proposes that, if useful knowledge is to be constructed, teaching cannot be divorced from the culture of the learners where the experiences are embedded. Unlike Dewey, Vygotsky links SC with culture. Vygotsky (1962) considers language as both a tool, and as a component of culture, which is used in cultural practices/activities. Teachers' use of social science terms (jargon) which Hirst (2003) suggests should be used with care and cultural practices/activities creates the context required to situate learning. In the case of this study, IK embedded in cultural practices/activities provides the context and is part of the cultural experiences which a learner brings into the classroom.

According to Vygotsky (1978), every activity in a learner's cultural development appears twice. It first appears on the social level; thereafter, it emerges on the individual level. These terms will be further discussed in Section 3.2.1. When a learner interacts socially with others, this is referred to as the inter-psychological level (plane). A learner gains experience of what is happening in and around his environment and this then forms part of his actual life experience. When alone, a learner ponders and reflects what has been gained during social interaction, in order to construct knowledge. This new knowledge then shapes his/her world view of the environment in which s/he is situated. This constitutes the intra-psychological level (plane) (Vygotsky, 1978, p. 57). Thus, Vygotsky (1978) views learning as preceding development, as evidenced in this statement:

> Learning is not development; however, properly organized learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning. (p. 90)

Bronfenbrenner (2005) views human development as possible if all the systems in a learner's bio-ecological environment are taken into consideration. The systems he considers to be important have the same components as those mentioned by Vygotsky and Dewey, but they are considered in terms of systems. He considers four main systems: *microsystem*, *mesosystem*, *exosystem*, and *macrosystem*.

The microsystem is the immediate environment of a learner where s/he gains experience and understanding and utilizes the gained experience for personal benefit. The mesosystem, which is above the microsystem, is made up of a number of microsystems in interaction and has a direct influence on the learner. Unlike these first two systems contributing to a learner's development, the exosystem has an indirect influence in forming the learner's experience, which, according to Dewey (1934) is necessary for reflection when learning. Teachers need to make these experiences accessible. Finally, the macrosystem is where culture is located and occupies the outermost layer. Some of the other elements which make up some of these systems are shown for each level in Figure 1 below.

Figure 1: Types of systems influencing development and example of elements in each system (Adapted from Bronfenbrenner, 2005, p. 5)

Bronfenbrenner (2005) advocates that four elements must be in place to successfully engage a SC approach that is compliant with SC characteristics. The elements are person-process, context and time (PPCT). These elements will be discussed further after I list the tenets of SC.

The SC connotation in Brown, et al. (1989), Lave and Wenger (1991), and Bronfenbrenner's (1979) ideas is evidence that the theorists of SC drew on thinking from Dewey, whose idea of experience is synonymous with the theory of socio-cultural theory of learning introduced by Vygotsky and discussed in Section 3.2.1. The NNCBE (2010, p. 29) values socio-cultural theory as evidenced from the inclusion of some of its tenets such as "cultural context with which we interact, which affects us and which we draw upon to construct understanding".

Using these theories as a foundation, Lave and Wenger (1991) went further to say that learning is a social activity which takes place during social interaction. Oliver (1999) explains that learning occurs naturally when the culture of the learner is brought into the classroom. In doing so, contextualization is achieved as the learning is situated in activities familiar to the learner. The work of Brown, et al. (1989), and Lave and Wenger (1991) emphasizes the usefulness of one’s culture to address teaching and learning encounters that encourage authentic teaching practices in a classroom. However, the work of these theorists concentrated on cultural practices within a context that is not common in the area where the present research study was conducted. It is this absence of local cultural practices in Science textbooks used in the curriculum in rural schools that often restricts teachers from providing situated contexts and applications in their practices. As a result, situated cognition is not easily implemented.

Moreover, the knowledge teachers construct with learners’ needs to be a ‘tool’, acquired not for the purpose of safe keeping in one’s mental faculties, but to be applied in one’s environment (Brown, et al., 1989, p. 33). The absence of an infrastructure that allows for knowledge to be applied to one’s environment makes it ineffective (Hale, 2013). Resnick (1987) suggests that SC is an approach entailing apprenticing learners to an expert in order to ground and enrich their learning experience. Lave and Wenger (1991) refer to this as being a ‘legitimate peripheral participant’ in that culture.

Enosi (2010) and Rogoff (1995) support the idea that learners undergo an apprenticeship program in IK. Enosi (2010) raises the idea of indigenous education as an approach in which a community transmits learnt culture, knowledge, skills and values from one individual to another through apprenticing them to knowledgeable individuals. The culture, knowledge in the culture, and the skills gained are the principles that can be used in the SC approach when teaching Science.

This affirms the SC approach to teaching Science which posits that knowing and doing are inseparable; and have a dialectical relationship. That is, information must be taught in context, while knowledge constructors (teachers and learners together) use tools as practitioners do (Lave & Wenger, 1991; Vygotsky, 1962; Dewey, 1859).

The implication in science teaching and learning is that the activities should be made explicit using the social and cultural context of the learners, and the local knowledge that they have already acquired when they served apprenticeships in their communities. Lave’s (1988) ideas of SC echo Giddens's theory of structuration (1984), which argues that an individual's cognitive activity cannot be divorced from the social context in which it occurs. The implication is that teachers need to create SC environments that support active engagement, discussions and reflexive thinking. In the case of learners in under–resourced schools, teachers can make use of activities from their communities that reflect science concepts. This encourages learners to model the behaviour they have observed in IK practices (Bandura, 1977). When they model science, learning for understanding occurs since learners relate cultural activities to their communities of practice and thus apprenticeship is socially situated (Fuller & Unwin, 2008).

According to Lave (1988, p. 43), the SC perspective is based on four major premises:

- Learning is grounded in the actions of everyday situations;
- Knowledge is acquired situationally and transfers only to similar situations;
- Social processes influence the way people think, perceive, solve problems, perform procedures, build declarative knowledge, and interact with others; and
- Learning is thoroughly enmeshed in participation in complex social environments that contain situations, and activities.

Based on Lave's premises, SC analysts and critics, such as McLellan (1994) and Herrington and Oliver (1999, p. 242), propose that in order for teachers' practices to adopt the characteristics of SC they must have the following features:

- Provide authentic contexts that reflect the way knowledge will be used in everyday real life;
- Provide authentic activities;
- Provide access to expert performances and the modelling of processes;
- Provide multiple roles and perspectives;
- Support collaborative construction of knowledge;
- Provide coaching and scaffolding at critical times;
- Promote reflection to enable abstractions to be formed;
- Promote articulation to enable tacit knowledge to be made explicit; and
- Provide for integrated assessment of learning within the tasks.

It was the intention of this study to investigate how these characteristics of the SC approach can be implemented by science teachers in schools in rural areas which lack formal science and/or work environments to allow learners to interact with the IK community of practice in order to relate local practice to formal science.

Lave and Wenger (1991) propose that learning with SC perspectives above has a tripartite action involving agent, activity and the world. This echoes Bronfenbrenner's (1979) theory of human development, in which he considers person, process, context and time.Concerning the design of SC approaches that can be engaged by teachers in rural settings, I consider the teacher who is grappling to engage the SC approach as the person or the agent, the activity or processes as the teachers' practices, the world or the context as the cultural practices in the learners' environment, and/or the learning in the moment and constructing new knowledge over time, historically, socially and culturally.

It is against this backdrop, showing elements such as person, process, context and the historical aspects, that in this study the SC environment was explored using the concept of cultural historical activity system. This will be explained further in Section3.2.3. SC environments are culturally organized and manifest the characteristics of an activity system. The concept of an activity system in this study will be in relation to the topic on pressure and other science concepts using the cultural practices of communities from which the learners come.

Figure 2 below, illustrates the relationship between three elements in SC. Each element's area of influence on potential learning and actions performed is indicated.

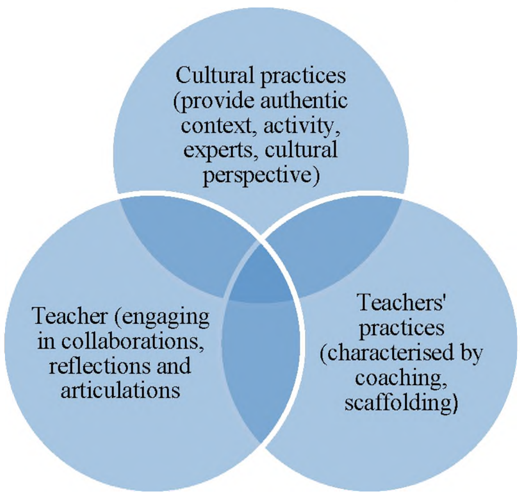


Figure 2: Constitutive elements of situated learning when engaging IK cultural practices (Adapted from Herrington & Oliver, 1995, p. 4)

According to Farmer, Buckmaster, and LeGrand (1992), Brandt, Farmer and Buckmaster (1993), and Rogoff (1995), a model emerging from the situated cognition framework of cognitive apprenticeships and communities of practice (Lave & Wenger, 1991; Wenger, 1998) has been widely discussed and developed. For example, McLellen (1996) discussed situated learning and its implications for the instructional design of multimedia. However, discussion relating to situated learning and its implication for the instructional design of IK is rare. If such discussions appear, they do not explain the complexities of how IK can be used in schools to infuse other knowledge systems. For example, Gerdes (2007) discusses ethno-mathematics and how it can be of importance in promoting mathematics literacy but it still needs to be adapted to the school context.

To summarize, the preceding section discusses models and the characteristics of SC proposed by Lave (1998) and Bronfenbrenner (2005). Of importance in the present study is how IK practices can be helpful to address *access, quality, democracy and equity* in schools where teachers cannot engage a SC approach on account of a lack of infrastructure supporting SC. The above discussion will partly answer one of the research questions in the study:

> *How do grade 11 Physical Science teachers in rural schools of the Zambezi Region facilitate learners' interaction with peers using IK when they engage with SC in their practices when teaching pressure and other science concepts?*

2.3.2 Cognitive apprenticeship

One of the outstanding features of SC is to expose the individuals intended to benefit from constructing useful knowledge, to 'masters' or experts in the subjects they pursue in the classroom (Wineburg, 1989; Tripp, 1993). This is referred to as cognitive apprenticeship and is dependent on expert demonstration (modelling) and guidance (coaching) in the initial phases of learning. Additional hallmarks of cognitive apprenticeship are reflection, articulation and exploration. Together, these five hallmarks of cognitive apprenticeship serve the purpose of scaffolding a learner (Ninio & Bruner, 1978).

There are two types of scaffolding, "soft" and "hard", and it is best for science teachers to engage the two types simultaneously (Brush & Saye, 2001). Soft scaffolding is achieved when the teacher "circulates the classroom explaining" any contingent issues learners raise (Simon & Klein, 2007). On account of soft scaffolding dealing with contingent issues, Van Lier (1996) refers to it as contingent scaffolding. During this process, explanations need to be based on familiar cultural practices/activities that are related to the concept the learner is questioning. In doing this, a multicultural approach to teaching a concept is achieved; that is, each learner's everyday knowledge and the ways in which s/he would have learnt a concept is brought aboard and this facilitates better understanding.

In contrast to soft or contingent scaffolding, hard scaffolding requires that the teacher reinforces practices through "planning ahead" (Brush & Saye, 2001). This is where s/he is required to detect cultural practices and cultural terms, which reflect Science, before beginning to teach. Scaffolding using the terminology that learners experience in cultural activities and relating it to pressure concepts taught can easily allow teachers to take learners to the "zone of proximal development" (ZPD) (Vygotsky, 1978). According to Vygotsky (1978), the ZPD is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86).

Valsiner (1997) introduces two more zones namely the zone of free movement (ZFM) and the zone of promoted action (ZPA). These zones aim to further explain how a child's development is organized in terms of the environment and relationships between the child and other people in the environment. Using the environment contributes to the SC approach as there interaction of novices and those in a community of practice occurs. Stott (2016) brings the ZPD, ZFM and ZPA concepts nearer to this study as she is of the opinion that the three are structures used by knowledgeable individuals to enable or constrain cognitive activities in novices.

Novices, or the learners, are already aware of certain activities which reflect Science within their communities. For example, the communities' existing ideas, related to the Science explained by the Albedo Effect and the Marangoni Effect, mentioned above, reflect pressure and other science concepts, and are typical examples of "real-world context and situations" that teachers need to bring into their discussions when teaching (Collins, Brown, & Newman, 1989). Infusing community terminology about pressure will enable learners to undergo development on three planes: "personal, interpersonal and thereafter undergo community's practices" as they are already serving within community apprenticeship programs (Rogoff, 1995, p. 9).

On the personal plane, learners are enculturated, and this enculturation is carried through to the interpersonal plane. Enculturation is understood as the acquisition of the terminology, behaviour and norms of a particular activity. The activities supported by concepts - such as those that are formalized in science learning such as the Albedo Effect and the Marangoni Effect - are employed to sustain the environment. Collectively, as novices are guided by adult members of their communities, learners use this conceptual knowledge in the activity to ensure that no one breaks the rules involved, in order to maintain the ecosystem in equilibrium. The division of labour manifested in communities where learners serve cognitive apprenticeship programs allows rules to be put in place. Rules are put in place after they observe the role of knowledge in the activities they do.

Furthermore, the presence of rules within the communities of practice with which learners engage during informal learning allows learners to interact in multiple roles and perspectives. As they do so, collaboration levels between the experts and the novice are improved. If the learning that results from such encounters is then brought into the teacher's practices when teaching pressure or other science concepts, self-regulation of learners is improved. That is, the knowledge constructed with learners builds upon the scaffolding of already accessible understandings.

2.3.3 Communities of practice

Communities of practice (COP) are self-organized and self-selected groups of people. Participants in communities of practice share a common sense of purpose and a desire to learn and know what the other knows (Brown & Duguid, 1996; Lave & Wenger, 1991; Wenger, 1998). As a group of people with a common objective, a community of practice either formally or informally engages in mutual activities. The aim in doing the activities is to realize some community standards and expectations. The use of common social terminology in the COP enables each group to be identified as a distinctive group from other groups.

Based on Bronfenbrenner's (2005) ideas, a community of practice is a microsystem where individuals interact to construct the knowledge necessary for them to understand the environment. Groups of COP using common social terms, or non-common terms in their shared practices form a mesosystem. The exosystem community of practice of a learner is made up of rules in the community to conserve the environment, has an indirect influence on a learner's experience and is located in the third layer. The microsystem, mesosystem, exosystem community of practice forms a macrosystem situated in the fourth layer, when all are interacting they influence a learner's experience.

Depending on the level at which an individual is in a COP, membership of individuals can be labelled as; peripheral, inbound, insider, boundary or outbound (Wenger, 1998). Peripheral status is given to one who is not fully involved and is a novice in the activities of the COP. This is where learners can be placed as they acquire IK. Being a novice enables an individual to acquaint herself or himself with the tasks, social terms and cultural artefacts or tools associated with the community of practice. When they finally acquaint themselves with the tools of the COP they can become legitimate members and take on the identity of the community of practice. Learners in their communities are novices as they grapple to understand cultural practices with which other community members engage.

One labelled as inbound in a COP is an individual who is in the process of becoming a fully participating member. Inbound membership status implies movement towards the acquisition of tools and rules of the COP to attain the required identity and become fully-fledged members. A trainee teacher, or a youngster acquiring some skills regarding certain beliefs of a particular community serve as good examples of one who is an inbound-being inducted into the activities in a given community of practice in order to equip himself or herself with the identity of that particular community.

An insider member of a COP is an individual who has become a fully participating member of that community. A typical example of an insider member is a teacher who knows how to fuse cultural artefacts or tools to ensure that SC is engaged, or a community member whose role in the community is to act as a custodian of cultural practices.

An individual on the boundary is not a fully participating member of the community, but participates by bringing a different set of skills or services to the community. A subject advisor in Science can serve this role, for example, after attending a conference on how Science can be taught, and disseminating such skills to the teachers. Similarly, in the area of cultural practices, a knowledgeable member of the community is responsible for amending some cultural practices in order for them to resonate with what he would have observed or discovered within the mesosystem. This illustrates that cultural practices are components of culture not stagnant but dynamic. This conception of the dynamic nature of cultural practices echoes with Sillitoe's (2000) suggestion that cultural practices are "flexible, adaptable and innovative" (p. 4).

Finally, an outbound individual in a community of practice is an individual preparing to leave the community. In the case of a COP situated in a rural community, like the schools under investigation in this research, a knowledgeable member moving from such a community to another serves as a good example of one who is an outbound member. A teacher opting to retire is another example.

A member of the teacher community of practice who is moving to another context/community in order to impart the importance of incorporating IK into science teaching would be an insider member of the teacher of COP. In my case, I move outwards to share knowledge and to create a new COP – the IK in science teaching/ learning. When immersing oneself in a community of practice and engaging cognitive apprenticeship, authentic context can be accessed.

2.3.4 Authentic context

Brown, et al. (1989) understands authentic activities as "ordinary practices of the culture" (p. 34). Vincini (2012) supports this understanding, as she suggests that authentic activities reflect the way knowledge in a given discipline is used in real life. In the case of Miller and Gildea (1987), learning through the use of a dictionary revealed that learners do not learn as well when they not immersed in an authentic context in which the words are found. So, in the case of rural school learners where real life situations providing authentic situations are in their cultural practices/activities, cultural practices can serve as authentic contexts when teaching pressure concepts or other science concepts. Authentic contexts from learners' communities are excluded by teachers in their practices. Instead, teachers mostly use examples of science concepts found in the recommended textbooks which does not enhance learners' understanding by using real life examples.

If teachers engage with cultural practices from learners' environments, it is possible that authentic context, which can reinforce the shaping of identities in the learners, is achieved. Teachers' use of knowledge that learners would have constructed in everyday contexts provides a crucial link for a more meaningful meaning making and socially acceptable science education that brings into account the historical significance and important cultural values.

A further implication for science teaching and learning when teachers' practices use cultural practices/activities is that the SC approach is made possible and SC environments support active engagement, discussions and reflexive thinking.

It is against this theoretical backdrop that the SC environment will be explored in this study using the framework of a cultural historical activity system discussed in detail in Section 3.2.3.

SC environments are culturally organized and manifest the characteristics of an activity system. The concept of an activity system in this study will be in relation to notions of pressure using the cultural practices of the learners' communities (see Section 3.2.4). Below, I now discuss pressure as a science concept.

2.3 Pressure as a science concept

Pressure is the force exerted per unit area. Mathematically it is expressed as $P = F/A$, where P denotes pressure, F force and A area. The standard international units of pressure are Newton per square meter (Nm^{-2}).Indigenous communities apply their understanding of pressure in cultural activities discussed in Section 2.4 below. These can be used in mediating teaching and learning activities.

A teacher's approach can affect how a learner learns abstract concepts like that of pressure (She, 2005). Kariotoglou and Psillos (1993) consolidate this when they point out that because learners view learning of pressure and other science concepts as abstract, they end up with many misconceptions. Tytler (1998) reveals that learners hold the view that "atmospheric pressure increases with altitude" (p. 934). The aim of this study is to reveal how pressure and other science concepts viewed by learners as abstract can be learnt when cultural practices are used to contextualize abstractions with real life applications.

For example, when learning the abstract concept of pressure a learner does not necessarily relate to the pressure concepts observable in daily experience. The teacher who facilitates the acquisition of pressure concepts also does not link the concept to the learners' experiences. If the teacher does use examples they often exclude those that the learner already knows. Examples of pressure the teacher presents are those found in other cultural environments, yet pressure concepts are encountered and applied by learners in many activities in their communities. Other science concepts taught by teachers are also experienced by learners as abstract as teachers often use one world view. In this regard Hodson (2009) suggests that all world views a learner brings into the classroom must be acknowledged and celebrated in order to facilitate the emergence of Afro-centered pedagogies.

2.4 Indigenous knowledge in pressure concepts used in my communities of practice

Understanding of indigenous knowledge in pressure requires that we understand what we refer to as indigenous knowledge and how this knowledge is related to Western modern science (WMS). Indigenous knowledge (IK) entails the indigenous ways of knowing nature. This is also referred to as traditional knowledge indigenous communities engage with to stay in harmony with nature and maintain the beauty of the environment. An Indigenous community is one found in a particular location and uses observations to stay in harmony with the environment (Hawkins & Thompson, 2007; Shiza, 2007). On account of an Indigenous community found in a prticular location, the knowledge emerging from their observation is localized unlike WMS which is universal.

To stay in harmony and keep the beauty of the environment, Indigenous communities address "axiological" (Hawkins & Thompson, 2007, p. 285) issues, cultural beliefs, practices, artefacts and observations that are used to construct knowledge. On the other hand, WMS uses empirical methods to produce knowledge. This study therefore values the uniqueness of IK since it exists in a particular location for the purpose of survival. Its use makes it possible to be passed on orally from one generation to another generation (Kibirige & Van Rooyen, 2006).

The challenge that IK might bring to research though is that it is not systematically measured like WMS. WMS is a significant improvement of human experiences of which cultural practices and observations are part of. WMS came as a result of considering what was done "historically" (Blunden, 2010, p.10; Hawkins & Thompson, 2007, p. 285). Indigenous communities use the past, history and reviewing allows them to perfect their IK. This has made WMS objective while IK relies on subjective interpretation.

Usher (2000) believes that the non-systematic of IK might bring some challenges as one might consider views which Indigenous communities have as knowledge. My view is that, the fact that IK is constructed using observations and passed on verbally does not necessarily mean that it loses its value or got distorted during transmission. Instead, from Marx's (1867) view, a practice is perfected and at the same time it develops the user. The users, who are the Indigenous communities keep using the cultural practices and artefacts which are the products. Each time they improve how they do and at they same time they develop cognitively. This view inspired me to select some cultural practices from rural communities dealing with pressure concepts which illustrate knowledge which can be used in SC.

Pressure concepts are applied by community members in different activities after they observe the phenomenon in practice. Community members extract the possible knowledge which can be used in either environmental preservation or sustainability. Such observed knowledge is used to ease the workload and this knowledge is shared amongst community members. If scientific explanation cannot be confirmed, then it is classified as a myth.

What follows is a discussion of how community environments with science knowledge can be used as tools when conventional SC situations are not present. Some of the explanations of the phenomena by community members, although regarded as myths, can be exploited by science teachers in rural settings to support a SC approach.

2.4.1 Analysis of myths to a support SC approach in pressure concepts teaching and learning

At one point in the development of WMS, the appearance of a pool of water in front of a person walking in a desert could not be explained. The fool's pool, as it was labelled, was explained using myths. This explanation endured until the laws of refraction were understood and then found to be the cause of a mirage, as it is commonly termed scientifically. Today WMS explains that a mirage observed in a desert, or on a long stretch of a refractive surface such as a tarred road during sunny conditions, can be attributed to total internal refraction.

Most science teachers refer to the historical development of a mirage when teaching refraction. They might take learners to sites where a mirage is observed and in doing so they comply with the tenets of the SC approach. As a result, authentic context is made available to the learners. Exposure of learners to a place where a mirage is observed allows learners to have a real encounter with a scientific concept that they can then model with their peers.

Modelling helps to access the ZPD proposed by Vygotsky (1978), because imitation occurs by the learner interacting with peers. Bandura (1977) views modelling as a successful and efficient way of learning. Jonassen (1999) proposes two variants of modelling: behavioural and cognitive modelling. The first is one most people are most familiar with and it entails imitation of the situation presented in the SC approach.

However, cognitive modelling is more aligned to cognitive apprenticeship emphasized in Section 2.3 and discussed as a tenet of the SC approach. Taking learners to such sites immerses them in situations where the real knowledge is applied.

Figure 3: Use of wild life animals' habitat to teach concepts of pressure (Adapted from *animals.nationalgeographic.com/animals/mammals/giant-anteater/)*

For instance, an ant-eater (*aardvark*), shown in Figure 3 above, burrows into the ground and lives there during the day. Phenomena not understood by Indigenous communities such as how it survives underground where there is limited air or no air is explained by using myths.

Asking learners how an ant-eater survives underground during the day paves the way for a rural science teacher to teach the concept of atmospheric pressure in a SC environment. Atmospheric pressure is the *pressure* exerted by the weight of ***air*** in the *atmosphere* of the Earth. Such a question creates a condition of disequilibrium. As Dewey (1934) suggested, a state of "disequilibrium" or "cognitive conflict" (Piaget, 1977) is a requisite in science teaching. Cognitive conflict motivates a learner to learn as humans always desire a state of cognitive balance or equilibrium-adaptation. Also, in the process a lively classroom talk ensues as the teacher and learner are equipped with pedagogical content knowledge (Shulman, 1987). This happens because the learner and teacher will use their indigenous pedagogical knowledge related to the habitat of the ant-eater.

An analysis of the habitat of this animal reveals that atmospheric pressure is not always a constant; that is, it fluctuates. Surrounding pressure in an area changes on account of temperature changes around that area. The heated air changes its density, thereby contributing to the fluctuation of atmospheric pressure in a given area. The atmospheric pressure might be high or low, but it does not deviate very far from the expected standard value of a place.

When atmospheric pressure around the habitat is high, in the hole where the animal is resting, it is low. This allows air to move into the hole. When atmospheric pressure is low around the area outside the hole, air in the hole is pushed out. Such movements caused by variation of atmospheric pressure enables the ant-eater to have a fresh supply of air while lying inside the hole. This analysis, which can be done by the teacher with learners at the site, allows the group to deduce that the habitat of such an animal is a breathing hole and this helps to solve the mystery surrounding the survival of this animal, while at the same time allowing for learning contextualized concepts of pressure.

To contextualize the learning of atmospheric pressure, teachers in the region arrange annual trips to the coast. At the coast where the pressure is low, teachers might use barometers to measure atmospheric pressure. The measured value of atmospheric pressure is then compared with that in the area where the school is situated. In many cases, these measurements are not done since the schools do not have barometers to measure atmospheric pressure.

As an alternative, instead of taking learners to the coast to understand the concept of pressure, the ant-eater example, which exists within the learners' environment, can be used to learn pressure concepts. The advantage of using local examples lies in the fact that the tenets of SC exists in the immediate environment.

Furthermore, a second advantage is that this acquired knowledge can be applied in their communities. In many instances, when excursions are planned not all learners can afford to go on the trip so the use of readily available local examples from the community makes deep learning possible for all learners since no learners are likely to be excluded for financial or other reasons.

Finally, the teacher faced by lack of teaching and learning materials can also address issues related to equity, quality and access in practice. The use of the above-mentioned approach allows such a teacher to teach at the same level as teachers in regions with better-resourced schools.

The idea of breathing holes mentioned in the previous paragraphs is not only common in the Zambezi Region where the study took place.

Another example where the above phenomenon is used to explain 'mysteries' is the case of the Native Americans in South Dakota in the United States of America. They came across a point where "wind was escaping through a small hole in some rocks" and referred to it as a cave which breathes (Ickes & Cammerer, 1935, p. 1). Air either escapes or enters into the hole or a cave which is attributed to variation of atmospheric pressure as mentioned before. When atmospheric pressure is low outside the hole or cave, air is blown from the hole or cave. High atmospheric pressure outside the hole or cave causes air to move into the cave.

The social science terms used by Indigenous communities concerning how animals who live underground survive and how life in a cave is supported are good areas to engage learners as they interact with communities of practices dealing with atmospheric pressure. Gardner (1991) refers to this as sharing of common terms to benefit members already in a community of practice as well as those who are novices.

The idea of using myths to support the SC approach is not enough. To introduce more tenets of SC, a teacher could also ask a community member to explain what the community believes about the survival of an ant-eater underground. Thereafter, WMS explanations from the teacher to clarify the event are introduced. Learners harmonize conflicts which arise on account of cultural differences between the two world views. Learners undergo what is referred to as collateral learning (Jegede, 1995). Jegede (1995) regards this as the construction of science concepts side by side where no disturbance is seen with their indigenous knowledge. Jegede (1995) cites four variants of collateral learning, namely, parallel, simultaneous, dependent and secured and points out that situated cognition can be achieved using the worldview of learners to teach science. To Jegede, parallel collateral learning occurs when conflicts exist between the contexts in the worldview the teacher uses and the worldview the learner holds. This is where use of SC helps the learner to construct new ideas as they shift from what he or she had considered as valid.

Dependent collateral learning which exists in the continuum between parallel and secured collateral learning comes as a result of merging of worldviews which in this case can be from the WMS and the IK as they are all incorporated to ease engagement of SC approach in rural under-resourced schools. In the last type of collateral learning, the simultaneous collateral learning entails bringing the worldviews at the same time to be learnt. This is where narratives, case studies, practical work can be taken from the two worldviews and used in the classrooms by science teachers.

Secured collateral learning on the other side of the continuum when engaged through use of SC approach helps to consolidate what already exists in the schema of the learner. Jegede, extols its potential for use in science teaching showing for example (when secured collateral learning is engaged) how ashes and palm oil are combined to form soap in Indigenous communities, but laments the fact that such activities are never mentioned when learners from these communities study saponification in chemistry. However, even though Jegede (1995) sees that cultural and social systems can be used to encourage situated cognition, he does not say how IK reflecting the cultural and social systems can be woven into the variants of collateral learning. The collateral learning model is viewed as consistent with border-crossing attributed to Aikenhead and Jegede (1999).

Collateral learning allows learners to actively engage in the activities, but not just as observers. As the teacher explains s/he also needs to introduce more examples of how the community of the learner engages with cultural activities related to the concept being taught. This is in line with what Lave (1988) proposed, as I stated earlier, that learning is thoroughly enmeshed in participation in complex social environments that contain situations and activities. To achieve this, science teachers need to detect more encounters in pressure concepts with IK. Learners can be taken to areas where community members apply the knowledge they have extracted from the environment as either a tool or for environmental preservation or sustenance.

2.4.2 Encounters in pressure concepts with IK supporting SC approach

The Bernoulli theory, Albedo Effect and Marangoni Effect are some of the concepts that Indigenous communities use but that science teachers rarely refer to despite the fact that they support the Science that they teach in the classroom. Activities conducted by Indigenous communities should be analysed to see if it is a possible to use the science knowledge reflected in them in the SC approach. Also, the beliefs held by the Indigenous community might shed light on embedded science concepts. What follows are some of the applications of pressure concepts.

Cultural practices relating to pressure and other science concepts, will allow rural science teachers to use the SC approach in their practices. For example, the principle of the Bernoulli theory is applied as a method to cross the Zambezi River (Mukwambo, et al., 2013). In this study we showed that Indigenous communities in the Zambezi Region of Namibia understand that at points where the Zambezi River is constricted, the velocity is too high to allow for safe crossing into neighbouring Zambia. Instead they select wider points of the river as crossing points where the velocity is lower and their dug-out canoes do not capsize.

A youngster who uses a canoe is inducted at an early age to paddle the dug-out canoe. This means that at school going age, the learners being taught Science in schools are not novices in this cultural activity. They are participants within a community of practices and are well versed in the practical applications of the Theory of Bernoulli (even though they may not know it as such). The implication of including such an encounter might reinforce the ways that the SC approach can be used by a science teacher in a rural school setting or context.

Similarly, Indigenous communities in the Zambezi Region of Namibia apply the elements of the Albedo Effect and Capillary Effect (Marangoni Effect) to preserve and sustain the environment as they engage with pressure concepts. Cain (2015) states, astronomers define the reflectivity of a material using the concepts of Albedo. They understand it as a measure of the amount of electromagnetic radiation emitted as compared to the amount absorbed. However, astronomers and other researchers believe it is more pronounced in the Arctic region (Beaudoin, 2014). Koch and Hansen's (2005) analysis concentrated on America and Asia, and excluded Africa where this study is situated.

Such a belief which forces teachers to focus on the Arctic region when teaching and explaining pressure concepts demonstrated by this effect, might perpetuate the inaccessibility and poor quality of understanding of pressure concepts, as it is uncontextualized. It is possible that sometimes, teachers do not even discuss this issue as they do not see any link between water evaporation and pressure concepts. However, a glance at people in the Zambezi Region fetching water from a well, borehole, river or pond will reveal that no-one uses a soot-contaminated vessel. A container used on the fire for cooking food or boiling water is never brought near the water source. The presence of soot would darken the substrate and foster increased heating and evaporation so some knowledge of the tenets of the Albedo Effect is applied in their cultural practices. Learners are part of this community of practice as they are seen doing this domestic chore with older members of the community. It is possible that narratives which Sandelowski (1991) views as source of knowledge can be used in discussing, for example, the Albedo Effect with learners in the classroom to situate the knowledge of pressure concepts the teacher teaches in a science classroom.

Water evaporates faster once soot is added to water bodies. For water to evaporate, the atmospheric pressure above the water surface will be less than vapour pressure from water on the earth surface such as a well. The two pressure systems will not be in equilibrium as expected. What causes this disturbance is the elevation of the water temperature brought about by dark particles of soot which makes water absorb more electromagnetic radiation (heat energy) from the sun.

The heat energy from the sun lowers the force of attraction (cohesive forces) between the water particles. In doing so, the particles lose the force holding them together and this accelerates them to leave the water surface. Those particles that leave build up at the surface and this are the source of the higher value of vapour pressure which then overcomes atmospheric pressure. This observation and its application have helped Indigenous communities not only to safeguard excess evaporation of water but also to restrict global warming.

A water body containing soot heats faster than a non-soot contaminated water body. Also, such a soot-contaminated body loses its heat energy more slowly at night. The implication is that the heat in soot-contaminated water slowly releases its heat energy into its surroundings. As it does so it keeps warming the earth's surface. This, to a small extent contributes to global warming.

Alternatively, soot-contaminated water in solid form (ice) melts faster compared to the melting rate of pure water. The case of ice melting quickly has denied some farmers a steady water supply for irrigation in certain areas of the world because rain water in their dams becomes quickly depleted.

Under normal situations where global warming due to the Albedo Effect is not a contributing factor, farmers expect their dams to be replenished by melting ice, which oozes from the mountains and fills the dams with water for irrigation or domestic use This observation was made in the United States of America where farmers ran short of water when soot-contaminated ice melted earlier than usual (Streater, 2009).

Although the Albedo Effect explained above is one of the situations where knowledge of pressure concepts is applied by Indigenous communities, it is also used to sustain and preserve the environment. However, the pressure concepts explained in this effect are camouflaged in the phenomenon in electromagnetic radiation and reflectivity.

In the next section, I discuss the principle of the capillary effect, in which pressure concepts are highlighted, to demonstrate that if pressure quantities are not monitored they could cause havoc in the environment. However, if properly monitored, as Indigenous communities do, the environment can be preserved and sustained for use by future generations. Such knowledge applied by Indigenous communities in their cultural practices/activities is suitable to use in SC approach in rural schools, which are far from or lack conventional technological resources as suggested in Section 2.1.

2.4.3 IK in pressure concepts used for environmental preservation and sustainability suitable for use in the SC approach

Capillarity is a phenomenon which causes liquid to move against the force of gravity due to pressure of cohesion and adhesion (Net Industries, 2015). Cohesive forces, forces of attraction between molecules of the same substance, are responsible for the phenomenon of surface tension. Surface tension is the elastic property adopted by liquids as they try to minimize their surface area.

Surface tension and capillarity are phenomena which are used by Indigenous communities in their cultural practices. A cultural activity which engages capillarity is demonstrated by when fetching water from a well, spring or borehole early in the morning before it is too hot. The reason behind this practice is that water volume decreases as it warms.

The observation Indigenous communities have made is that when it is warm the amount of water decreases as the temperature of the surroundings rises. The causative factor contributing to a lower volume of water in the water sources is thermo-capillarity. Thermo-capillarity is the movement of liquid particles from a region with low surface tension to a region with high surface density, caused by a difference in the temperature in that medium, which creates a surface tension gradient. This is also known as the Marangoni effect.

Water particles in the void of the borehole or spring act as the region with low surface tension when warmed by the sun; hence, water particles move downwards into the aquifer through the connecting capillaries. Whereas water particles in the aquifer have a higher surface tension, as a result exerts a force to pull water from an area where a person fetching it for domestic use is reachable. Fedosov (1959) supports this notion, as he discusses “Motion of a drop in viscous medium due to temperature gradient” (p. 4). Net Industries (2015) point out that, “The movement of groundwater through the soil zone is controlled, in part, by capillary action” (p. 2).

Surface tension determines the height to which water rises, and it depends on temperature (Becky, 2010). In support, Kalwar (2013) reveals that water not only moves downwards but it also uses capillary action to overcome the force of gravity as it moves upwards. The surface tension produces vapour pressure which is more than atmospheric pressure. However, when the sun rises, vapour pressure on the surface is less and the result is less water is in the area where water is fetched.

Clay (2009) supports the idea that water movement in the soil is determined by surface tension and capillary action. This is crucial for communities that rely on underground water, and for civil, environmental and water engineers' understanding of the stability of buildings and roads, as well as the environmental impact on human development.

Besides noticing thermo-capillarity, Indigenous communities have also noted solute-capillarity. The movement of a liquid in solute-capillarity is on account of the differences in concentration, which brings about surface tension gradient. A liquid with a high concentration exerts force on a liquid with less concentration thereby agitating movement.

In this regard, Indigenous communities have noted that if soapy water from bathing or laundry mixes with clear water in ponds or streams, the water evaporates faster. The surface tension, a magnitude which depends on pressure outside the bubble and pressure inside, is altered. This causes water to evaporate faster. To curb this excess evaporation, community members discourage one another from bathing or washing directly in the river or pond. In this matter, they preserve water for many biological processes serving the fauna and flora.

The cultural practices concerning embedded pressure concepts explained in the previous paragraphs are a testimony illustrating how Indigenous communities apply science concepts. These are suitable for presenting to learners, or for taking learners to such sites so that they are immersed in a community of practice where they can acquire the science terms that will fuel classroom talk as Lemke (1990) suggests. In doing so, a teacher incorporates the SC approach to environments in a way which addresses equity, quality, access and ~~a~~ democratic practice.

The Albedo effect and capillarity are some of the phenomenon explored in this study. Other factors will be generated when brainstorming with teachers, and as described in Chapter Five, after an orientation of the cultural practices to do with pressure which I have described in this chapter.

Cultural practices that emerge in discussion with the participants can also be used for cultural translation, as Bhabha (1994) suggests. As discussed in the next section, this can be used to facilitate essential epistemological access. According to Nuuyoma (2012) teachers in rural schools face a lack of infrastructure to support the SC approach and this makes epistemological access almost impossible. Thus IK as a tool, if accessed and embraced, would address these disparities between well-resourced and under-resourced schools (Odora-Hoppers, 2001).

2.5 Cultural translation

Stairs (1995) advocates the need for teachers to be 'culture brokers'. As a culture broker, a teacher infuses indigenous culture with WMS culture, moving back and forth to facilitate learners traversing from their everyday culture into the WMS culture. This is known as cultural border crossing (Aikenhead, 1996). This study thus foregrounds IK to create a hybrid curriculum facilitating cultural transmission and assimilation as proposed by (Aikenhead 1997, Aikenhead & Mitchel, 2011).

A hybrid curriculum is a product of cultural translation (Bhabha, 1994). Bhabha argues that knowledge structures in different cultures operate in the same space. Thompson (2013) supports this as he proposes that teachers' practices need to adapt the way in which scientific ideas are communicated to new audiences. As teachers use IK to engage with SC, they facilitate "border crossing" (Ramorogo & Ogunniyi, 2010, p. 26), the process of moving from what learners have experienced in their IK context to reconciling it with WMS, This fuels cultural translation which aligns with socio-cultural theory, which will be discussed in the next chapter. Cultural translation enables teachers to combine different types of curriculum in their practices.

2.6 Engaging types of curricula

Namibian curriculum issues were noted in Chapter One of this thesis. However, no effort was made in the section of learning and methods to use in the curriculum to suggest how SC approach could be engaged in rural under-resourced schools in Namibia. Yet, it might be possible to improve the PCK, TCK, PK and CK of science teachers when one intends to engage SC approach in rural under-resourced schools through embracing the Afrocentric view (Hawkins & Thompson, 2007)). These four intertwined knowledge components mentioned in Shulman's (1987) framework can be viewed using the IK agenda supported in Afrocentric framework to enhance science teachers' practices. I now discuss the types of curriculum with a view to later linking these frameworks and revealing their importance.

In this study, curriculum is interpreted using Connelly and Clandinin's (1988) understanding that curriculum is a course of study made up of a series of textbooks or a specific outline of topics to be covered and objectives to be attained. It represents the paths that schools follow and the paths they intend to follow and as well as the experiences of the individuals following that curriculum. Curriculum is explicitly and implicitly an intentional set of interaction activities designed to facilitate learning and development. Such an understanding of curriculum allows theorists to classify curriculum based on learning theories which may be; social, information processing, personalist, or behavioural.

Longstreet and Shane (1993) have labelled divisions in curricular orientations as: child-centered, society-centered, knowledge-centered, or eclectic. These various ways of classifying a curriculum have resulted in different types of curriculum. Some classifications identify seven to eight types of curriculum. Glatthorn (2000) for example identifies seven types of curriculum which are recommended, written, assessed, taught, learned, supported and hidden. Some of these have a dialectical influence with another in particular with the taught curriculum. Other types of curriculum have a weak influence on the taught curriculum.

Kelly (2004) identifies five different types of curriculum. These are; the hidden curriculum, the planned curriculum, the received curriculum, formal curriculum and the informal curriculum.

The hidden curriculum also called the implicit curriculum refers to content material which students learn, because of the way in which the work of the school is planned and organized but which are not openly included in the planning or even in the consciousness of those responsible for the school arrangement. It focuses on teachings that arise from the culture of the institution, the behaviour, attitudes, and hopes that manifest that culture. It is the unintended curriculum.

For the purposes of this study where cultural practices, cultural artefacts and social terms are used to support contextualization and promoting the use of SC, the hidden curriculum is the embedded activities which sustain the environment and slow global warming. When the approach is implicit, the beneficiaries resort to other means to curb environmental degradation. Kelly (2004) supports this as he points out that all material included in a curriculum shapes the identity of an individual. The planned curriculum can also be referred to as the explicit curriculum. This is concerned with the subject content that will be imparted. The mission statement of the school or NIED plays a part in formulating this type of curriculum. In the case of Namibia, the authority responsible for articulating the mission statement is NIED. The curriculum openly indicates the type of knowledge and skills that the school and government institutions recommend for students/learners. The received curriculum is what the learners/student experience in the process of engaging with the planned curriculum.

The formal curriculum represents those activities which are undertaken during the school time table. The informal curriculum refers to activities done outside the school timetable. This is sometimes referred to as extra curriculum. Even though these activities are done outside the planned activities they play an important role in the development of learners. They allow learners to acquire indigenous pedagogical knowledge (IPCK) which the science teacher can use in his practice, indigenous technical content knowledge (ITCK), applicable in science practical activities and indigenous content knowledge (ICK) valuable as prior knowledge.

In an earlier study by Mukwambo (2013), I pointed out that sanctioning IK in the science classroom allows teachers to draw on learners' IPCK which is part of their background experiences. Also, because learners are in apprenticeship programs in their communities, they can apply skills acquired in learning to handle different cultural artefacts when conducting practical activities thus demonstrating ITCK. On the other hand indigenous content knowledge (ICK) gained during extra-curricular activities while on apprenticeship programs allow learners to understand science concepts which would have been culturally translated. Culturally translating the various curriculum types promotes a multicultural and multilingual approach to science teaching since learners' ICK is engaged during a teacher's practice.

Other benefits of endorsing an SC approach which includes IK reflected in cultural practices, cultural artefacts and social science terms is that teachers will not restrict their teaching to specific pedagogical content knowledge (SPCK) as noted by Rollinick and Mavhunga (2014). In the case of this study, teachers engage their real experiences with the environment. SPCK is knowledge which is in a learner's planned curriculum whereas IPCK, ITCK and ICK are what learners and teachers have gained through their use of indigenous ways of knowing nature (IWKN).

2.7 Epistemic therapeutic nature of IK

The nature of this study was to find a *way* for under-resourced rural schools to realize the educational goals through engaging a situated cognition approach. To achieve this, the following constructs or concepts associated with indigenous knowledge (IK) are discussed. These are *social justice*, *transformative pedagogy*, addressing existing *inequality* in the educational terrain, *contextualizing*, *situating*, *problem solving and multicultural education.* These relate to the rehabilitating and therapeutic nature (Baloyi, 2009) of IK. According to Breidlid (2013), the rehabilitating nature of IK is manifested in axiology (ethics and anaesthetics) since it focuses on the relationship of human beings both to one another and to the entire ecosystem.

According to Semali and Kincheloe (1999), this focus and emphasis is absent in Western Modern Science (WMS). As a result, these constructs are not addressed in education systems where the hegemonic nature of WMS has caused epistemic and economic marginalization (Breidlid, 2013). WMS exercises its hegemonic muscle and ignores coexistence in nature. To offset the deficits associated with the sole use of WMS, I argue that when IK is used in combination with WMS the result is a transformative pedagogy that might address the goals of education. This is because IK explicitly embraces multicultural and social justice perspectives. Additionally, it contextualizes and situates the teaching/learning processes in relevant ways.

To address the rehabilitating nature, however, it is necessary to select an *ontological*, *epistemological* and *axiological* paradigm. These paradigms are briefly explained are as follows: the ontological paradigm is concerned with nature of existence, the epistemological paradigm deals with what counts as acceptable knowledge and the axiological paradigm is concerned about values, their nature, origin, and permanence. An example of a value is the Ubuntu philosophy (Le Grange, 2012; Mukwambo, et al., 2014) that has the potential to restore educational values eroded by WMS's deculturalization effect (Hawkins & Thompson, 2007).

An understanding of the three paradigms, may thus ease addressing of *equity, quality, democracy* and *access* as reflected in the NNCBE (2010) in Namibia where this study was conducted. It could be argued that the structure, the framework of the methodology discussed in Sections 4.1.2 – 4.2.2, the literature reviewed, theoretical frameworks, and data presented and analysed depend on the ontological, epistemological and the axiological positions. Guba (1989) views ontology as concerned with "What is reality?" Ontology is also more concerned with "What is there?" Badewi (2013) understands ontology as a conception of reality, whether there is single reality or multiple perspectives of reality.

On the other hand, Bryman (2001) views ontology as concerned with the nature of social entities, describing two positions, positivism and social constructionism paradigms. From the view of Guba and Lincoln (1989), positivism is a research paradigm that is associated with research in which new surfaced knowledge is aimed at filling a knowledge gap and reality is perceived as objective. On the other hand, Guba and Lincoln (1989) view constructionism as a research paradigm that is associated with research aimed at solving a problem. To them, the ontology is reality that is constructionist or interpretivist.

Both types of ontologies: objectivist and interpretivist act as the basis of an approach to a research paradigm presented in Chapter Four in this thesis. The positivist ontology employs deduction to come up with reality; whereas constructionism employs induction in the analysis of data.

The distinction between ontology and epistemology is that epistemology is about the data that counts as acceptable knowledge and that in this study were the cultural practices or cultural artefacts that can combine with WMS. This view is also supported by Badewi (2013) who holds that epistemology is how people get the knowledge they have. In the positivist research paradigm, the epistemology is empiricist (testing of hypothesis is used to come up with knowledge). By contrast, in the constructionism paradigm, the epistemology is interpretivist and induction is employed in data analysis.

It has emerged in the above paragraph that two reasons exist to conduct a study. The reason might be to fill a knowledge gap or solve a problem observed. Studies aligned to filling a knowledge gap have as an ontological view that there is existence of a single reality. This ontological view explains why only the context depicting WMS employed in situated cognition when teaching and learning science is problematic. For the positivists, who are in this camp, the only cultural context considered suitable for use in situated cognition is the WMS cultural context. Furthermore, the epistemological view in positivist camp is objective. Furthermore, the connotation of the universal is seen in this paradigm.

A research paradigm in which the aim is to solve a problem has the ontological view that multiple realities exist. The connotation of relativism emerges at the other end of the continuum. There are contexts that can also contribute to reality. That is, instead of focussing on the WMS context only, other contexts such as those aligned to IK are as highly relevant. This explains why this research adopted a worldview that multiple realities exist. This epistemological view is constructionist and subjective.

In the discussion above, context invokes multiple realities. This emerged as the epistemological view of this study where the research argues that contexts from different cultural perspectives can come up with reality. The study investigated how the reality that indigenous knowledge accesses assist rural under-resourced schools to engage situated cognition.

Physics uses multiple views of reality. The wave theory of light, for example, was one perspective used to discuss the phenomenon taking place in the presence of light from the sun or any other source. The view explained reflection, refraction, interference, diffraction and the Doppler Effect. When this view failed to explain some phenomenon observed with light, for example, the photoelectric effect produced by light, acknowledgement and embracement of other views emerged. The particle theory of light was embraced in which light is considered as being made up of particles. The particle theory of light was made possible by either conducting research aimed at closing the knowledge gap or conducting a research to solve the problem.

This study adopted the same stance. There was a need to come up with a solution to enable rural under-resourced schools to engage situated cognition. As stated in the other sections of this literature review chapter, the theorists of situated cognition (Lave, 1988, 1996; Lave & Wenger, 1991; Rogoff, 1995; Wenger, 1998; Wertsch, 1991) propose that the situated cognition theory is applicable, useful and suits well-resourced schools, with technological materials supporting WMS culture. As evidenced from the data which emerged in this study, many instances in which cultural practices and cultural artefacts reflecting science exist. In the practices and artefacts engaged, Indigenous communities use traditional knowledge to solve social problems. Yet, the above-mentioned authors do not acknowledge how cultural practices and artefacts from indigenous communities can be used in situated cognition. This study thus sought to close this gap.

In response to this observed disequilibrium, Le Grange (2012) points out that the earth is undergoing an intensive WMS techno-scientific transformation is relevant. This triggered my interest to adopt an interpretivist paradigm informed by Afrocentricity (centre of focus is on African ideas) (Hawkins & Thompson, 2007). This aimed to establish how other ways of knowing can be embraced in multicultural learning environments or contexts. However, like many other studies this study lies somewhere on the continuum between positivist and constructionist. This explains why abduction which Jensen (1995) advocates (Chapter Four and Chapter Seven) was embraced during the data analysis process.

It is recognised, however, that the use of the interpretivist paradigm is however limited as it does not go beyond the descriptive level. Hence, social realism proved useful in addressing this limitation as it allowed explanations to surface. The adoption of an interpretivist research design made it possible for this research study to use phases that the research employed and these are discussed in Chapter Four. In addition, the interpretivist paradigm influenced the research methods selected. Another justification for using the interpretivist paradigm has to do with embracing the use of multiple realities in that it highlights issues related to axiology discussed earlier. Axiology can be taught in schools using the Afrocentric approach (Hawkins & Thompson, 2007; Hogue, 2011). In addition to ontology and epistemology, axiology allows one to use an Afrocentric lens (Hawkins &Thompson, 2007; Hogue, 2011).

Hogue (2011) understands axiology (ethics and aesthetic) as a philosophical study of values. Axiology is a group name for ethics and aesthetics. Ethics explores what is good or bad in an individual's practices, whereas aesthetics investigates the constructs beauty and harmony (ibid).

The ethics and aesthetics affect the way research is done and what we value in the data generated from the participants. The other philosophical branches discussed above; epistemology and ontology do not assume a reflection on ethics and aesthetic. The process of looking at likeness in this research allowed me to contrast the values brought by the WMS worldview alone and values which emerged when WMS is incorporated with the IK worldview.

The WMS worldview used in teaching science in schools has not only fueled epistemic and economic marginalization but also the desire for material advances as suggested by Tomar (2014). This has caused disregard and disrespect for the values that are acquired from the IK worldview such as environmental conservation. This is evident from some of the cultural practices and their products discussed in this chapter (the soot case) (see Section 2.4.2) Teachers' willingness to incorporate IK using situated cognition enables learners benefit from the wisdom and values of their communities. Community members (Boethel, 2003; Klein, 2011) can assist learners in their work while at the same time they can nurture and develop values not taught by teachers who uncritically endorse the view that only one reality exists. Likewise, parents are usually more informed of IK issues as these were orally transmitted from the previous generation. Thus, as learners seek assistance on cultural practices related to science issues the ethics and morals addressed in axiology are considered. In this way, radical social change can be set in motion to counter the use of only one perspective in science teaching.

This is one of the positive outcomes of embracing 'multiple reality ontology'. Social change comes with teachers interacting with other members in a community of practice (Lave & Wenger, 1991; Wenger, 1998) who can ease epistemological transfer. Knowledge sourced is used in science teaching as mediating tools. Working individually cannot bring social change as ideas sourced from the community need brainstorming. This explains the embracing of brainstorming as an instrument to generate data in this study.

Social change is an important tenet in Freire's (1974) approach to scientific literacy and epistemological transfer. This is anchored on the notion of conscientization and dialogue that I have referred to previously. Sanders (1968) views conscientization as a conscious change of mentally involving an accurate realistic awareness of an individual's surroundings. In the case of this study, conscientization refers to being conscious of the need to embrace an ontology which views reality as multiple. Conscientization does not only rest on the premises of quality as highlighted by Freire (1974) but also on *equity*. *Equity* and *quality* are some of the goals of education in Namibia.

When conscientization is facilitated through sourcing knowledge in other worldviews, a more equitable scientific literacy is possible for all schools in the system. This cannot be achieved if the unitary view of reality is used as rural under-resourced schools lack access to WMS technological facilities. Besides IK acting as an epistemological therapeutic tool, engaging an ontology that emphasizes the existence of multiple realities also addresses multicultural issues.

2.8 Multicultural Education

According to Breidlid (2013), the model of epistemological transfer applied in the past was used as a colonizing tool. Consequently, its advocates used derogatory terms to refer to IK in order to undermine and eradicate it. The underlying aim was to weaken the beneficiaries of WMS economically and inculcate a 'look west' policy. These disconnected Indigenous communities from their IK and as they became dependent on a WMS worldview.

In schools, for example, if only one worldview is promoted the implication is that the international world is culturally homogenous. Teachers and learners who resort to using only a WMS worldview to understand nature tend to abandon IK. In terms of a social realist analysis this means that by adopting an exclusively WMS worldview they have closed off other worldviews that could be used in order to facilitate SC engagement. Putnam (1999)-suggests that incorporating other ways of viewing nature are entirely compatible with expected explanations of the laws of nature

Milne (2009) who analysed the New Zealand curriculum advocates the multicultural approach as a way of preventing schools from using monocultural approaches. She argues that the latter approach does not acknowledge that learners are from varied ethnic and cultural backgrounds. In the case of this research, science teachers need to be aware that not all schools have the same facilities, and they need to engage cultural practices, artefacts or science language from the community appropriately to reflect the science concepts they teach. The analogy (Milne, 2009) used is that of a white paper with a picture on it which remains white whenever one looks at it. This helped the New Zealand government to come up with a curriculum, which effectively addressed cultural aspects. This has helped to prevent the epistemological domination and marginalisation in New Zealand that perpetuated the status quo. Similarly, the New Zealand approach can be employed in Namibia since the Namibian curriculum encourages the use of IK but does not state how SC can be engaged in rural under-resourced schools to embrace a multicultural approach. In a similar vein, Hodson (2009) argues for a need to acknowledge and celebrate each culture of learners in a classroom situation.

From a sociological lens, the culture of which IK is a component encompasses societal structures as well as activities and ways of thinking. When diverse cultures are used to construct knowledge, every individual may be epistemologically empowered. This is unlikely when only one worldview is used, it marginalizes the intended beneficiaries and deprives learners of opportunities to develop robust cultural identities that are representative of their communities. The potential of IK to transform one from being marginalized to being epistemologically empowered is where the epistemological therapy nature of IK is manifested.

Further support for the use of many cultural settings in a science classroom to facilitate SC is advanced by Kearney (1984) who maintains that the separation between culture, worldview and epistemology is actually very thin. Thus, those responsible for epistemology construction should use culture to contextualize and situate learning by embracing other relevant cultural practices with diverse worldviews. This will facilitate the engagement of the SC approach in rural under-resourced schools.

2.8.1 Contextualizing and situating learning through IK use

Contextualizing science teaching entails sensitively weaving in learners' prior knowledge and everyday experiences as a catalyst for understanding science concepts. Rivert and Krajcik (2008) understand it as involving only those challenging science concepts. In my view, all science concepts constitute a challenge if appropriate pedagogical styles such as the SC approach or learner-centeredness are not employed. It is acknowledged, however, that weaving IK experiences with WMS requires that the teacher is knowledgeable of the relationship existing between them. Breidlid (2013) understands IK as encompassing worldviews, cultural values, and cultural practices derived from worldviews related to ecology, scientific fields and environment which science studies can infuse. This might be suitable to use in SC approach. The situatedness nature of IK makes this knowledge type different from WMS. As it is also localized it finds its way to apprentice those learners who struggle to understand the science concepts the teacher will be handling.

On account of IK based on a particular cultural context and also situated in a particular community, when used in any of the pedagogical styles it rehabilitates the marginalized learners in areas where the WMS worldview has not been used for understanding nature. As this is done the epistemic therapy character of IK is still also revealed. Contextualizing using IK allows to teach science while ensuring that social justice education is addressed.

2.8.2 Social justice Education through IK lens

Social justice education theories are aligned to social transmission theory which according to Demarrias and LeCompte (1995) posit that society's survival is through maintaining and replicating the existing socio-economic and political structure. From the view of Mthethwa-Sommers (2014), the two main forms of social transmission theory are functionalism and structural functionalism. DeMarris and LeCompte (1995) and Mthethwa-Sommers (2014) see functionalism as aligned to the belief that schools should serve to strengthen the prevailing social and political order and encourages assimilation of students/learners into a homogenous culture. Currently, this is what is happening as transformative pedagogical styles are not in place as evidenced by failure to transform practices using IK. Structural functionalism accepts that the role of schools is:

- to uphold the status quo by sorting students into future workplace positions;
- teach students obedience of authority and powerful figures; and
- assimilate students into the dominant culture (p. 9).

In contrast, from the view of Adams, Bell and Griffin (2007) social justice education theories oppose the idea of schools serving as transmission tools of the dominant culture. In the absence of other knowledge systems embraced such as IK, schools serve to preserve inequities, inaccessibility, poor quality, undemocratic policies and social injustices that exist in society the government aims to eradicate. Instead of serving as transmission tools for the dominant group or class in power, social justice education theorists contend that schools should serve as sites for social betterment in which social justice, an ideal of democracy, is practiced and cultivated (Adams, Bell & Griffin, 2007). Social justice education theories maintain that schools should serve as sites of democracy with all its inherent ideological, cultural, religious, and social diversity, and should serve to work toward social justice, a barometer of democracy.

In view of bringing social transformation where the practices of science teachers are realigned to observe the tenets of social justice, IK cultural practices reflecting science can be weaved with WMS. In doing so, schools might not keep on perpetuating what has been happening which is not in line with the approaches which the curriculum advocates. For example, adherence to the use of WMS without it weaved with IK enables the teachers not to embrace the socio-cultural theory of teaching and learning science encouraged in the NNCBE (2010). This has been revealed through the views of Mthethwa-Sommers (2014) as he pointed out the characteristics of functionalism and structuralism transmission theories above. The role which IK plays in allowing the removal of monocultural view of science teaching and embrace a multicultural view also make IK act as an epistemic therapy tool.

2.9 Concluding remarks

In this chapter I discussed the need to ensure that the knowledge that learners construct at school should not be inert. That implies that teachers need to include the context where the information is derived from and how to apply it in the community of the learner through the SC approach.

I have indicated that in some instances using the SC approach is an impossible task for rural school teachers. They are faced with the challenge of a lack of places to apprentice learners as there may be no places that employ technological knowledge available in their vicinity. As a result, the goals of education, namely *equity, quality, access and democracy*, will not be met.

As a solution, I discussed how IK, using some cultural practices of science concepts, can act as appropriate environments that teachers can refer to when contextualizing and situating learning. In discussing IK, another aim was to reveal the properties of IK so that factors enabling or constraining rural school grade 11 Physical Science teachers' practice to engage with SC when teaching pressure or other science concepts is revealed and then excluded through cultural translation. Cultural practices/activities are supported by social realism and socio-cultural theory. Since social realism, discussed in Chapter Three, supports the existence of more than one world view, practical activities, case studies, models and focusing on cultural practices might be another good example of how to weave IK into WMS when used as mediating artefacts.

CHAPTER 3: THEORETICAL FRAMEWORKS AND ANALYTICAL TOOL

A theoretical framework guides what the person 'notices' during the course of data collection or as an event takes place; it is also responsible for what the person 'does not notice' – suggesting that people may not notice or observe things which fall outside their conceptual / theoretical frameworks (Imenda, 2014, p. 193*).*

3.1 Introduction

In this chapter I discuss the theoretical frameworks which guided this research process of data generation, its interpretation and explanation as proposed by Imenda (2014) in the epigraph. To accomplish this aim, I used socio-cultural theory and social realism as the theoretical frameworks. CHAT is also discussed as it is used as an analytical tool in this study.

3.2 Theoretical framework

The theoretical framework is the foundation used to construct knowledge in a research study (Grant & Osanloo, 2014). Imenda (2014) explains that a theoretical framework reveals the application of a theory, or a set of concepts, to shed light on a research problem. A theoretical framework, as a visual or written product is important in designing a study (Miles & Huberman, 1994). Mertens (1998) adds that a theoretical framework has implication for study decisions. The theoretical frameworks employed in this study are socio-cultural theory and social realism.

3.2.1 Socio-cultural theory

Socio-cultural theory, like situated cognition (see Section 2.2.1) also views learning activities as situated (Jarret, 2008). Socio-cultural theory is based on the premise that learning is a product of social interactions, involving adults, peers and teachers (Vygotsky, 1978).Vygotsky observed further that everything is learned on two levels, namely, interpsychological and intrapsychological (ibid.). The second aspect of Vygotsky's theory of learning is the zone of proximal development (ZPD). The ZPD concept has been explained partially in Section 2.3 and is further explained in detail in Section 3.2.1.2.

3.2.1.1 Intrapsychological and interpsychological levels of development

In the intrapsychological level also known as the higher mental function, a learner assimilates or accommodates and internalizes knowledge initially externalized while adding personal value to that knowledge (Vygotsky, 1978). The process of changing or adapting knowledge gained in the intrapsychological stage is not copying but involves transformation of that knowledge.

The interpsychological also known as the lower mental function, is characterized by interacting socially with knowledgeable individuals (Berge, 1999). Communication is important in the interpsychological plane. Language together with the help of knowledgeable adults and peers plays a role in the development of an individual's understanding of his environment. Language is used to direct or command and in the process an individual is regulated. Vygotsky distinguished between two types of language/speech which develop during the interpsychological plane, namely, the emotional release and the social contact (Vygotsky, 1978). It is the social contact which allows a developing individual to know his surroundings. The social contact has elements of science terminology which allows such an individual to know his or her immediate environment. Wolf (2008) in support of social and environmental contact suggests that emotional contact is required in order to express desire of some need. Also, it plays a role in indicating the nature of his or her environment. In the presence of adverse environmental changes emotional contact is used.

Language as an element of culture forms a cultural system when it interacts with other elements of culture such as cultural practices, norms and beliefs conveyed through language in any given community (Vygotsky, 1978). However, a distinction exists between a cultural system and a social system but when the two exist together, they are referred to as a socio-cultural system. Parson (1991) understands a social system as an interrelationship of parts where each part is orderly arranged and has a fixed place and a specific role to play. Interaction between a knowledgeable individual and the one being supported is a good example of a social system. According to Scott (2013), socio-cultural theory is made up of a social system with cultural elements as its components. Learning is considered as collective and constructed through historical, social and cultural contexts (Jonassen, 2004). This explains why in this study cultural practices were analysed to assess their suitability to be used in the SC approach.

Those who support a child in his/her field of learning do so in order to scaffold the child to perform some culturally specific actions. The use of culturally specific activities to mould a child's thinking differs between cultures because different cultures stress different values (Blunden, 2010). Faitar (2009) supports this as he suggests that different cultures are bound to do things differently depending on their traditions and history.

For example, in the context of this study, communities with abundant water supplies do not emphasize cultural practices aimed at water conservation unlike those in the Zambezi Region where water is scarce. To conserve water, a child is inducted into cultural practices to prevent water evaporation (see Section 2.4.3). However, in communities where water is readily available and constantly replenished by rain, they do not have rules to conserve water. Thus, the IK of communities varies from community to community as it depends on what each community cherishes. In this regard Fabiyi and Oloukoi (2013) note that "different views and concepts of IK especially on how it relates to sustainable strategies to appropriately respond to climate variability exist" (p. 2). The cultural practices act as mediatory tools to facilitate the learning process of a child. Using that as a base, cognitive development may occur in the intrapsychological level highlighted earlier.

According to Ellis (2000), learning is successful if the activities to be learnt are scaffolded starting from the actual and potential levels of development or what is called the Zone of Proximal Development (ZPD). The ZPD is the second aspect of Vygotsky's theory of cognitive development.

3.2.1.2 The zone of proximal development

Vygotsky posited that cognitive development depends upon full development of the ZPD which can be achieved during social interaction (see Section 2.3). Vygotsky also considers cognitive development to be dependent on mediating tools used in the epistemological transfer since he viewed learning and teaching using a cultural lens. However, like other theorists who advocated and advanced SC approach they never focused on culture with a focus in IK in particular. ZPD is understood as the difference between what a learner can achieve without assistance and what she/he can do with assistance. The other two zones related to the ZPD resonate with the epistemological view of this study as Stott (2016) suggests that the two additional zones provide context and create a picture of the physical and cultural space important in a learners' immediate environment.

Socio-cultural theory emphasizes the situated nature of knowledge and reveals the interdependence of learning and activity found in certain communities of practice (Wertsch, 1981; Lave & Wenger, 1991). According to socio-cultural theory, which this study uses as a theoretical lens, learning entails participating while using mediating artefacts to internalize and externalize socially organized practices in a community of practice comprising novices and experts (Lave & Wenger, 1991). So in this study socio-cultural theory helped me to understand how science teachers in rural schools could use the SC approach in teaching pressure and other science concepts.

Wertsch (1991) clarifies the ZPD as "the distance between a child's actual developmental level as determined by independent problem solving, and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 60). Wertsch regards the ZPD as a solution to explain a learner's cognitive process.

To activate the ZPD, in the Zambezi Region, science teachers organize trips for learners to various regions in Namibia so that they can see science concepts being applied. In doing so, they aim to tap into what a learner already knows and thus align their practices with the SC approach.

The need to activate what a learner already knows is partially achieved as an explanation of concepts is done during the visits. However, the places they visit are not a familiar context for the learner. In some instances learners do not know in advance what will happen or the reason for the activity. Secondly, learners are taken to these sites after the concepts have been taught or before they are taught. However, in their communities, theories of science are applied by community members in cultural practices, such as the making of cultural artefacts and related activities. These can be used to progress a learner's actual development level to the expected potential zone of development. This would then facilitate the teaching of science concept using the SC approach in under-resourced schools.

In science teaching and learning, theories inform the science teachers' practices in formal settings. Improving practice might suggest culturally translating specific pedagogical styles through, for example, the use of IK practices in under-resourced schools where SC cannot be engaged. I this regard, Engeström, (1987) conceptualizes ZPD as the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the contradictions, potentially embedded in everyday actions. Such thinking motivated me in expansive learning to support the use of SC in the teaching of science concepts through the use of IK.

Socio-cultural theory is a branch of constructivist theory originating from Piaget's views on the cognitive processes involved in meaning-making and learning. The socio-cultural strand of constructivism which underpins this study originates from Vygotskian psychology and views meaning-making as originating from individuals socially interacting with cultural products. In the context of this study, the cultural practices of IK as related to the concept of pressure and other science concepts are the focus of enquiry. The study helps to develop meaning-making skills using mediating tools in science and SC in under-resourced schools through incorporating appropriate examples of IK.

3.2.1.3 Mediated action and internalization

Mediated action is part of cultural historical activity theory (CHAT) and involves a higher mental function with its origin in social and cultural activities (Postholm, 2008; Veresov, 2010). Mediation action entails an interaction between the individual and mediating artefacts/tools and signs. Artefacts in the case of this study are the cultural practices/tools relating to pressure or other science concepts, used by a community to regulate and sustain the environment. Cultural practices that mediate activities in teaching and learning have characteristics which have an impact on teachers' practices. For example, like any other mediating artefact, cultural practices as mediating artefacts carry with them a contextual characteristic which this study aims to engage. Cole and Engeström (1993) claim that when developing curricula course designers encourage the use of a range of mediating artefacts to support and guide decision-making. These include rich contextually located examples of good practice such as case studies, symbols and guidelines. Mediating artefacts do have short comings, however, as they are so contextually and culturally specific that they may be difficult to adapt.

The highly specific and context-bound nature of cultural practices means that they are best understood by the community who use them as tools for mediating. This is why I advocate for the cultural translation of examples of cultural practices into the Namibian science curriculum using Indigenous community members as active contributors to the teaching and learning process. The cultural practices relating to pressure practiced in communities are artefacts. The use of such artefacts to sustain the environment influences community members' activities. They in turn develop or create new artefacts which consequently affect their actions

(Leontèv, 1981; Miettinen, 2006). Cultural practices as experiences do not develop in a vacuum, instead they are influenced by social and cultural factors so are culturally specific in a way that examples given in textbooks are not. Therefore, environments that support SC need to be located in the learners' own environments. If not, it makes it almost impossible for internalization to take place as teachers see indigenous cultural practices as irrelevant in supporting the SC approach.

3.2.1.4 Internalization and externalization

Wertsch (1991) and Säljö (1999) suggest that teaching and learning is about how a community or society uses tools or artefacts that exist in a given culture or society for thinking and acting. The community, the rules which the community devises, the tools which are the outcome of human activity and the division of labour mediate the activity of human beings. Dialectic mechanisms like internalization and externalization are human activities which are also mediated by tools, the community, rules and the division of labour. If in science teaching and learning, tools or artefacts of a community or society are used then we reproduce culture and that leads to internalization. On the other hand, externalization is a process in which we create new artefacts, tools or new ways of using them (Engeström, 1999). The use of cultural practices to foster internalization and externalization does not take place currently in under-resourced schools in the Zambezi Region since they lack environments supportive of SC engagement.

Internalization as a process entailing the analysis of external signs and eventual synthesis into the intra-psychological domain, remains a constructive activity perfected in cultural practices used by indigenous people. The complementary process of externalization is also constructive and entails the analysis of internally existing intra-psychological cultural practices like those of pressure used by some communities and in the process they are further modified. Mediation, externalization and internalization yield development in humans. In short, internalization refers to transforming the external interaction into a new form of internal interaction and not simply duplicating it (take note that externalization is not a mirror image of internalization) (Hedegaard, 2004). In support of these ideas, Valsiner (2006) claims that "all human meaning constructions take place within the internalization/externalization process that has a structure of layers" (p. 14). To understand internalization and externalization as processes operating continuously at every level of human activity, cultural historical activity theory is applied as an analytical tool in this study (Vygotsky, 1978).

Meaning making as stated above is not divorced from cultural products. These cultural products need to be observed from the world of the actual, empirical and real. This is best explored through the lens of social realism as it analyses cultural, structural and individual systems (Case, 2013).

3.2.2 Social realism

Social realism has some fundamental concepts supporting what science teachers' practices must reflect (Elder-Vass, 2008). To understand this I define social realism and some of its tenets. Schwandt (1997) explains that "social realism is the view that theories refer to real features of the world. 'Reality' here refers to whatever it is in the universe (i.e., forces, structures, and so on) that causes the phenomena we perceive with our senses" (Schwandt, 1997, p. 133).

Unlike socio-cultural theory which has a social system and a cultural system as components, social realism theory deals more with social systems. Social realism is based on the understanding that real social structures and systems exist (Bhaskar, 1978). The same social structures and systems are emergent entities which operate independently of human ideas (Archer, 1995; Willmott, 1997; Phillips, 1987). Social structures, customs, traditions norms and cultural practices/activities are real. If they were not real, the chances of existing in space and time will not be there. These have existed before and after the knower and they have a causative influence on social events (Archer, 1995).

Social realism proposes the stratification of reality and this makes events visible but the mechanisms behind them not as readily observable (Bhaskar, 1998). Social realism uncovers underlying invisible mechanisms in social phenomena which science teachers in the context of this study, could engage for SC. These could be cultural practices which, as components of IK, reflect how science knowledge is applied as tools in Indigenous communities. However, CHAT explained in Section 3.2.3 emphasizes the use of tools as mediating artefacts in teaching. Social theory in this study allowed me to explain why some science teachers cannot use cultural practices and cultural artefacts while others who have the appropriate facilities in their environments can engage the SC approach.

Social realism has a dialectical foundation that encourages contradictions emphasized in CHAT. Contradictions arise when inconsistency in knowledge is observed in activity systems with common aims. Archer (1988) supports the presence of contradiction in social realism. She proposes the existence of two types of relations within the cultural system. The first is composed of contradictions and complementarities. The contradictions and complementarities are logical or epistemic relations, found internally in particular cultural forms. The second type of relation is composed of social or political contradictions and complementarities. These arise between competing ideational systems or cultural forms. Contradictions are points of cultural tension since they are induced by the layered system as understood from the premises of realism.

The fundamental idea in critical realism is the natural taken as (physical and biological) and social (sociological) reality should be understood as a systematically arranged system of materials with causative influences inducing events to occur (Morton, 2006). The three layers proposed in this theory are: the real, actual and empirical. The terrain of the real includes the mechanisms (or structures) that contribute to generate the actual event. The real layer forms part of the unobservable which must be understood in order to explain that which is observed. The terrain of the actual includes events which have been triggered by the mechanisms. Finally, the empirical includes the observable experiences. Elder-Vass (2006) proposes this as he suggests that 'actual' events and entities are inherently multileveled and downwardly inclusive.

Bhaskar (1993) views empirical reality as that which can be observed whereas actual reality is the second layer of reality camouflaged by the empirical layer. The actual layer is manifested when events are activated. Alternatively the actual layer can be described as that which occurs. Sustaining the environment requires that community members understand the components of the real layer which emerges in the other layers.

The real layer is whatever exists, whether people are aware of it or not, and it can be social or natural. It is related to causal powers which are not isolated from the nature of the entity. For example according to Archer (1995) a property of an object causes it to behave in the way it manifests itself and will always have an effect on other systems connected to it. In the area of world views, the hegemonic nature of WMS which Breidlid (2013) suggests makes science teachers embrace only one world view when teaching science concepts. Jegede (1995) whose collateral theory is discussed in Section 2.4.1 sees the effect as inaccessibility to science concepts by science learners.

Elder-Vass (2008) suggests that the three domains of reality discussed above have a certain ontological depth. Combining the causal mechanisms from a number of different levels equips community members with experiences which are not only going to end as sense data (Elder-Vass, 2008). These experiences as part of reality are applied in the community to sustain the environment and the experiences are part of structural systems which can be employed in SC. The relationship between the three levels of reality has been explained by Bhaskar (1993). These levels are subsets of the other. The empirical is a subset of the actual. The actual in turn acts as a subset of the real. Figure 4 illustrates the relationship between the three levels.

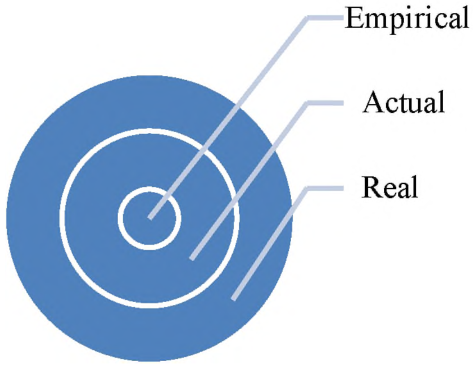


Figure 4: Three levels of reality (Adapted from Bhaskar, 1978, p. 1))

In the above diagram elements which are in the empirical set are common in the other sets. Some of the elements in a deeper layer emerge into the other layers. This introduces the concept of the stratification of reality (Collier, 1994) found in society in which a school is a component.

As stated above elements in a layer below can emerge into layers above it. This occurrence is not only peculiar to structural systems dealing with reality but is common in all structural systems in the society (Bhaskar, 1994).

Society is viewed as made up of layers in which each layer emerges from the one below it. For example, an Indigenous community is stratified in that it comprises individual community members. These individuals form social groupings from which certain practices arise which are then communicated to the entire community if they are seen to benefit the Indigenous community. A number of social groupings are a sub-stratum which forms the Indigenous community (Elder-Vass, 2007). The same scenario is observed at a school.

For example, a science department at a school is stratified and this stratification determines what emerges (Davis & Moore, 1945; Elder-Vass, 2007). A science department is composed of a head of department, the teachers, laboratory assistants and learners. Certain characteristics in learners, teachers and others are not seen but what emerge are the norms the department is expected to teach. Learners, despite having IK which they have used to understand the environment, might find that their world views do not emerge in science teaching practices if their prior knowledge is not used as a contextualizing tool. The prior knowledge embedded with IK can be applied in the SC approach through the use of artefacts as materials which can be used in all types of practical work (Erinosho, 2013). However, what emerge are the cultural practices of science based in the context of a different culture. The cultural practices used for teaching Science are in some of the layers of the whole stratified layers.

Each layer has certain peculiarities which makes it distinct from the layers above or below. Depending on the strength of the peculiarities, a layer can influence the other layers and this can result in it emerging. This led me to argue that the perspective which science teachers bring to their practice can reflect Science as viewed in a culture which is alien to the learners. This emerges at the expense of the views of how the learners perceive the same concepts based on how they understand nature (Martin, 2003).

It is possible that when teachers marginalise learner's ways of understanding nature and privilege ways of understanding the world from other cultures they conceive those learners' social structures, customs and traditions are not real. In the example cited earlier of Indigenous communities that discourage its members from doing laundry in a river or fetching water using a soot-contaminated container, these practices have both use-value and exchange-value since they reflect knowledge which the community uses to sustain the environment. These practices function as tools to perfect their environment and they are consistently used by each successive generation. The fact that they are tools indicates that they have use-value and the fact that they are exchanged from generation to generation indicates that they have exchange-value (Marx, 1867; Padgett, 2007).

Archer (1995) maintains that social structures, customs and traditions which are all seen in Indigenous communities exert a causative influence on social events and individuals' actions. According to this view Archer (1988, 1995) suggests that a social system is comprised of a cultural system, a structural system and individuals. The three relate to each other through social interaction and she further adds that these three components make up social reality. It is the social interaction which brings about either social change or continuity. According to Archer, a social change or continuity is referred as morphogenesis/morphostasis (M/M).

Morphogenesis occurs when new ideas displace the old ones. The SC theory supports this since understanding of a concept is always constantly under construction as Brown et al. (1989) emphasize. In the case of this study, I do not see IK views replacing WMS views but rather that these two views coexist to complement each other (Schmidt & Stricker, 2010). The WMS view of teaching and learning Science is maintained and IK view of teaching and learning Science cannot be rejected. Mukwambo, et al. (2014) view this approach as entirely possible since Africanisation with strong roots in encouraging IK is accommodated. In accommodating Africanisation, the Afrocentricity philosophical model is embraced (Hawkins & Thompson, 2007).

The Afrocentricity philosophical model is different from the Eurocentricity philosophical model in the way *cosmology*, *ontology* and *epistemology* mentioned in Section 2.7 are viewed (Hawkins & Thompson, 2007). From the cosmological focus, the Afrocentric view of structure of reality is animate and inanimate matter are interconnected and the same reality is spiritual and material (Asante, 1991). This allows the Ubuntu philosophy to flourish in which animate and inanimate are given the same respect and treatment. This explains why Indigenous communities see regularities which are in the Albedo effect in order for them to support the values of Ubuntu in which any matter is important and must be sustained to ensure that humans keep on getting what they want from the environment. This view of Ubuntu allows those who use the IK perspective to consider that trees and animals are all living organism and is a view which is in WMS.

The Afrocentric view on ontology posits that elements of the universe are spiritual (invisible) and are connected. The focus that animals and plants are spiritual also allows Indigenous communities to view animals and plants as having life. The Afrocentric knowledge is brought about by considering the affective part (Hawkins & Thompson, 2007). The causal part is not all that important for Indigenous communities. This view is attested from a narrative which follows which might also be used as a mediating tool when teaching.

An old man/woman is found warming himself with wood fire in winter. The heat energy generated comes from wood. He is found separating the pieces of wood when he sees too much smoke coming out from the burning fire. He ensures that the pieces of wood are not touching each other. He separates them. From there the fire burns with a mixture of blue and a little yellow flame. He is aware of what affect the smoke to come out and what makes his fire not warm but in the dark when asked what causes the fire to produce too much smoke and why it is not warm. Such a narrative which is culturally contextualized allows teachers to use it as a case study or a cultural science situation to use to do practical work which is aligned to the culture of a learner as he situate the science concepts in which oxygen is studied as a gas which support combustion. Use of such practices might prevent science practices to be morphostasis (Archer, 1995).

Failure to use culturally related situations in narratives or practical work makes morphostasis prevail, then a multicultural approach of teaching and learning Science discussed in Section 2.8 will not flourish. There will be a failure to promote Afrocentric philosophy which encourages the use of the learners' ways of understanding nature.

In addition, a third option emerging from M/M is that of common elements of the new view (IK view) merge with elements of old view (MS view). This can lead to a form of morphogenesis which is particularly noticeable when there are areas of consensus as well as tensions between the old and the new activity. The tensions serve to fuel perfection of the activity.

Msila (2007) an IK theorist, suggests three alternative methods similar to those of Archer's (1995) theory of M/M which can be used to tap IK. These are namely:

a) IK must be developed as a separate strand besides the conventional science education system, b) to revamp the entire current education system and c) to use the current education system and harness it with an African context.

These three alternative methods of bringing about social change are all types of morphogenesis. However, the first and second are not viable for this study so the third alternative was used to incorporate IK structures which are cultural structures to support the SC approach when teaching WMS. The suitability of the third method lies in the fact that an Africanisation lens can be used and when two systems interact (WMS and IK systems), contradictions emerge. The idea of contradiction echoes with what the CHAT discussed in Sections 3.2.3, 3.2.3.1 and 3.2.3 reveals. There are contradictions revealed in informal teaching which inducts learners to understand nature through the use of the IK viewpoint. This addresses the concept of sustaining the environment using cultural practices or structures. However, formal teaching is silent on this since the concept of pressure or other science concepts are not contextualized through referencing knowledge in the learners' environment.

Cultural practices as part of the cultural systems, also structural systems and individuals as aspects of social reality can be understood if one uses Archer's dualism perspective. Separating the three components of reality allows one to see or make judgement on how each causes a dialectical causative effect on each other. The interplay between the three occurs at what Archer refers to as the socio-cultural level discussed in the previous section. Below is further elaboration on social reality.

Archer (1988) understands cultural systems as composed of cultural forms. She understands culture as beliefs, values, norms and ideas. In my perspective I include cultural practices, cultural artefacts and cultural terms as part of culture. Within cultural systems, relationships exist which can be either contradictory or complementary and they are also logical and epistemic. The second relationship is that of social or political contradictions.

The other aspect of social reality is that the structural system can be understood using views of other theorists. Gidden's (1984) structuration theory views structural systems as rules or resources which determine human agency or behaviour. In my study I agree with Porpora (1998) who considers structural systems as the emergent properties of human relationships among social positions. Porpora (1998) posits that despite some differences which might emerge on the view of social structures, causal effects on individual members of society are shown in certain layered interests, resources, powers, constraints and obstacles that are embedded into each position by the relationship.

Cultural structures emerge fuelled by cultural systems. Cultural structures are modified to suit the prevailing condition in order to counteract the adverse effects. That is IK as a cultural structure is not static but dynamic (Mwaura, 2008). IK changes as the users take an argentic position, and adapt it to the prevailing environment.

Human agency will come in as an effect of the interplay of the two other components of social reality, namely cultural systems and cultural structures. The structural systems which might be aligned to a particular ideology might in some instances enable or constrain teacher agency. Also, the ideology might influence how science teachers might bring experiences related to IK into their science practices.

I will use social realism in its broad sense as this allows me to take into account all the versions of realism. Realism as a philosophy in social theory has one feature in common (Wikgren 2004). They all refute the idea that humans can have any objective or certain knowledge of the world, but accept the possibility of alternative valid accounts of any phenomena (Phillips, 1987). In the case of IK, it serves as an alternative view of how indigenous people adapt themselves to the environment around them. Putnam (1999) supports this by saying there is no "God's eye view" on phenomena of the environment (p. 9). The tenets discussed allow me to apply a realist social theory that is pertinent to changing the practices of science teachers (Priestley, 2011).

I have indicated that social realism deals with cultural systems and social theory deals with both cultural systems and social systems but the historical aspects are not explicit. Elder-Vass (2006) suggests that experiences from which cultural practices emerge can be understood better if they are described or explained using historical and social history. This will allow me to discuss CHAT to close the gap which might arise when I interpret or analyse data using historical issues. Including CHAT as an analytical tool with socio-cultural and social realism allows me to employ an explanatory critique and uncover how science teachers can engage SC.

3.2.3 What is CHAT?

The Cultural Historical Activity Theory (CHAT) in this study focuses on a broad approach to analysing teaching and learning and the contexts under which these two activities occur. Foundational to activity theory is Marx's view. This view does not harbour the materialist doctrine that people are products of environment but instead the theorist takes as his starting point that people are products of their cultural environment and the same people are active agents in bringing about a change in their cultural environment (Bhaskar, 1989).

Besides using culture as a factor to analyse teaching and learning activities, historical and the social aspects are included when dealing with CHAT (Leont'ev, 1981; Wertsch, 1981; Engeström, 1999). Also, by employing CHAT, interviews used in the methodology chapter enable the researcher to discern if the teaching and learning activities of the teacher yields the desired SC approach for under-resourced schools. An analysis of the language the teacher uses during interviews can reveal whether teaching and learning activities engage the SC approach (Koschmann, 1994).

Also CHAT, which examines human activities such as cultural practices, can uncover tensions caused by systemic contradictions (Cole & Engeström, 1993; Engeström, 1987). In human activities contradictions emerge. This happens when the conditions of an activity place the subject in contradictory positions that can impede achieving the object or the nature of the subject's participation in the activity while trying to achieve the object.

In relation to this study, the contradictions are the teachers failing to address *quality, equity, democracy and access* which the curriculum advocates (UNICEF, 2011). The 2011 UNICEF study in Namibian schools only looked into elementary structures like provision of classrooms, toilets and their implication for the welfare of the teachers and learners. It did not address whether teachers fail to address the Namibian goals of education mentioned previously. Infrastructure supporting the SC approach and CTL, for example was left out in that discussion yet it plays a key role in teaching and learning activities. Rena (2007) supports the idea of infrastructure playing a pivotal role in quality delivery, by pointing that "inappropriate infrastructure in all educational institutions hampers educational quality (p. 3). Also, the UNICEF (2011) study did not compare informal schooling.

In comparison to informal schooling which develops one using social and cultural capital, formal schooling does not equip learners with knowledge to sustain the environment. Dip (1988) comments that in formal education, teachers pretend to do well during teaching practice, students pretend to be immersed in the process of learning and, institutions pretend to be catering to the interests of students and perpetuating the needs of the society. The dominancy of WMS epistemology as Breidlid (2013) cautions, silences IK epistemology and deprives the learner of his/her social and cultural capital which could have been used either as narratives, case study or practical work to see what is happening when his IK worldview is incorporated.

In my view the SC approach does not take place as learners show gaps in their science symbols after going through the curriculum material. This is illustrated in Table 1 in Chapter One (see Section 1.5) which shows the symbols after sitting the national examinations. Contradictions of this nature can be analysed using CHAT. These contradictions emanating from the absence of resources which support the SC approach fostering CTL in under-resourced schools in rural communities are the focus of this study as they will assist in answering the sub-questions. Marxism is the underlying social theory which informs CHAT's focus on contradiction and how it brings about development.

3.2.3.1 Origin of CHAT

It is not only the Marxist conceptions on which CHAT is anchored. Marxist social theory has its origins in the period of the Enlightenment. Enlightenment generally emphasizes the power of reason and the use of logic and criticism to discover the natural laws governing human society. Kant (1788) defines enlightenment as the process of thinking for oneself, and employing and relying on one's own intellectual capacities in order to determine what to believe and how to act. Kant's understanding of how one construct knowledge and other conceptions from materialist philosophers like Feuerbach to Marx and Plekhanov paved the way for CHAT. Later strands of constructivism, namely cognitive and social theory also played a role in CHAT.

Theories dealing with culture and social factors in particular have influence on teaching and learning activities. Dewey's (1916) idea-based social constructivism which states that people's ideas or thoughts affect the physical environment, and the affected environment in turn influences their thoughts are sources of CHAT. This resonates with the dialectic tenet from Marxist social theory where two or more interacting systems or objects influence each other. In support of this Scribner (1997) states that individuals make meaning of the world while they modify and create activities that trigger transformations of artefacts, tools, and people in their environment.

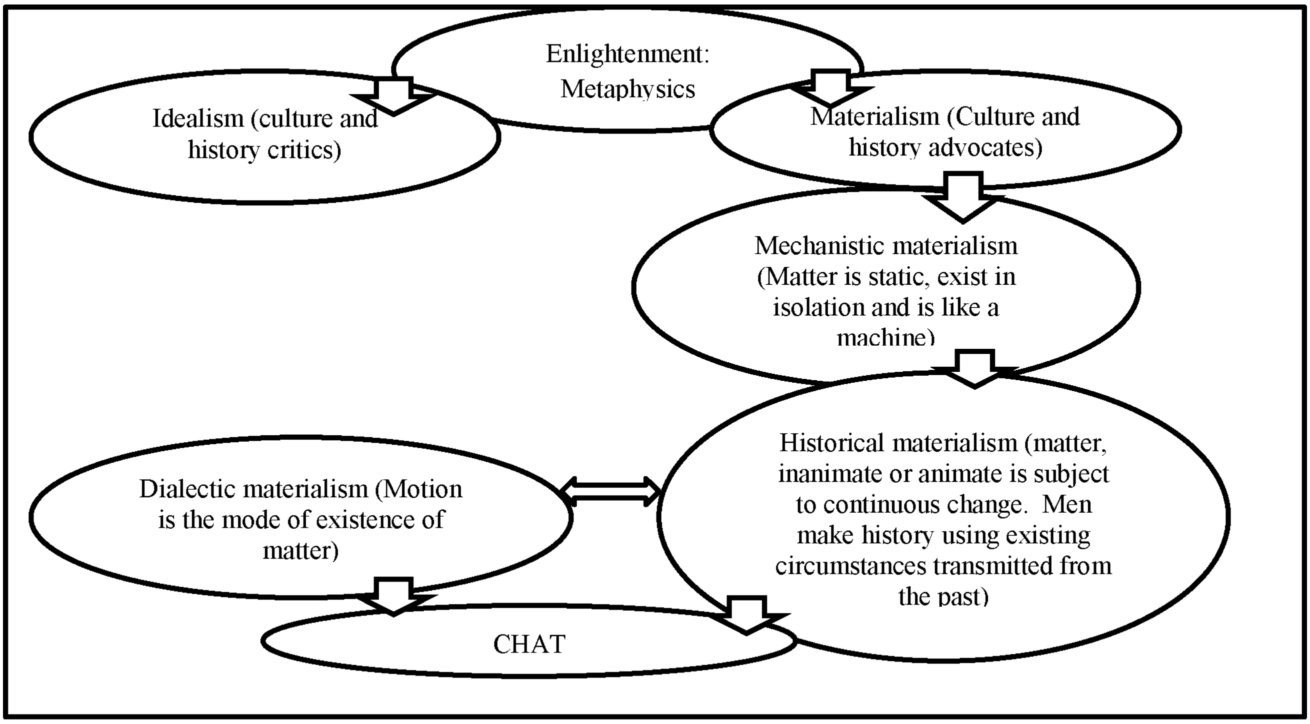


Figure 5: From Enlightenment to CHAT (Adapted from Blunden, 2010, p. 24)

The Marxist theory is unlike the Hegelian conceptions which are cultural critics, the human body is considered as fixed and a given product of the environment. Contrary to this, the Marxist theory from which CHAT has a strong foundation supports that the human body is a product of both activity and environment which are the foci of this study. This is to say that the human body is itself an artefact and a cultural product.

CHAT like any other theory which shaped it like those in Figure 5 above has its own concepts. CHAT concepts such as mediation, internalization and externalization were formulated by Vygotsky (1978). Vygotsky was in total disagreement with the idea that separate organisms and environment. His understanding was that an organism and its environment are components of a complex system that co-creates consciousness through human participation in activities (Vygotsky, 1978).

3.2.3.2 Cultural Historical Activity Theory (CHAT)

To theorize and analyse how the SC approach can be engaged in rural under-resourced schools I employ CHAT both for methodological guidance and as an analytical tool. CHAT provides a bridging theory for analysing science teaching practices. As an epistemological theory, CHAT advances that understanding during learning that takes place through collective and social activities designed purposefully and conducted around a common aim (Dick & Williams, 2004). This resonates with the SC discussed in Section 2.2.1. CHAT understands learning as a social cultural process that is historically connected. In addition CHAT emphasizes the use of tools as mediating artefacts in the learning process as I have indicated in Section 3.2.3.2 above.

The main unit of analysis is a collective, artefact-mediated (Section 3.2.3.3) and object-oriented activity system revealed in networked relation to other activity systems (Engeström, 1987). Activity systems are multi-voiced and connect many points of view, traditions and interests. Given the conceptual base in Marxist social theory, González-Rey (2015) states that it is not surprising that contradiction within and between activity systems are seen as potential sources of change and improvement. This is also supported by Foot (2014). Activity systems are open-ended learning systems that can adopt new elements from outside (Mukute & Lotz-Sisitka, 2012) and have the potential for expansive qualitative transformations. In this study the mediation process will be explored using the lens of activity theory.

The views of developed activity systems analysis as a research methodology within CHAT were conceived by Engeström (1987) on the basis of Vygotsky's socio-cultural theory in the 1920's in Russia. Vygotsky, during the Bolshevik Revolution, was tasked to incorporate Marxist ideas into psychology. Marxist ideas were used to explain relationships between individuals and the environment thus investigating how individuals engage with activities (González-Rey, 2015). This was the first generation of the activity system (Figure 6).

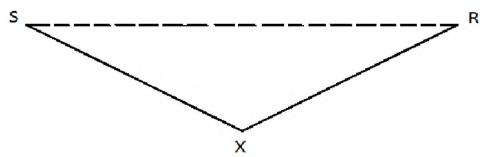


Figure 6: Culturally-mediated action. Adapted from Vygotsky (1978, p. 40)

Vygotsky (1978) conceived the activity system following the Marxist tradition of believing that conflicts exist between interacting entities. The subject, object and tool represented by S, R and X respectively perfect each other and then coexist. The subject, tools and object develop during the process of engaging with an activity.

Engeström (1987) used the expansive learning ideas to perfect Vygotsky's model. Engeström concluded that human activity systems are tied to culture and history. His ideas led to the following: the subject is involved in an activity; the motive of the activity brings the object and tools such as language or theories used for mediation. The product of the object is the outcome as illustrated in Figure 7 below which shows the dialectical relationship between the components reflected through use of double arrows.

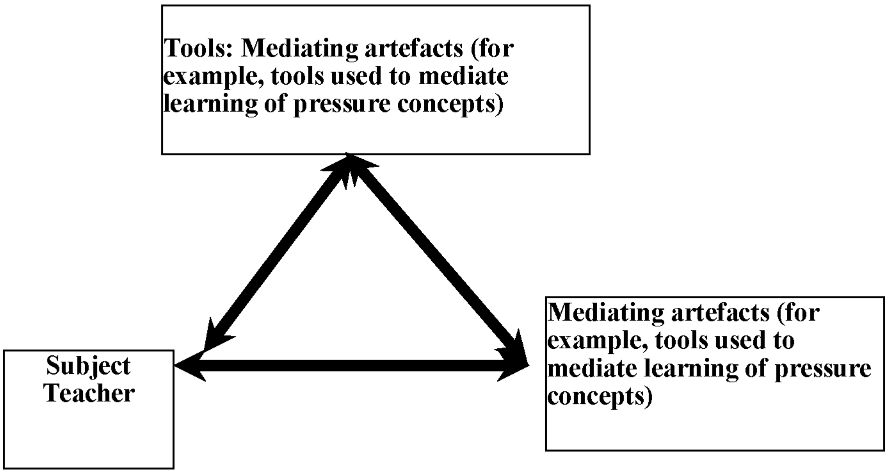


Figure 7: The common reformulation of mediated action, after Engeström (1987)

The Vygotskian model was however found to have shortcomings in that it did not consider the connections between the subject and its community although these components are dialectically related (Ratner, 2002, 2006). Also, Jonassen (2004) suggests that the "interacting components form an activity" (p. 204). Leontèv and Luria (1968) made contributions to the development of this model as they found that the components in the activity system need to communicate. Engeström (1987) then connected the components diagrammatically as illustrated below (Figure 8), in what is called the second generation activity theory in its generic form.

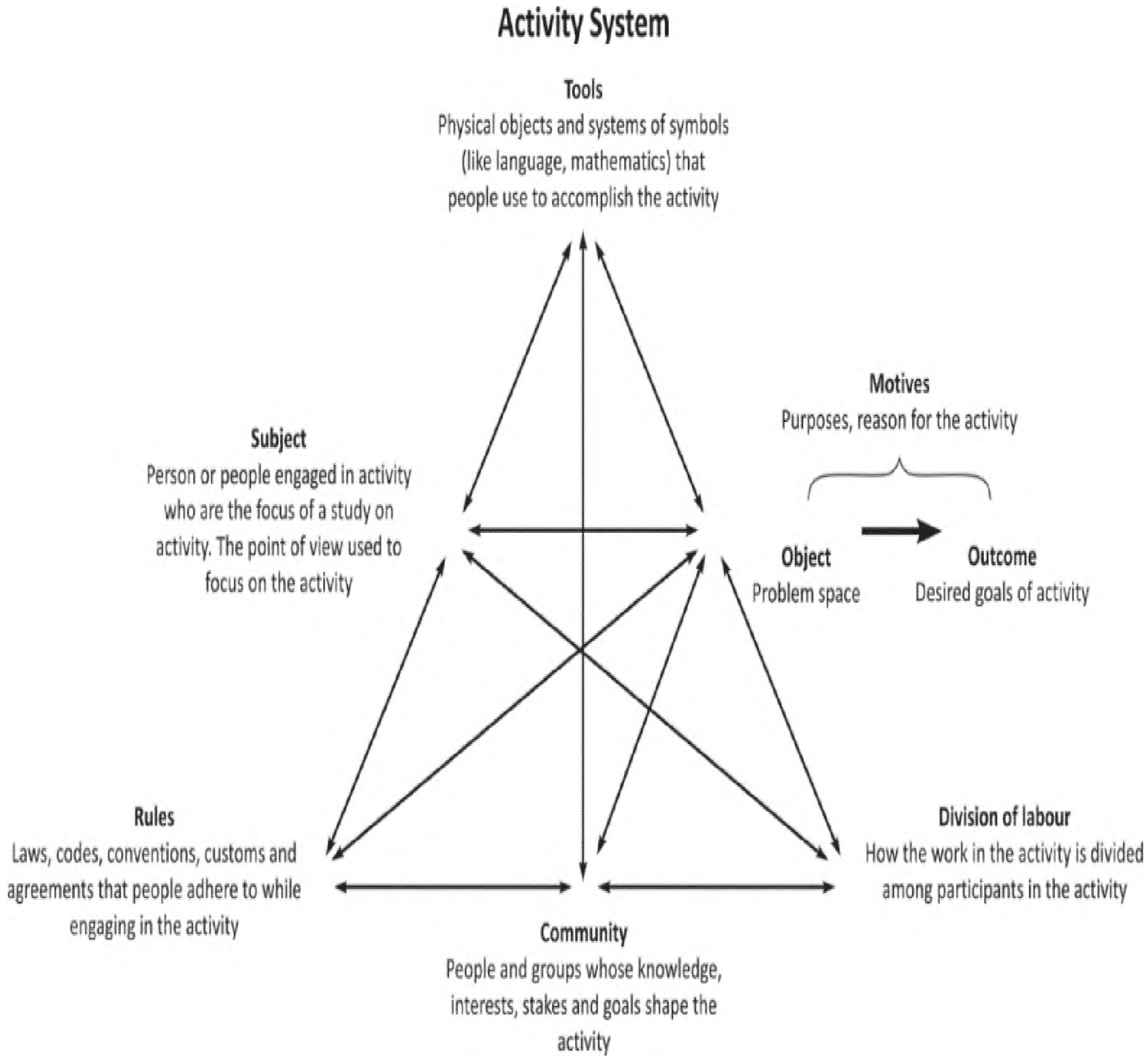


Figure 8: **Second generation activity system showing relationship within the elements (Adapted from Engeström, 1987)**

The second generation activity model will be used to answer sub-question 1, as well as to address the second sub-question stated in Chapter One. Figure 9 below shows how one can interrogate each component of the activity system to understand factors that enable or constrain the learning processes.

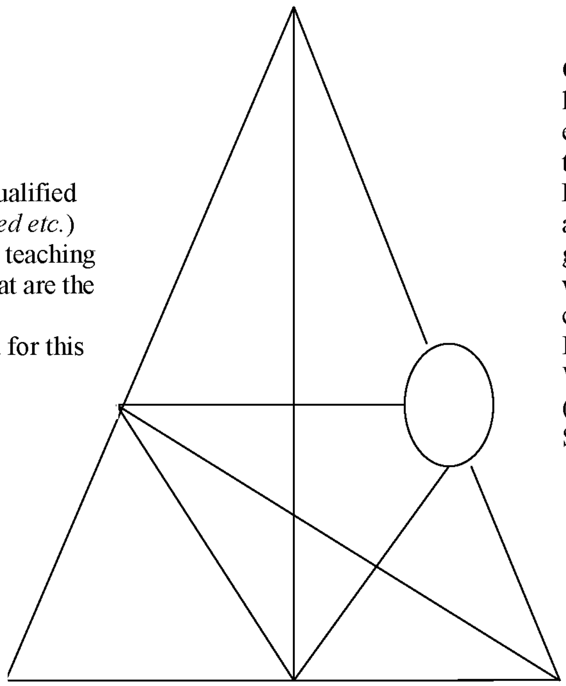


Figure 9: **Activity system: Relationship within the elements. Adapted from Engeström (1987, p. 78)**

To answer the questions posed, I focused the main interest of this study in the area intersecting the teacher's activity system with the knowledgeable community member's activity system. Also, the relationship between each component of the activity system and the other need analysis. Activity systems are not "isolated" or operate in a vacuum "but are more like nodes in crossing hierarchies and networks, they are influenced by other activities and other changes in their environment" (Kuutti, 1996, p. 34). I analysed how each component in the teacher's activity system interacts with a component in the community member's activity system. Even though one activity system may influence another, I narrowed this study to look into two activity systems in interaction. These are namely that of the teacher and the community member respectively as I wanted to find how the activities of the teacher can engage activities of a community member in order to meet the goals of education. I suggest that such an endeavour will allow the SC approach to be engaged. This has allowed me to bring in the third generation activity theory illustrated in Figure 10 below.

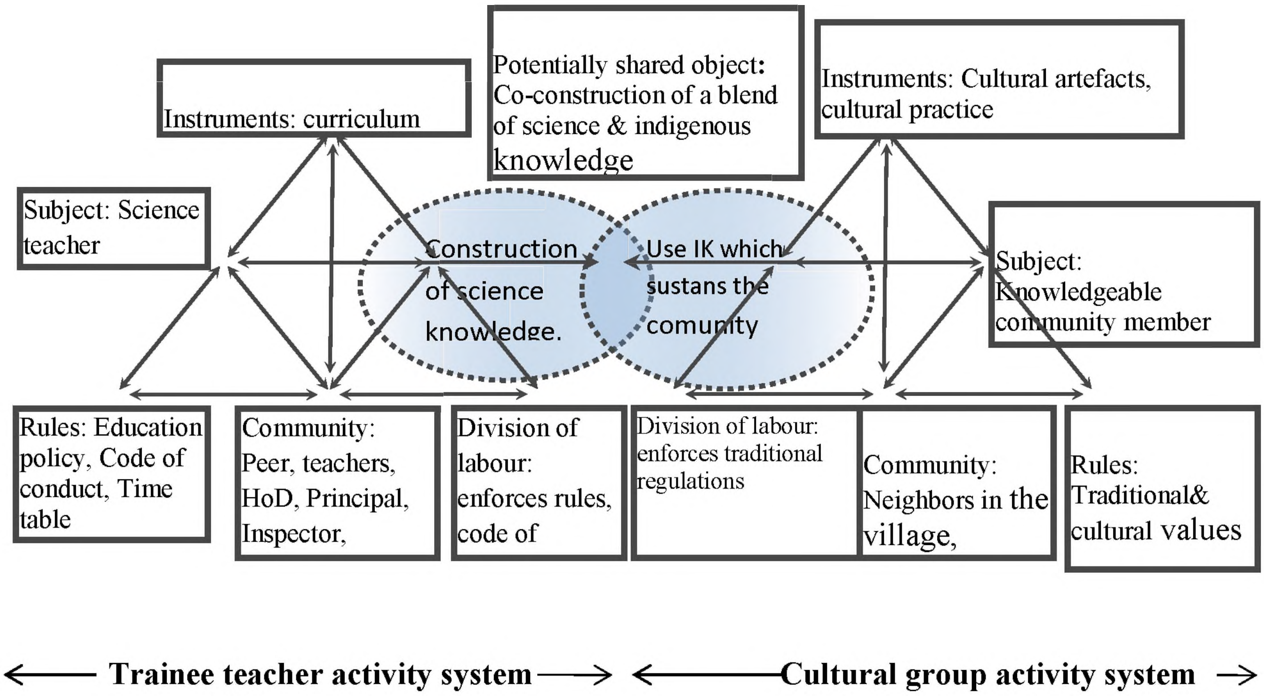


Figure 10: Third generation activity system. Adapted from Engeström (2001, p. 131)

The potentially shared object in the above activity system will form the central focus of this research. I analysed cultural practices in relation to science education in SC. Culture, history and the social entities are components of IK compatible with CHAT and linked with the methodology.

The use of ELC with participating teachers paved the way for seeing the mechanism generate the events in the cultural practices, artefacts and the social terms. The participating science teachers working together with the researcher were in a position to uncover the unobservable mechanisms which were used only by Indigenous communities, sometimes without knowing how their practices sustain the environment. The information obtained while using ELC paved the way for understanding the enabling or constraining factors. The use of ELC was guided by the premises in developmental research further explained in Section 4.2.2.

3.3 Concluding Remarks

In order to use the activity systems analysis, the methodology applied specific concepts within CHAT. These are mediated action, internalization and externalization which Vygotsky used to describe human activity. Questions that I have raised as research questions will address mediational activities. As a researcher, I then designed the data collection methods to specifically capture data that will inform the participants.

The process of how the data were generated is discussed in Chapter Four.

CHAPTER 4: RESEARCH METHODOLOGY

It is worth remembering that what we observe is not nature itself, but nature exposed to our method of questioning (Heisenberg, 1958, p. 78)

4.1 Introduction

This qualitative study explored and expanded the use of the SC approach by Physical Science teachers in under-resourced schools in the Zambezi Region of Namibia. By employing the interpretive paradigm, I used narratives to extract themes in order to come up with analytical statements. As Heisenberg (1958) suggests in the epigraph, observing without questioning is not useful in solving an educational social problem. This led me to structure this chapter using the following headings: (i) describe the framework of the methodology, (ii) discuss the research process, (iii) explain the site and sampling techniques, (iv) describe the procedure used in designing the instruments and generating the data, and (v) provide an explanation of how I achieved validity and trustworthiness of data and ethical issues. A justification of this structure that sheds more light on each section follows.

4.1.2 Justification of the structure

Using the method of questioning as the 'path' allows one to create a picture of what the environment in under-resourced schools can offer to support science teachers' engagement with SC (O'Leary, 2014, p. 105). The two objectives of this descriptive qualitative study in which CHAT, developmental work research and an expansive learning cycle were used are: (i) to explore how science teachers in rural schools use the SC approach in teaching the concepts of pressure; and (ii) to develop meaning-making skills in Science with reference to how concepts of pressure can be taught using SC in under-resourced schools through incorporating appropriate examples of IK.

The study dealt with the concepts of contradictions/tensions, activity systems of science teachers and Indigenous communities and expansive learning. According to Meyers (2007), these are the key concepts in Developmental Work Research (DWR). Using DWR aimed at developing practices that could facilitate the engagement of the SC approach in under-resourced schools in rural settings. DWR as an interventionist methodology was applied as a guiding tool to enable science teachers who had analysed the activity systems of Indigenous communities to see whether the cultural practices in such activities could prove useful in applying SC. The adoption of an interventionist stance in this study enabled me to directly intervene in practice, to work with other members in community of practice to come up with a social change in science teaching practices as reiterated by Lave and Wenger (1991).

The steps that were undertaken to address the objectives of the research questions stated in Chapter One (see Section 1.7.2) are explained. These steps are to (i) describe the framework of the methodology, (ii) discuss the research process (iii) explain the site and sampling techniques, (iv) describe the procedure used in designing the instruments and generating the data, and (v) discuss the validity and trustworthiness of the data and explain the ethical issues involved. Further justification of the chosen structure is from the ontological and epistemological view.

4.2 Framework of the methodology

In this qualitative study the ontological view is reality is subjective. In subjectivist ontology, humans socially construct reality based on our experiences in our daily activities (Kamil, 2011). Epistemologically, the researcher actively interacts with the participants and by doing so Walton and Hassreiter (2014) suggest it is "flattening the power gradient" (p. 5). The methodological framework was aligned to the inductive process. The researcher and participants mutually and simultaneously shaped the factors for conducting the research.

The researcher analyses and interprets the activity systems of science teachers and the Indigenous community using CHAT as discussed in Section 3.2.3. CHAT is grounded in the work of Engeström (1996) and his DWR programme.

4.2.1 Justification of the framework of the methodology

Selection of CHAT in the methodology was based on the fact that it involves or analyses how a given work is achieved, who does what, what the goal is, what tools are used and what rules guide the system. Learning and teaching are work. So, people work, play, think and solve problems together (in an activity system). This is a manifestation of the fact that they demonstrate an accumulated set of habits and values and learn at the same time. Learning is not an isolated act; rather it is situated (Hendry, 2013). Meyers (2007), adds that learning is situated in time and space and influenced by the surrounding actors, resources and behavioural constraints" (p. 4). He also notes that teachers are agents in the learning process as through their activities, teachers play a role in determining the contexts in which learning takes place.

Cultural-historical activity theory, then, as a dynamic model, is particularly appropriate for the study of how SC can be engaged in under-resourced schools. CHAT enabled the discussion of developmental work research (DWR) in the methodology. The sections which follow describe the fundamental concepts of the research approach, that is, the activity system, contradictions and expansive learning.

4.2.2 Developmental work research in the methodology

As mentioned earlier, the proposed research adopts a qualitative, formative interventionist case study approach in DWR and expansive learning methodology (Engeström, 1987). DWR is located in the tradition of cultural-historical research (Engeström, 2001).

DWR applies an interventionist methodology to activity systems such as those in CHAT and involves the concept of the expansive learning cycle (ELC) (Engeström, 1987). DWR is based on the mediational theories of Leontèv (1978) and Vygotsky (1978). The importance of culture, context (discussed in Chapter Two) and history in Vygotsky's work allowed me to conclude that DWR is associated with socially distributed activities such as teaching practices and cultural practices which helped to surface an epistemological transfer (Breidlid, 2013) suitable to those who are disadvantaged caused by the dominancy of WMS which has an "assimmilation" nature as (Hawkins & Thompson, 200, p. 287) view.

The socially distributed activity system is then the central unit of analysis in this study. This paves the way for the conclusion that an activity is the tiniest meaningful authentic context for understanding individual actions. However, at an elevated level it can be used to describe and evaluate systemic interactions and relationships such as teachers' and community members' activity systems which I focused on.

The components of an activity system together with their roles and diagrammatical representation have been discussed in Section 3.2.3.4. Within and among the different elements of the system, tensions exist (Engeström, 1999; Blackler, 1995). On account of the nature of their dialectical relation, a tension in one section of the system triggers agitations in all the parts of the system (Ratner, 2002, 2006). These tensions fuel continuous transformations and the development of new practices emerge when fueled by the same tensions. This resonates with Karl Marx's social conflict theory that suggests that change is not random, but the outcome of a conflict. However, Marx's social conflict theory is grounded in material inequality conflicts which give rise to development in activity systems. The activity systems under exploration are grounded in knowledge disparity in the section of the object of an activity system. Meyers (2007) supports the latter as revealed below:

> Contradictions arise when new ways of thinking or doing come in conflict with traditional or currently accepted ways of thinking and doing and may occur within each of the elements, between elements, or among activities, resulting in tensions within the system. (p. 5)

In this study the new ways of thinking or doing were the practices of teachers, whereas the traditional ways were the cultural practices of the Indigenous community. Cultural practices as social structures address the goals of the Namibian education system. The activity system of the latter addresses global warming which preserves the environment. However, in under-resourced schools with poor infrastructure teachers could not engage the SC approach using new ways. In view of this, the DWR with its interventionist character was found suitable for addressing the gap.

Interventions in DWR follow the stages of the cycle of expansive learning: historical analysis, actual-empirical analysis, modelling, examining and implementing new models, reflecting on the process and consolidating the new practice (Virkkunen, 2004). These stages are illustrated in Figure 11, which also indicates which research question is dealt with at each stage and comes in as one of the components of DWR.

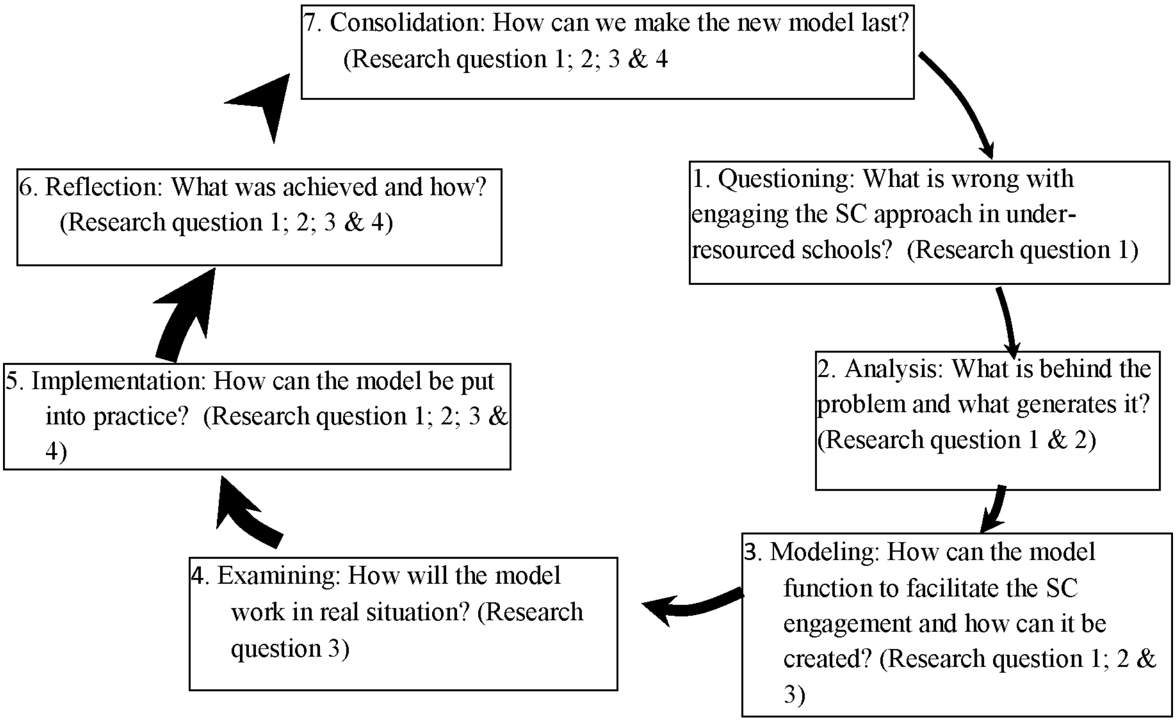


Figure 11: Stages in Developmental Research Work. (Adapted from Engeström, 1996, p. 135)

Data generation in such a case study involves analysis of contradictions, mirror data and change laboratory workshops (Engeström, 2007). Intervention seeks to eradicate the knowledge practice gap. In support of the DWR, the expansive learning cycle was used.

4.2.3 Expansive learning cycle

The expansive learning concept takes advantage of the tensions described under DWR (Meyers, 2007). As mentioned previously, an activity system does not exist in isolation and contradictions are not adverse but act as catalysts for changing activity systems like the two under exploration (Meyers, 2007).

The interaction of an activity system with other activity systems is prevalent, for example when it receives rules and instruments from other activity systems. External forces influence from outside and this makes the activity system "adapt to environments" (Lewontin, 1982, p. 163). These external influences are initially appropriated by the activity system and turned around or modified in order to adapt to internal factors. These antagonistic forces within the system make the activity system perpetually insistent for equilibrium. It is this property which makes it a learning cycle. It is analogous to Vygotsky's (1978) ZPD explained in Section 3.2.1.1. The 'more capable peer', in the case of this study is the researcher seeking to stimulate an innovation and change in the practices of science teachers which sets up internal contradictions.

Using interventionist qualitative research with several strands did not allow me to impose new models on the research context. I stimulated the implementation of a culturally modified hybrid curriculum by first presenting my views and tasked teachers to check whether they were valid. In return, teachers were asked to bring more examples to implement in new practices. The selected practices were then adapted into the activity system and the conflicts which arose were observed. These were aimed at relating existing practice, creating a new critically and socially constructed practice for science teachers in under-resourced schools. Such teachers cannot be divorced from the community, and are therefore regarded as components of the social setting. As a social setting, ELC is multi-layered and interconnected with other social settings (Cohen, Manion & Morrison, 2010). Cultural practices where IK is embedded were analysed in relation to their use in SC. A qualitative research case study allows investigators to "maintain a holistic perspective and study real-life events" - in this case it refers to the activity systems of a teacher and of a community member (Yin, 2003, p. 2). This qualifies it to involve the methodology of expansive learning. A detailed diagram showing instruments used in each of the stages of ELC is illustrated in Figure 12 below.

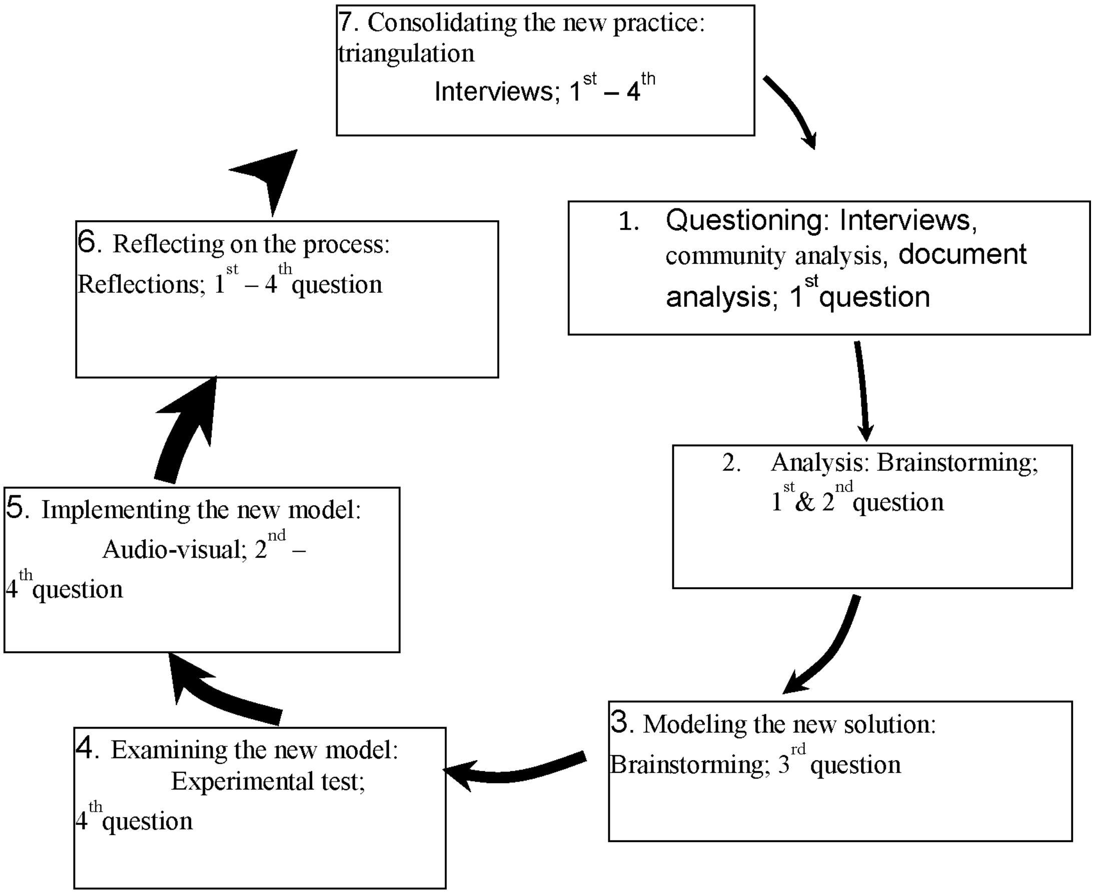


Figure 12: The expansive learning cycle showing stages, instruments to be used and questions that they answer (Adapted from Engeström, 1999, p. 384)

Each stage of ELC shows the instrument which was used for generating data. Also, the question which the instrument/s answered is also shown. For example, the questioning stage answered question 1, stage 2 involving analysis, research question 1 and 2 were answered. In the stage of modelling, research question 3 was answered. The examining stage went to answer research question 4. The implementation went to answer research question 4. Finally, in stages 6 and 7 the responses obtained while engaged in the activities answered all four research questions. The ELC helped to come up with work practices for the science teacher after they had interacted with communities of practices from the local Indigenous community members.

The context in which the work practices of practitioners are developed is referred to as a change laboratory, which can be achieved through an intervention workshop. The change laboratory is based on the theoretical ideas of the double stimulation proposed by Vygotsky (1978) and of expansive learning proposed by Engeström (2001). The change laboratory aids both intensive, deep transformations and continuous incremental improvement in the practices of the subjects. Subjects in the activity systems under analysis, when in a problematic situation, turn to the external environment. The problem is the principal stimulus and the environment is the secondary stimulus. Mirror data comes from the instruments used at the research sites. The DWR in which the ELC was adopted was realized in phases. These phases are explained in the preceding sections.

4.3 Phases of the Study

The nature of this study required that it should be divided into two phases. The first phase dealt with exploration where data generating instruments were used. The exploration data generating instruments answer sub-questions 1 and 2 which were asked as below:

- How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching pressure and other science concepts? [Interviews, community analysis, document analysis, brainstorming and reflections will be used to answer this question]
- What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts? [Brainstorming, audio-visual evidence, reflections, and interviews will be used to answer this question]

The second phase dealt with expansive data generating instruments and aimed at expanding ideas gained in Phase one, guided by questions 3 and 4:

- What expansive learning and mediation tools can the study develop to support the use of SC in the teaching of science concepts through the use of IK concepts of pressure and other science practices? [Brainstorming, reflections, and interviews will be used to answer this question]
- What insights can be obtained from a SC-driven pedagogy? [Experimental test, audio-visual evidence, reflections, and interviews will be used to answer this question]

It is in the 2nd phase where ELC activities were realized in order to expand ways in which the SC approach can be implemented in under-resourced schools. The research questions answered in the second phase are the 3rd and 4th research questions. The phases are explained below.

4.3.1 Phase One: Exploration phase dealing with research questions 1 and 2

Phase one data were generated at the start of the study for later use. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), (2010) describes data generated before starting or at the commencement of a study. Depending on the nature of the study, exploration data can be generated before the commencement of the study (Bamberger, 2010) as was the case in this study. Data generated during exploration consist of two types; determinate and indeterminate data. This study used determinate data which is data closely linked to exploration. The fundamental importance of collecting "Phase one data was always critical for performance evaluation as it is impossible to measure changes without reliable data on the situation before the intervention began" (Bamberger, 2010, p. 2). Like any other data, exploration data requires specific instruments to generate it.

In this study, community analysis, document analysis and brainstorming played a key role in generating this type of data. These instruments were used in the stages of the expansive learning cycle. The reason for using a number of these instruments was determined by the need to triangulate the data generated. Also, the use of a number of instruments assisted in offsetting the power gradient between researcher and the science teachers and between the teacher and the community members (Donnelly, 2007). For example, when using brainstorming power, the power gradient or knowledge gradient was not a factor. In a brainstorming workshop, criticism of ideas at an early stage is discouraged.

A detailed explanation of what these instruments entail and how they were used in the first phase to generate data is explained in Section 4.5.1 below. Since exploration data is generated for the preceding phase, I argue this below. The nature of exploration data allows the emergence of data in the expansive learning cycle.

4.3.2 Phase Two

Expansive learning cycles such as the one shown in Figure 12 are made up of several smaller cycles of learning activities. These are referred to as miniature learning cycles and require less time to use (Engeström & Sannino, 2010). These were used in this research to come up with data to answer research question three and four which sought to highlight enablers and constraints and how the SC approach can be expanded in under-resourced-schools respectively. This led me to engage with expansive learning cycle data generating instruments.

Expansive learning cycle data are data generated by the researcher and the participants. In the case of this research this data falls into the second phase. In this phase, the data generating instruments were: interviews, reflections, audio-visual techniques, and experimental tests (Godfred, 2015). Even though brainstorming was used in the first phase, it was also employed in the second phase when this study was conducted. The reason was similar to the first phase where I mentioned that brainstorming was used since it removed the power and knowledge gradient between the researcher and the subjects of the research. Again, the reason for using a number of research instruments lay in the need to address triangulation. The ELC phase described falls under qualitative research methodology. Such a methodology was designed to immerse the participant researcher with the people under study and their culture (Weinreich, 2006). The research participants and their culture are located in a particular site and these are discussed below.

4.4 Research site and participants

The research participants comprised grade 11 Physical Science teachers in three schools in the Zambezi Region of Namibia. Community members were included as they were important in revealing cultural activities relating to pressure and other science concepts.

A total of six teachers two from each school, participated in this study. It was considered necessary to have two teachers from each school in case one decided to withdraw from the study as data could still be generated from the school. Three community members, one from each of three communities, were also selected. The same reasoning applied in the choice of representatives per community. A number of schools, science teachers and community members exist in the Zambezi Region but specific criteria and sampling techniques were employed to produce the sample size for this study.

Two ways of selecting a sample exist, namely, probability and nonprobability. Probability sampling is applied in quantitative research as it entails an element or participant in the research process that needs to have a nonzero probability of selection. Since probability sampling deals with quantitative data the details of its characteristics are not relevant here. This study used nonprobability sampling which is discussed below.

As a researcher, I relied heavily on the judgement of the science teachers and on the experiences gained revealed in Chapter One. Four types of nonprobability sampling exist, that is, purposive, snowball, quota and convenience sampling. I was interested in using convenience sampling in my study. Convenience sampling data was generated from those participants most conveniently accessed (Neuman, 2007).

This explains why convenience sampling of three schools as research sites was done, taking into account "typicality or possession of the particular characteristics being sought" (Cohen, et al., 2010, p. 115). Another characteristic considered in selecting schools was whether the school was under-resourced or not. Teachers were selected on the basis of their prior exposure to ways of incorporating IK.

Convenience sampling was also used to select community members who lived close to the participating schools. The selected schools were found to be ideal points since if the results supported the SC approach, teachers would be able to use the surrounding sites in their practice. Lastly, the communities and their community member were selected on the basis of whether they employed indigenous practices in which science concepts are used as tools.

After choosing the research site and the participants, instruments mentioned in the expansive learning cycle were then put in place. The data generation activity was then organized in phases. The instruments used in each phase are explained in the following section.

4.5 Data generating instruments used in each phase

The data generating instruments comprised information from documents and audio-visual material. These instruments comprise data in the form of text or pictures. I therefore decided that these instruments comprising data from documents would be in Phase one as they generate the exploration data. According to Bogdan and Biklen (1998) materials such as photographs, videos, diaries, manuals, memos, instructional materials, case records, and memorabilia of all sorts are suitable as additional information to supplement the principal data generating instruments of observations and interviews.

Instruments which generated data using interviews, experimental tests, reflection and brainstorming in this study were used in the second phase. These instruments were grouped in the second phase of this study since they revealed data which would have remained hidden when I instituted the first phase. Farber (2006) explains the process of doing an activity twice as a second sweep whereby a speck which would have remained in the first sweep is removed by the second sweep. I discus the instruments used in the first phase of the study below.

4.5.1 Phase One instruments

There were three instruments used in this phase. Document analysis, community analysis and brainstorming were used in that order. As a participant observer I was involved in the process of brainstorming since this instrument aimed to generate data for the second phase of my study. Also, I was actively involved when teachers and community members were engaged with the other instruments. A detailed analysis of Phase one instruments follows.

4.5.1.1 Document analysis

Bardach (2009) suggests that “sources of information, data, and ideas fall into two general types: documents and people” (p. 69). In the case of documents, Yanow (2007) asserts that:

> Documents can provide background information prior to designing the research project, for example prior to conducting interviews. They may corroborate observational and interview data, or they may refute them, in which case the researcher is ‘armed’ with evidence that can be used to clarify, or perhaps, to challenge what is being told, a role that the observational data may also play. (p. 411)

Document analysis, as one of the instruments used in qualitative research, exists in three forms. These are public records, physical evidence and personal documents (Administrative methods, 2010). Examples of public documents used in this study are the official and school curricula, textbooks used for teaching concepts of pressure and annual reports from the Directorate of Namibian National Examination used in Section 1.5 to obtain Table 1.

Physical evidence refers to physical objects which the research encountered. These are the artefacts which the researcher and the participants interacted with to generate data. A detailed discussion of this appears under community analysis which is discussed in the next section. Similarly, personal documents pertain to accounts from people that are used to produce data. As with the physical evidence I classified them as suitable for community analysis which will be discussed under the respective section below.

Document analysis was used as my main method in this study to provide exploration data since our "modern world is made through writing and documentation" (Prior, 2003, p. 4). Weber, Roth and Wittich (1978) describe documents as situated products produced in social settings. Owen (2013) considers documents as responsible for maintaining the identity of institutes such as schools, universities and others and provides material for the policies followed at such educational institutions. Although important in research, document analysis may have some shortcomings.

Document analysis aims at generating facts but data generation using document analysis is not an easy endeavour. Caulley (1983) cautions that "the facts of history and evaluation never come to us 'pure,' but crude" (p. 24). Data from a document is always presented using the world view of the author of the document. This also applies to curriculum documents on approaches to teaching pressure and other science concepts are presented using the world view of the author/s. A similar situation also exists with community cultural practices using pressure or other science concepts used as examples by the author. Are science teachers then in a position to devise a culturally modified hybrid curriculum which meets the aspirations (*access, quality equity and democracy*) of the Namibian government? Bhabha (1994) considers a multicultural hybrid curriculum as one which does not separate knowledge from culture. Also, one might ask, whether science learners are in a position to apply the science knowledge gained to improve their standard of living or sustain the environment? In answer to both questions I believe that a multicultural hybrid curriculum will not be feasible as cultural practices used by communities for centuries to curb global warming and preserve the environment are not being sustained as they are not part of the activities that learners engage with. This has led to the need to apply community analysis to investigate cultural practices as alternatives to support the SC approach.

4.5.1.2 Community analysis

Community analysis is one of the types of document analysis mentioned above (Section 4.3.1.) as physical evidence. Blakey, Milne and Kilburn (2012) understand community analysis in research as:

> What happens when you put your personal knowledge and understanding into a bigger picture of the knowledge and understanding held by a community, this encourages you to question your assumption and to look for patterns, reasons why and possible answers. (p. 341)

Depending on the type of community being analysed, cultural artefacts are good examples for community analysis (Administrative methods, 2010). A relevant example of a cultural artefact for this research could be soot-blackened containers mentioned in Section 2.4.2.

Other valuable data from the community is personal data such as accounts from people, actions from individual community members, experiences, and beliefs (Administrative methods, 2010). All classified as personal data they can assist in answering research questions such as: "How do Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching pressure concepts?" and "What factors enable or constrain rural school grade 11 Physical Science teachers' practice from engaging SC when teaching pressure concepts?" Also to be tackled in this first phase of the research is brainstorming.

4.5.1.3 Brainstorming

Brainstorming was used as "a tool of creative problem solving" (Isaksen & Dorval, 2011, p. 3). Its advantages are that criticism is withheld until a later stage and wild and unusual ideas are shared. Many ideas are generated which can be useful when the ideas are weaved with IK. These properties of brainstorming anticipated answering research questions one and two.

Participating teachers were asked to list the concepts of pressure as well as other topics in Physical Science. Thereafter, they were asked to indicate how they would teach the concepts using the SC approach. However, they were cautioned that Zambezi Region does not have conventional facilities for this approach so they needed to check how these concepts are dealt with at community level. At community level, Indigenous communities use IK ideas to deal with issues related to the environment. They were told to discuss and modify ideas they had seen and model how they would present those ideas in a Physical Science classroom. Modelling entailed taking situations which the team members had seen in indigenous communities which were representatives and similar to those seen in WMS. They were then tasked to make models of the situations whereas a model was taken as a physical, computational, or mental representations that stand for scientific phenomenon or processes (Schwarz & White, 2005). Group brainstorming was done and the properties of brainstorming were observed.

There was poor attendance when I tried to gather the teachers into a group for the purposes of brainstorming. I then decided to meet two science teachers at each participating school for the brainstorming session. The ideas generated at one school were then checked and verified by teachers at two other schools. Verifying the science in the ideas brainstormed was easy since the teachers had been asked to conduct an experiment on pressure. The practical activity conducted allowed the teachers to see what they were supposed to do with the ideas generated by the brainstorming session.

4.5.2 Phase Two instruments

The second phase of this study is the main data generating phase as interviews were part of the instrument to generate data (Kvale & Brinkmann, 2009; Kvale, 1994). Also, in the second phase, data from other instruments namely, experimental tests, reflection and brainstorming was incorporated. A detailed analysis of instruments used to generate data in Phase two follows.

4.5.2.1 Interviews

Kvale (1983, 1994) maintains that a qualitative research interview seeks to describe and find meanings of central themes in the life world of participants. As a researcher who used an interview as a data generating tool, my main task was to understand the meaning of what the interviewees say. Interviews provided direct contact with participants and paved the way for analysis (McMillan & Schumacher, 2006). Interviews were used to obtain information on characteristics, attitudes and behaviours of groups that share common attributes (Krueger & Casey, 2000). The interview schedule was pilot tested to find if it worked in the 'real world' by trying it out first on a few people.

The science teachers I interviewed had similar characteristics, attitude and behaviour as they share the same goal. The similarity in characteristics, attributes and behaviour are shaped by fact that they operate in a similar environment. They used the same curriculum materials and were situated in the same area as the sites of research. This also applied to community members whose characteristics, attributes and behaviour were similar since they shared and sustained the same natural resources such as water.

Interviews were found to be an appropriate measuring instrument since I felt that I needed to meet face to face with participants in order to generate data in discourse which borders common and mutual interest (Godfred, 2015). Interviews given (see Appendix interview for teachers before exploration) provided a complete description of participants' experiences (Giorgi, 2009; McNamara, 1999). To gain access to these life experiences, an interview was administered as follows.

Before I held a meeting with the teachers, I interviewed each of the six teachers as shown in the expansive learning cycle. This first interview with each of the six teachers aimed at answering research questions one and two. Since the main question was: "How do Physical Science teachers engage SC in teaching pressure and other science related concepts at the nexus of indigenous knowledge and WMS?", I also needed to interview Indigenous community members. Indigenous community members are the custodians/owners of indigenous knowledge (Hinz, 2011). These communities are well-placed to know why certain practices are employed in their communities. So, to tap into the knowledge of the Indigenous communities, I interviewed the three community members selected by the teachers when they were asked to find cultural practices reflecting Science.

Also, after the expansive learning process was completed, the interventionist process was over and interviews were administered to teachers. The aim of administering the last interview was to find out whether the new model could be used by science teachers to support the SC approach in schools. Some responses useful for question three and four emerged from the data generated by the last interview administered. In this second round of interviews, community members were not interviewed. After the interview, brainstorming as a data-generating instrument was used

The interviews were conducted with each of the remaining participating teachers. It was difficult for the teachers to commit time for the interviews and to keep to the scheduled appointments for interviews. Each interview took twenty minutes which proved to be long for teachers. Some of the teachers interviewed gave responses which needed to be followed up for more elaboration from the participating teacher.

4.5.2.2 Brainstorming

Brainstorming also occurred in the second phase and was guided by Osborn's (1957) suggestion that "judgment may choke ideas, and let us keep it in its place" (p. 44). Brainstorming was incorporated at this level even though it was engaged in Phase one for the purpose of triangulation. Three types of triangulation are named namely, time, space and person triangulation (Polit & Beck, 2014). Time triangulation entails generating data for the same research questions at different times during the research process which is why brainstorming was used in both phases. Space triangulation entails generating data for the questions at different sites. Finally, person triangulation entails generating data for the same phenomenon using different groups of participants but with the same aim of finding how they will respond to the research questions.

I met with the six science teachers to discuss their views after the first session of brainstorming. At this stage each teacher had to give feedback on what he/she had observed the community members doing. Each teacher had to list those cultural practices which reflected science and explain how they could be included in science teaching to support the SC approach.

Brainstorming also provided ideas which were subjected to an experimental test. The model which each teacher brought to support the SC approach was given to the other participating teachers for discussion and comment on its suitability. After a peer review of each model, each teacher then subjected his/her own model to an experimental test.

The observations by the participating teachers all indicated that the cultural practices, artefacts and terms revealed the mechanisms which Indigenous communities relied on for subsistence. It is possible that the participating teachers' results were shaped by the experimental test on pressure conducted earlier since it validated the data generated. The experimental test is discussed below.

4.5.2.3 Experimental test

An experimental test was introduced to each teacher and was then tasked to conduct it as a way of constructing knowledge aided by the use of direct and indirect observation or experiences. Each teacher was further tasked to make a comparison of what he/she discovered with what he knows from WMS. Justification for this procedure lies in the fact that it mediated between competing world views, namely, the WMS world view of science and indigenous ways of knowing nature discussed in Section 1.1. Another justification for the experimental test was that after the test the science teachers became more engaged and interested in the concepts they discovered, especially when they noted that these concepts were applied by Indigenous communities. Stohr-Hunt (1996) supports this view by pointing out that the use of experiments in learning makes participants more engaged and interested in the material they will be learning.

Although various terms exist to denote an experimental test such as laboratory work, experimental work and practical work, I agree with Millar (2004) who prefers the term practical work. Practical work does not limit science teachers to an environment only supportive of the WMS perspective as embracing the term practical activity allows science teachers to conduct science practical activities using any resource found in the community and elsewhere. Using practical activities acknowledges the SC approach and is one of the ways in which IK can be weaved with WMS.

This focus allowed including practical work in a miniature expansive learning cycle as shown in Section 6.2. The cultural practice beliefs about pressure is viewed by Putnam (1999) as supported by empirical evidence and constituting genuine knowledge. These beliefs were subjected to a practical activity to see if they can act as mediating artefacts when engaging the SC approach and to induct the science teachers into how they can also change practices which engenders scientific literacy in learners. To achieve this, audio-visual techniques were also employed as the aim was to do a detailed analysis of cultural activities found in Indigenous communities.

4.5.2.4 Audio-visual techniques

The need to generate reliable records of research work and to build valid observed materials to be used as a source for understanding and interpreting a certain phenomenon and/or research problem governed my choice of procedures and resources (Garcez, Duarte, & Eisenberg, 2011). Therefore audio-visual techniques as data generating tools were considered imperative for this study where the human activity system is too complex and demanding to be effectively described (Loizos, 2008; Pinheiro, Kakehashi & Angelo, 2005). The audio-visual data generating instrument, with its sound and visual components made producing data from a human activity system less demanding.

Justification for using audio-visual instruments in this study was based on the understanding that data generated provided a form of feedback to the researcher and participants when brainstorming and during the fieldwork. In addition, Duarte (2002) suggests that the researcher can critically evaluate his/her performance and improve it gradually. This was essential during the modelling done in the expansive learning cycle. Some of the data generated during audio-visual technique was also used for triangulation and validation. Finally, the use of audio-visual material also highlighted contradictions between the discourse and behaviour (Pinheiro, et al., 2005). Contradictions were the focus of this study when the activity system of a science teacher and that of the Indigenous community member were analysed using CHAT as an analytical tool.

The use of audio-visual techniques comes with certain requirements. It is necessary to have a critical partner while recording. With this in mind, I tasked a friend to use a camera to capture details such as body movement, expressions and both verbal and symbolic ethno science language. Valuable data could have been lost if I had not taken care when recording (Sadalla & Larocca, 2004).

4.5.2.5 Reflections

Stone (1989) reports that at his trial in 399 B.C.E Socrates pointed out that a life which is unexamined has no value. Examining one's experiences is a reflection or thinking activity which enriches one's knowledge spectrum. Reflection, or thinking about our experiences, is the fundamental key to learning. Reflection enables us to analyse our experiences, make some alterations to change misconceptions and then apply added knowledge in our daily cultural activities.

Examining or reflecting on experiences makes it possible for communities to come up with cultural practices which they adhere to in order to adjust to the environment. If experiences are not examined, then modification of past knowledge based on new knowledge is not feasible. Reflection is an important step for qualitative researchers to take in order to address imperfections (Roller & Lavrakes, 2015). An unexamined life experience is like a distorted image in a mirror as not all images in a mirror are true reflections of objects.

Sources of information produced in qualitative research require a similar approach. Not all information encountered is perfect. However, information can be perfected by reflecting on what one has encountered. This then compelled individuals to engage in reflection in order to come up with an idealised model in which distortions were assumed to be absent even though they are present. This understanding made me question what is generally accepted as true or ideal.

In an attempt to remove the imperfections in the data obtained a reflection exercise was used. The teachers who participated in the research were asked to write reflections in stage six of the expansive learning cycle during the second phase of data generation. These reflections were aimed at disclosing the teachers' views on the instrument used to generate data. They were tasked to comment on whether the instrument was suitable for use to obtain the data generated. Also, they were asked to reflect on the data obtained and consider whether the models produced for engaging the SC approach in under-resourced schools were suitable.

Analysis started only after the data from all the instruments was gathered and recorded. The analysis of data was done taking into account the phases which were used to produce the data. A thorough description of how data was analysed follows below.

4.6 Data analysis

Data analysis entails significance or coherent meaning (Neuman, 1997). Shamoo and Resnik (2003) support this as they understand data analysis as a method that provides procedures of drawing inductive inferences from data and distinguishing the themes present in the data. In analysis, labelling and coding all the generated data will enable similarities and differences to be recognized.

Data was generated from interviews, audio-visual techniques, document analysis and experimental tests. This allowed a content analysis of the data which was a suitable procedure since it entails the categorisation of verbal or behavioural data. The sole aim was for the purposes of classification, summing or tabulation. Israel and Hay (2006) list some of steps needed in order to do data analysis.

- Reproduction and reading through the transcript - make brief notes in the margin when interesting or relevant information is found;

- Go through the notes made in the margins and list the different types of information found;
- Repeat reading through the list and categorize each item in a way that offers a description of what it is about;
- Indicate whether or not the categories can be linked in any way and list them as major categories (or themes) and/or minor categories (or themes);
- Compare and contrast the various major and minor categories;
- If there is more than one transcript, repeat the first five stages again for each transcript;
- When you have done the above with all of the transcripts, collect all of the categories or themes and examine each in detail and consider if it fits and its relevance;
- Once all the transcript data is categorized into minor and major categories/themes, review in order to ensure that the information is categorized as it should be;
- Review all of the categories and ascertain whether some categories can be merged or if some need to them be sub-categorized; and
- Return to the original transcripts and ensure that all the information that needs to be categorized has been done.

The process of content analysis was a lengthy one requiring the researcher to go over the data repeatedly to ensure a thorough analysis was done.

Data was analyzed taking into account the phase in which it was generated. In the first phase, data from document analysis and community analysis was sourced. The second phase of data analysis entailed analyzing data from interviews, reflections, brainstorming, audio-visual evidence and experimental tests. The following section explains this.

> An inductive analysis of data in the potential shared area and similar points in the activity system was conducted, bringing to the surface positive or negative tensions, depending on the type of objects concerned. This was used to detect the "categories and patterns seeking for plausible explanation". (McMillan & Schumacher, 2006, p. 362)

The analysis process described above is largely inductive, that is analysis that lets data speak for itself as it follows a pattern case-result-rule (Danermark, 2001; Kirkeby, 1990). My next level of analysis was abductive, which involves analysing the data from the viewpoint of the theory that supports the study. Jensen (1995) also understands abduction as a re-description or recontextualization. To recontextualize involves observing, describing, interpreting and explaining concepts or constructs using a new context. This perspective is appropriate since the WMS context was used previously and science concepts were explained using WMS cultural views however in this study an Afrocentric context is introduced. In essence, abduction emphasizes the search for suitable theories to an empirical real-life observation, which Dubois and Gadde (2002) refer as "theory matching". Patterns in empirical real-life observations are related to known theories. An example is when patterns in cultural practices, artefacts and social science terms found in Indigenous communities are matched with known theory.

In a broader sense, abductive analysis can be seen as an overall term for all forms of interpretation made from a pattern or system of classification (Danermark, 2001). He added "here we interpret and re-describe the different components/aspects from different hypothetical conceptual frameworks and theories about structures and relations" (ibid., p. 150). Abductive analysis is "theoretically guided re-description" of data (ibid., p. 151). Abductive analysis in this study was informed by the three theoretical approaches discussed in Chapter Three.

Recontextualization was achieved through the use of socio-cultural, social reality and cultural historical perspectives in order to come up with the SC approaches responsive to a particular disadvantaged community. Social context in science concept teaching changes as learners move from an informal learning system to a formal learning system (Le Grange, 2007). Also, social class, world view affiliation and gender are some of the factors that affect how people view something and end up subscribing or affiliated to a particular social context. Recontextualizing using a social factor or a world view a learner is connected to help to deepen a learner's understanding as some of his ideas are pulled into identifying patterns in experienced empirical real-life observations that are related to known theories.

Historically, contextualizing brings aboard context that reflects politics, culture, economics and societal norms. Use of one particular world view with ideas embedded with examples from other cultures is part of the politics used in excluding learners from certain communities and so democracy as one of the goals of education is not met. This is also true regarding factors related to economics, the absence of social and cultural structures which can be used to engage SC approach requires that abductive measures be taken to come up with methods to ensure that the social reality on the ground is addressed. The use of socio-cultural, social realism and historical factors contributed to the choice of CHAT as an analytical tool.

The analysis was done using CHAT. Each question in Section 1.7.2 was responded to in the various phases of the expansive learning cycle. Concepts and relationships in the raw data were identified as they were organized into a theoretical explanatory scheme. The theoretical explanatory scheme created a base for the construction of analytical themes and these themes were used to draw conclusions.

Furthermore, selected data from different instruments were introduced and analysed, making it easier to identify emerging themes (Miles & Huberman, 1994). This method was useful in identifying similarities and differences in the thinking of participant groups, as well as identifying occurrences of 'unusual' data from transcriptions. Thereafter, data coding was made possible to generate findings by carefully weighing evidence through checking their frequency of occurrence or absence, across participant groups and instruments. Possible explanations or interpretations were weighed up and related to the literature while using the theoretical framework as a lens to focus the findings.

The concept of the SC approach together with its tenets and other conceptual frameworks discussed in the literature review are currently scattered. To organize them, socio-cultural theory and social realism were used to organize the dispersed concepts presented in Chapter Two and these were supported by data generated in this chapter. The supporting data evidence generated provided the context which I used for prediction as I came up with analytical statements in Chapter Eight. To ensure that I carried out this qualitative study and its data analysis, I needed to abide by the ethics of research, which I discuss below. Table 2 is a summary of the data analysis process.

Table 2: Summary of data analysis processes

Type of analysis	Mode of inference	Research question addressed
Interviews, observation and document analysis	Inductive analysis Initial categories from field work interviews and documents Abductive using SC lenses?	How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching pressure and other science concepts? [interviews, community analysis, document analysis, brainstorming and reflections were used to answer this question] (Chapter 5)
Analysis of contradictions [brainstorming,	Abductive using CHAT Historical analysis Critical Discourse Analysis	What factors enable or constrain rural school grade 11 Physical Science teachers'

audio-visual evidence, reflections, and interviews will be used to answer this question]	Abductive using CHAT; SC; IPCK may be SCR	practice with regard to engaging SC when teaching science concepts? (Chapter 5)
Analysis of change laboratory workshops	Abductive using CHAT, Boundary learning processes, Zone of Proximal Development	What expansive learning and mediation tools can the study develop to support the use of SC in the teaching of science concepts through the use of pressure in IK and other science practices?[brainstorming, reflections, and interviews were used to answer this question] (Chapter 6)
[experimental test; audio-visual evidence, reflections, and interviews will be used to answer this question]	Abductive using CHAT, SC approach, IPCK	What insights can be obtained from a SC-driven pedagogy? (Chapter 6)
Views from each instrument in relationship to each research question	Holistic use of modes of inferences to analyse, interpret and discuss data emerging	Data analysis, interpretation, discussion and findings (Chapter 7)
Patterns in each research instrument responding to research questions	Summary of findings from data that emerged	Findings of the study (Chapter 8)
Implications and recommendations		Overview (Chapter 9)

In order to use the type of analysis described in the above table to come up with the mode of inference which finally answered the research questions, some research ethics were observed. These are now discussed below.

4.7 Research ethics

Ethics are important in research. Ethical behaviour represents a set of moral principles, rules, or standards governing a person, a profession or an activity. Lichtman (2010) points that to be ethical one need to treat participants fairly and avoid coercing them into participation and disseminate data generated without their nodding. Major principles associated with ethical issues are: do no harm; address privacy and anonymity; ensure confidentiality of data generated from participants; obtain informed consent; protect data ownership and rewards given to deserving participants. How each of those ethical principles was addressed is revealed in the section which follows.

4.7.1 Ethics related to data generation

Generating research data involves personally interfering in people's lives (McMillan & Schumacher, 2006). To avoid possible pitfalls, confidentiality, anonymity and privacy were addressed, and a caring attitude towards participants was exercised. Creswell (2003) suggests that there is a "need to respect the participants" (p. 64). The following actions were taken to address issues related to ethics.

A letter seeking permission to be allowed to collect data was sent to the University of Namibia Katima Mulilo Campus (UNAMKMC) (see Appendix 1). Other letters were sent to the headmasters of the participating schools and to science teachers and community members in 2015 (see Appendices; 2HX, 2HY, 2HZ; 3TXA, 3TXB, 3TYC, 3TYD, 3TZE, 3TZF and 4CM1, 4CM2, 4CM3). The teachers and communities were asked to sign a letter agreeing to participation in the study. Permission was also sought from the headman of each participating community. Only when these ethical considerations were in place, did the data generation process begin. However, the first letters signed by some of the participants got lost. To ensure that research conditions are in place I asked the participants to sign the same letters.

4.7.2 Ethics related to data management

A critical friend assisted with data capture and data management. Data were stored in different sources, audio-visual were safely stored to protect the anonymity of the participants. When all ethical considerations were ensured, data were generated and analysed. This was followed by validation and triangulation, as explained below.

I could not have obtained the research data if I had not explicitly validated participating teachers' knowledge. Although some of them are my former students I did not act as if my knowledge was superior to theirs as I really valued their contributions and experience. I also took care not to impose my views which I achieved by soliciting their opinions before making any recommendation.

4.8 Trustworthiness, validation and triangulation

In pursuit of trustworthiness this study addressed the issues of credibility, transferability, dependability and confirmability (Guba, 1981). Credibility measures, tests or studies what is actually intended. Transferability is the "extent to which the findings of the study can be applied to other situations" (Merriam, 1998). Dependability reveals that under the "same context, with the same methods and with the same participants, similar results would be obtained" (Shenton, 2004, p. 71). Finally, conformability is ensuring that the findings are indeed the results of the study (Patton, 1990).

Validity was addressed through the conceptualization and operationalization of concepts in the study and researcher participation. This ensured that the instruments measured what they purported to measure. The use of various data-generating techniques, as described above, enabled triangulation of data. From the multiple data generated using different instruments, "convergence among multiple and different sources of information was searched to form themes in the study" (Creswell & Miller, 2000, p. 126).

4.9 Limitations to the study and sample size

This research could not control extraneous variables such as the participants' background, mood, anxiety and intelligence quotient. For example, teacher E, at school Z opted to withdraw as he occupied a management position at school which meant he was often busy or unavailable. Teacher B at school X was often either uncooperative or reticent about sharing her opinions on science knowledge. Finally, some teachers who did not have science degrees found it challenging to come up with practices reflecting science.

The extraneous variables of the environment, such as light intensity or whether it was raining or a dry day might influence the way the participants responded. In the case of situational issues teachers did not want to be kept long during our contact sessions. For example in cold weather teachers were reluctant to remain at school to participate in the research.

A sample of six teachers was selected since in qualitative research a huge amount of data does not necessarily lead to more information (Ritchie, Lewis, & Elam, 2003). A bigger sample might have been conducive to work with as this also could have increased understanding of science concepts during the research process, but a small sample was selected since the time frame for conducting the research was limited.

4.10 Concluding remarks

The purpose of this chapter was to describe the research objectives, the methodology and the target population. The chapter also explained the sample selection and justified the methodology used in the research design, the data generating instruments, the implementation of the expansive learning cycle and it provided a package used for the qualitative analysis of data.

The results of the data collected through the use of the instruments mentioned in Chapter Four are presented in the following chapters. Chapter Five deals with the display of data from exploration, Chapter Six deals with presenting the data from Phase two and Chapter Seven presents an interpretation of these data.

CHAPTER 5: EXPLORATION DATA PRESENTATION AND ANALYSIS

Displaying data helps us to understand what is happening and to do something – either analyse further or take action – based on that understanding (Miles & Huberman, 1994, p. 11).

5.1 Introduction

In Chapter Four, I mentioned two phases that would be used to generate data. The data that falls under these phases are: data generated during exploration and data generated during expansive learning. The data that emerged during exploration answered research questions 1 and 2 while the data resulting from the expansive learning cycle answered research questions 3 and 4. This chapter's objective is to present the data that emerged during exploration. Presenting or displaying data as suggested in the epigraph above prepares for understanding of the phenomenon under study. Miles and Huberman (1994) further describe data display as a planned, compacted grouping of data that allows conclusions to be drawn, action to be taken and results in an understanding of the phenomenon under study.

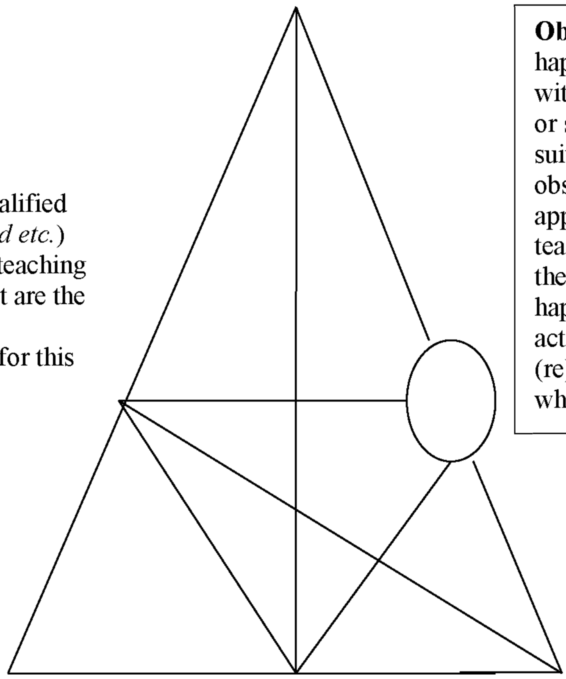
In this chapter, I present data that partly responds to research questions 1 and 2:

- How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching pressure and other science concepts?
- What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts?

Using the second generation CHAT framework I unpacked research question 1 into the following sub-questions as shown in Figure 13 below.

Mediating Artefacts: What are the physical and/or mental tools used to engage SC when teaching pressure concepts? Are the tools in use well suited to these goal(s)? How have these tools changed over time? In what ways are the tools in use constraining or influencing the way the work is done? Do subjects (teachers) have sufficient skill to use the available tools effectively in relation to applying SC cognition when mediating pressure concepts? What other tools could be needed for the work? What knowledge and skills are needed for teachers to engage SC in mediating concepts in pressure? Are they present? Can they be sourced? From where? How and by whom? How willing are they (subjects) to try new tools?

Subjects Are teachers qualified *(informed, skilled, focused etc.)* to engage with SC when teaching pressure concepts? What are the different kinds of skills/knowledge needed for this pedagogy?



Object: What can we *observe* happening in relation to engaging with SC when teaching pressure or science concepts? How well suited are the actions we can observe to the goals of application/use of SC when teaching pressure concepts? Is there is a misfit? If so why is it happening? What actions/activities can be (re)focused towards the use of SC when teaching pressure concepts?

Rules: What are the formal and informal (cultural) rules that promote or constrain teachers from engaging with SC when teaching pressure concepts?? To what degree are these explicitly stated? Are there problems with these rules? What are the other structures that shape the way the work is done?

Community: Who else is interested/affected when SC is applied to the teaching of pressure or science concepts? How can they be brought on board?

Division of labour: Who does what in the teaching and learning process? Does this matter, or is it merely a sensible division of labour? In what ways does the division of labour constrain or enable SC when teaching pressure concepts? Is there any need to share the work in a different way? Why and how?

Figure 13: Activity system: Sub-questions answering questions in Phase one

The analysis of data using figure 13 above allowed an understanding of the activity system of the community and that of the teachers. The use of instruments for exploration; mainly document analysis, activities from the community and brainstorming also generated data which were used in Phase two of this study.

Data generated through the use of documents (which are the tools the teachers use as mentioned in Figure 8) are displayed first (see Tables 3, 4, 5, 6 and 7). This is followed by presenting data generated from community analysis and brainstorming to culturally translate the tools used by

Physical Science teachers in order to facilitate the SC approach in under-resourced schools. Themes formed from categories and sub-categories observed in each instrument are shown in Table 5. This restricted me to explore the use of the SC approach by Physical Science teachers in under-resourced schools in the Zambezi Region of Namibia in order to answer research questions 1 and 2.

To this end, in this chapter, I analyse the curriculum tools that are used in the activity system of the teacher. I further use the viewpoint of CHAT to analyse the data as well as to respond to the research questions in Phase one, including the research sub-questions as shown in Table 3 above. The data emerging from the instruments is displayed in Section 5.5 and references the second generation activity system while answering research questions 1 and 2.

5.2 Curriculum tools with the potential to engage SC

In this section, I present the curriculum tools with the potential to assist engaging SC in the teaching and learning of science. By means of document analysis I ascertained what the curriculum suggests science teachers do in order to engage the SC approach and to discover the enablers and constraints in engaging this approach.

The documents analysed in this section are components of the curriculum. They comprise; the Physical Science textbook, the supporting Physical Science textbook and the grade 11 Physical Science syllabus. Analysis was also extended to include cultural practices, cultural artefacts and social science terms from the indigenous community in which observed facts were used in the SC approach.

According to Braslavsky (2003), the curriculum can be viewed as the plan that communities, educational professionals, and the government have available which has the power to influence what knowledge learners should acquire during their lives in the school system. The curriculum also includes questions such as; 'why, what, when, where, how, and with whom to learn which explains why some of the sub research questions in Table 2 above are stated using why, what, when and where. Dewey (1902), Smith (2000) and Kelly (2004) state the five strands of the curriculum, namely; explicit, implicit, hidden, excluded and extra curriculum explained in Chapter Two. In respect of the document analysis used in this study, the recommended Physical Science textbook, a supporting Physical Science textbook by a different author, the official curriculum and school curriculum documents were analysed. While displaying and discussing data, the focus was on the role played by the elements represented in Table 3.

These documents contain some of the science concepts that teachers have to teach. Even though a number of diagrams were used by the authors of the Physical Science textbook to facilitate teaching and learning, not all of these were selected. Those selected were ones which I found useful in answering the research questions in Section 1.7.2. Using the displayed data the responses to the research questions in the exploration phase are summarized in Section 5.5.

Documents from the Ministry of Education pertaining to how teachers should conduct the situated cognition (SC) approach were also analysed. In the two textbooks that were analysed, the focus was also on diagrams, models, symbols, case studies and practical activities which drew the attention of learners to encounters in science which linked to experiences in their environment. In the other documents analysed, the absence of diagrams allowed me to focus on the written text related to SC. Tools in Figure 8 which uncover only those responsive to WMS were complemented with those from the activity system of the indigenous community. In doing so, the study was able to answer research questions 1 and 2 which guided the exploration phase. This was achieved by looking into the disturbances, shortfalls and discontinuities in the curriculum tools that constrain or enable the use of SC.

5.2.1 Data from the recommended Physical Science textbook

Clegg's (2005) "*Physical Science H/GCSE: Localised for Southern Africa*" is the recommended grade 11 to 12 textbook. According to the research sub-questions in Table 3 which investigate the mediating tools, this textbook can be regarded as one of the tools used by teachers as a mediating tool to conduct their science practices. Some of the cultural practices, cultural artefacts and social science terms reflected in Clegg's (2005 textbook are listed in Table 3.

Table 3: Data from "Physical Science H/IGCSE: Localised for Southern Africa" Clegg (2005)

School X, Y and Z			
Cultural practices	**Cultural artefacts**	**Science language from Indigenous communities reflecting WMS**	**Research questions answered**

Salt processing from sea water at Walvis Bay.	Victoria Falls Bridge across the Zambezi River.	Not seen	1, 2 & 3
Transmitting electricity using pylons.	Plastic containers around the environment	Not seen	1, 2 & 3
Uranium mining in Gabon not sustainable.	Plastic containers as materials made from plastic	Not seen	1, 2 & 3
A rusting chassis of a car in Damaraland.	Glucose, maize meal, soap, polythene, terylene and nylon as examples of large molecules	Not seen	1, 2 & 3
Neutralizing a farming area using lime.	A geothermal spring	Not seen	1, 2 & 3
Comparison of rate of a reaction with rotting of an egg, rotting of an apple and explosion in a building.	Lightning	Not seen	1, 2 & 3
Pumping water using a windmill for domestic animals to drink.	The sun and energy	Not seen	1, 2 & 3
Fetching water from a borehole using a rope and a metal container.	-	Not seen	1, 2 & 3
Energy in a storm caused by latent heat of water.	-	Not seen	1, 2 & 3
Burning fire and methods of heat conduction.	-	Not seen	1, 2 & 3
Vision of an object is the result of light reflected from the object into an observer's eye.	-	Not seen	1, 2 & 3
Playing music using instruments from the community.	-	Not seen	1, 2 & 3
Nuclear plant.	-	Not seen	1, 2 & 3

Although the data in the table above does not give an exhaustive list of all the material in the Physical Science textbook they are sufficient to answer research questions 1 and 2 posed in this study. Physical Science teachers also use supporting Physical Science textbooks. The data from one of the supporting Physical Science textbooks is displayed in Section 5.2.2. All the data generated were analysed in Chapter Seven.

5.2.2 Data from a supporting Physical Science textbook

The supporting Physical Science textbook at school X "*Physical science: Namibian senior secondary certificate: Ordinary level*" is written by Kachinda, Ajayi and Endjala (2009). The same textbook is also used as a supporting textbook in the other two schools which participated in this study. To close the gap in the implementation of SC in "*Physical science: Namibian senior secondary certificate: Ordinary level*", Kachinda, et al. (2009) included diagrams and explanations which are linked to learners' experiences. The following research sub-questions (Table 3) are also answered. What is happening in relation to engaging with SC when teaching pressure or science concepts? How well suited are the actions observed to the goals of application/use of SC? These are shown in the table below.

Table 4: Data from "Physical science: Namibian senior secondary certificate: Ordinary level" Kachinda, et al. (2009)

School X, Y and Z			
Cultural practices	**Cultural artefacts that can enable or constrain engaging SC**	**Social science jargon**	**Research question answered**
Fetching water from a borehole and then measuring a rope used to fetch water when it fails to reach water level	Rope, borehole	Borehole and a well	1 & 2
Making a measuring cylinder	Measuring cylinder	-	1 & 2
Riding a bicycle	Bicycle	-	1 & 2
Opening a door, opening tinned food	Lever, spanner	Hard and easy	1 & 2
Playing on a see saw	A pole supported on a fulcrum	-	1 & 2
Opening a door	Door lever	-	1 & 2
Selecting a stool or chair based on stability	Stool and chair	-	1 & 2
Stability of a double decker bus	Double decker bus	-	1 & 2
A rhinoceros charging at a person	rhinoceros	-	1 & 2
A metal pot with wooden handle placed on the fire		-	1 & 2

The items mentioned in the table are some of the ideas which are discussed with students when the Science teachers aim to develop science concepts related to the tabulated issues. Their view is that the descriptions are sufficiently detailed to develop these science concepts without visiting the sites where such activities are practised in the community. Also, they do not bother to take the learners to these sites, for example, to a carpenter in the community who fits doors nor do they invite him to the school to explain how a lever in a key operates.

5.2.3 Data from NNCBE

The NNCBE (2010) serves as a comprehensive guideline to how all subjects in schools should be taught. In this document evidence of some constraints are manifested as there is a notable absence in science teachers' practices which focus on activities from Indigenous communities. The division of labour (Fig. 5.1) as to who does what in the teaching and learning process, focuses on WMS activities. The NNCBE (2010) recognizes the communities' contribution in teaching science concepts and is specific on what must be taught and how it should be taught. It offers guidelines on the objectives of the Namibian education system. Some ideas that relate to this study are reflected in Table 5. These were coded and arranged into themes. The codes for detecting sections in the same category were: cultural translation (CT); sociocultural (S-C); Africanisation (AF); situated cognition (SC) and indigenous knowledge (IK). To address reliability during the process of coding of data, recoding was done. That is, after the first coding was done, I started coding afresh using a document which I had not marked before. Also, with the aim to address reliability, a knowledgeable critical friend was given an unmarked curriculum document to analyse to code and identify themes. I then compared this with the one I analysed before. This was also done in other sections which required coding with the "peer feedback" (Greco, 2016, p. 87)

Table 5: Data from official curriculum (NNCBE, 2010, pp. 26-30)

Categories	Themes	Example
• Curriculum framework has to adapt to change. • Teaching methods and materials will be adapted to learners with special educational needs. • Each learner is an individual with their own needs. • Teacher must select and develop the most appropriate materials. • Curriculum to be implemented coherently and consistently, well-articulated, meaningful and relevant to the learner, manageable by the teacher, and reflecting the demands of society.	Cultural translating	Example for bullet number 1,2,3,4 can be use teaching materials for rural under-resourced can be use of a *mapukuta* to teach a blast furnace
• Apply learners' knowledge creatively and innovatively. • Basic Education also prepares for the society. • Develop strong cultural and individual identity and positive values. • Possibility to influence globalization. • Exploring, investigating, enquiring, recognising, contextualising, hypothesising, interpreting, weighing up alternatives	Sociocultural	When they conduct practical work where they explore why indigenous communities discourage use of soot-contaminated

• Analysing, synthesising, evaluating, thinking creatively, and creating knowledge. • Learners learn best when they are actively involved in the learning process through a high degree of participation, contribution and production. • There is consistency in the delivery of the curriculum in schools throughout the country. • Learn through communication with others - playing, experimenting, experiencing things, new knowledge and acquiring new skills do not happen in isolation. • Learners do not come to school like empty buckets. • Extend the learners' prior knowledge and experience. • Collaborative learning should be encouraged. • Allow learners to participate. • Children are always exploring their social and material environment, and learn through communication with others - playing, experimenting, experiencing things, and by reflecting on them. • Teaching emphasizes the varied processes and learning experiences needed for the creation of knowledge, rather than relying predominantly on the transmission of knowledge by the teacher.		containers in sources of water is an example satisfying bullet 14, 12,11,10,9
Productive and sustainable socially, economically and ecologically. Developing an environmentally sustainable society is to provide the scientific knowledge and skills, and attitudes and values needed to ensure that the environment is respected and sustained.	Ubuntu and Africanisation	Practical work done reflecting how indigenous community protect the environment, such as processing hide using ashes instead of chromium salts.
• The community around the school can be an important support and resource, as well as a source of knowledge. • Community may have persons with expertise in language and cultural traditions, crafts, sports, health, entrepreneurship, agriculture, etc. who may be used to support teaching or co-curricular activities. • Learners to use the immediate environment, everyday situations, everyday items and waste materials to investigate phenomena. • Improvise teaching and learning materials from easily available and inexpensive objects in the immediate environment. • The home and community actively support the holistic development of the learner.	Situated cognition	Teacher takes learners to a site where a community member uses a *mapukuta*, constructing a house using local materials, making fire using traditional methods act as example

• Use the local environment and community as an extension of the classroom. • Provide learning experiences which motivate the learner to learn more.		for most of the bullets.
• Concept of knowledge thus embraces indigenous knowledge and local and national culture as well as international and global culture. • Reflect on and apply the learner's existing knowledge and ideas, to bring in new knowledge, and to facilitate and direct them in transforming knowledge. • Point of departure is always what the learners already know and can do.	IK inclusion	Explaining WMS concepts using the view of indigenous such as the case of an ant eater in Chapter 2

The themes tabulated are some of the concepts which were discussed in Chapter Two. Not all of the concepts discussed in the literature review Chapter Two were reflected in the above table. This does not mean that they are not essential, instead they are implicitly reflected in the major themes in the table.

5.2.4 Data from the grade 11 Physical Science syllabus

Data obtained from the Namibian senior secondary school certificate (NSSC) Physical Science syllabus for ordinary level code 4323 is presented in Table 6 below. In collecting the data I was interested in data which suggest how teachers can address the use of SC. Also, I checked for suggestions in the syllabus on how the SC approach could be addressed when teachers teach science concepts. In particular, I checked for any suggestions in the syllabus on how science teachers can include experiences which are related to the learners' experiences, cultural practices, familiar cultural artefacts and relevant social jargon. What follows in Table 6 are my findings.

Table 6: Data from the Physical Science syllabus

Idea checked	Suggestions from the syllabus related to ideas checked	Research question answered
	Mentioned as a philosophy teachers need to adhere to in their practices	2
Cultural practices	Nothing found	2
Cultural artefacts	Nothing found	2
Social science jargon	Nothing found	2
Issues addressing contextualizing	Nothing found	2
Issues addressing SC approach	Nothing found	2

When I failed to find explicit suggestions in the syllabus on how to address the SC approach to ensure *quality*, *equity* and *access* which the NNCBE (2010) advocates, I decided to analyze the school science curriculum in detail. The three schools represented in this study use the same school curriculum. I present this analysis in the section which follows.

5.2.5 School curriculum

There is a uniform school curriculum which prescribes which science concepts should be taught as well as how they should be taught. Very minor changes have to be made by the teacher during practice. This made it possible to probe how certain non-numerical concepts were manifested.

Non-numerical concepts such as the level of inclusion of the SC approach, IK practices and engagement of ideas of CHAT, sociocultural theory and social realism were checked in the document. These non-numerical concepts were tabled on a DAFOR scale which engages measures of non-numeric concepts like; dominant, abundant, frequent, occasional and rare. What follows in Table 7 documents what was found in the school curriculum document retrieved from one of the schools. To address reliability, a critical friend was not invited here but instead recoding was done by me.

Table 7: Data that emerged from the analysis of the Physical Science school curriculum

Non-numerical concepts	Dominant (5)	Abundant (4)	Frequent (3)	Occasional (2)	Rare (1)
Engaging SC activities					√
Engaging IK practices					√
Manifestation of Sociocultural theory				√	
Manifestation of Social realism					√

According to Agresti (2010), the ordinal scale allows the description and inference of ordinal categorical data such as how science teachers interact with non-numerical data in their practices as discussed in Chapters Two and Three. The analysis of documents was followed by community analysis as explained in Section 5.3.

5.3 Community Analysis and Brainstorming

The six teachers were tasked to analyze cultural practices, cultural artefacts and science terms reflecting science concepts taught in the classroom. This task facilitated the answering of research question 1: *How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching science concepts*? Through brainstorming and discussion teachers identified key science-related practices used in the community. The science ideas detected in these practices were then used to guide how the SC approach can be implemented in the under-resourced schools where these teachers work. I present their findings in Sections 5.6 to 5.8.

5.3.1 Data revealing cultural practices reflecting science concepts

The data generated here did not only serve to answer the questions for Phase one, they also served as a base for the engagement in ELC. That is the two activity systems were viewed as a whole not as divorced from each other as revealed in Sections 4.2.3, 3.2.1.4 and 2.2.1 as each teacher was then asked to look into the environment of the Indigenous community. Each teacher was required to mention at least four cultural practices. Pseudonyms were used for all teachers as follows: teacher A, B based at school X; teacher C and D at school Y and teacher E and F at school Z. In the following section I give a brief description of the main subjects of the activity system.

Teacher A at school X was the most experienced teacher in the group. She held a diploma from the University of Namibia and had 34 years teaching experience. She shared practices, artefacts and social science terms which were not disputed by others during the brainstorming session. Her expertise showed during the expansive learning cycles. In this regard, Chambliss (1989) noted that good teaching performance is not just a result of talent but to exposure and practice. Talent is a social construct and one excels in any activity through doing it repeatedly and this leads one to see the pattern of doing the activity. Teacher B from the same school as Teacher B has a diploma from a College of Education and had taught Physical Science for eight years.

Teacher C at school Y holds a Master's degree in Agricultural Science. She has 21 years teaching experience. Her experience and vast knowledge led her to agree that there is much untapped information in indigenous communities which can be used for engaging situated cognition in schools which are under-resourced. Her explanation was that multiple roles in teaching and learning are shared with learners and different perspectives of knowledge are brought into the classroom (Oliver, 1999). This resonates with the idea that there is no unique perspective in knowledge (Putnam, 1999). When Teacher C aligned the newly gained skills she pointed out that the strategies introduced support sociocultural theory which the NNCBE (2010) advocates.

Teacher D at the same school as teacher C is a holder of a BEd degree in education with specialization in science from the University of Namibia. Although he has taught for only five years he sees the potential of using cultural practices, artefacts and social science terms to facilitate SC engagement in under-resourced schools.

Teacher E, at school Z has a diploma from a College of Education as does his colleague, teacher F. Teacher F has taught for 10 years and unlike teacher E who is only a classroom teacher, Teacher F also holds an administration post at the school. Table 8 below gives a summary of what emerged while interacting with these six teachers.

Table 8: Cultural practices which can support SC approach

School X	
Teacher A **Some suggested cultural practices reflecting science**	**Can such cultural practices be engaged in a SC approach and in which concepts?**
African furnace (*mapukuta*) used for processing metals.	Metal processing.
Extraction of oil from *mungongo* seeds.	Density, separation of mixtures.
Traditional fire making.	Friction and factors determining it.
Traditional beer making.	Fermentation, fractional distillation.
Teacher B **Some suggested cultural practices reflecting science**	**Can such cultural practices be engaged in a SC approach and in which concepts?**
Hide processing.	Tanning industry, ashes and other products from the forest which are environmentally friendly are used.
Processing of millet.	Methods of separation. Convection currents related.
Use of traditional herbs when transporting fish and ways of carrying them.	Refrigeration, cooling.
Avoiding lightning by not standing under a tree	Conduction.
School Y	
Teacher C **Some suggested cultural practices reflecting science**	**Can such cultural practices be engaged in a SC approach and in which concepts?**
Traditional beer brewing techniques.	Fractional distillation, fermentation.
Fire making.	Friction and factors determining it.

Cooling of water for drinking or drinks using clay pots.	Latent heat of evaporation, cooling.
Charcoal making.	Dry distillation and fractional distillation.
Teacher D	**Can such cultural practices be engaged in a SC approach and in which concepts?**
Some suggested cultural practices reflecting science	
Fermentation used in traditional drinks.	Learners can view how fermentation takes place.
Charcoal making.	Dry distillation and production of raw materials.
Energy source from cow dung.	Biomass.
School Z	
Teacher E	**Can such cultural practices be engaged in a SC approach and in which concepts?**
Some suggested cultural practices reflecting science	
Drums and other materials used in brewing beer traditionally.	Learners can be asked to go and view and participate to gain more insight.
Winnowing of millet.	Separating mixture by taking advantage of weight.
Use of clay pots to cool water for drinking. Pot placed under a tree and covered with wet sand or sack.	Latent heat capacity.
Underground water detection using a tree whose leaves are evergreen throughout the year.	Analogous to searching a water leaking pipe using a radioactivity element.
Teacher F	**Can such cultural practices be engaged in a SC approach and in which concepts?**
Some suggested cultural practices reflecting science	
Houses thatched with grass and walls made of poles and plastered with clay soil.	Use it when teaching materials to show how materials can have their properties altered to suit a certain task.
Leather, processed and unprocessed and ashes.	Associate ashes with alkaline substances.
Accessories for beer brewing such as pounding stick and the *duri* (the wooden container where millet is placed to be pounded).	Increasing rate of reaction.
Shrubs used for preventing fish from going bad.	Coolant substances.

To support what the teachers had indicated and also for further use I captured some of the pictures which I thought could be used in a SC approach. Even though only a few were selected, this does not mean those not shown were irrelevant.

5.3.2 Data revealing cultural artefacts

Cultural artefacts are products of activity systems discussed in Chapter Three as well as mediums of production. Their presentation in this table enabled me to see the science concepts and theories informing certain practices in the community to find out how they could ease epistemological transfer of WMS as highlighted by (Breidlid, 2013) (see Section 2.7).

Their presence in the community is also a revelation that members of the community use science even though they might be unaware of specific science concepts. The cultural artefacts noted by the participating teachers and suggested ways of using them in science learning are listed in Table 9 below.

Table 9: Cultural artefacts which can support a SC approach

School X	
Teacher A **Some suggested cultural artefacts reflecting science**	**How can such cultural artefacts be engaged in a SC approach and in which concepts?**
Drums and other material used in brewing beer in communities.	Allowing learners to be at the site and have a talk with the community.
Shrubs used in fish transportation to prevent them from decaying quickly.	Bring them into the classroom and explain cooling while displaying them to learners.
Chamber pot or a urine spoiled blanket.	Bring such artefacts into the classroom and talk about sublimation and relate.
Smoked meat or fish and ways in which food is preserved.	Show learners pieces of food preserved traditionally.
Teacher B **Some suggested cultural artefacts reflecting science**	**How can such cultural artefacts be engaged in a SC approach and in which concepts?**
Fish preserved using sun or smoke.	Show learners items of food preserved using traditional methods.
Pounding stick and the other accessories for processing millet.	Visit a site where people are pounding, ask learners to observe the final product and comment.
Bringing the traditional dancing skirt (*mashamba*) to teach sound	Involve learners in a dance and ask them to comment on sound produced. Also, in material selection for use.
Decorative artefacts made from palm leaves and dyed.	Demonstrate how paper chromatograph works.
School Y	
Teacher C **Some suggested cultural artefacts reflecting science**	**Can such cultural artefacts be engaged in a SC approach and in which concepts?**
A canoe and paddle.	Teaching pressure concepts.
Muchimbani herbs for preventing fish from decaying quickly when transporting them.	Take learners to the market and show how the herb is used by fisherman. Also, fisherman can explain how they use it.
Clay pot for storing traditional beverages.	Also, learners can be taken to a site where such pots are used and the user is asked to explain then teacher blends explanation with WS.
Small scale milk processing into sour using local materials.	Acids and bases.
Teacher D	

Some suggested cultural artefacts reflecting science	Can such cultural artefacts be engaged in a SC approach and in which concepts?
Lighting fire or selection of a day when it is windy to separate millet and its husks.	Separating of mixtures/convection currents and this can be done with learners to see that the membrane separates items.
Recycled 5 and 20 litre containers used as wood stoves.	Can be brought to school and compare how fire burns if the fire is in an open space.
Cow dung.	Alternative source of energy.
Recycled pipes used at a site where dry distillation is taking place.	Take learners to a place where charcoal is being processed.
School Z	
Teacher E	**Can such cultural artefacts be engaged in a SC approach and in which concepts?**
Some suggested cultural artefacts reflecting science	
Ash	Used for neutralizing the soil also locals sprinkle ash in the vegetable garden and on the snail-infested ground to deter them.
A pair of traditional wooden spoons.	Separating mixtures.
Teacher F	**Can such cultural artefacts be engaged in a SC approach and in which concepts?**
Some suggested cultural artefacts reflecting science	
The use of grass for roofing.	Properties of materials and their use.
Use of wooden material to construct a canoe.	Materials of less density are suitable for water moving bodies.
A device for purifying metals when making tools.	Elements extraction and purification.
Use of hat during summer.	Sun burn and radiation.

Cultural artefacts listed in Table 9 as tools if used in the SC approach require clear explanation to build understanding. So, it was imperative to investigate language use and how science concepts might be distorted in an effort to engage the SC approach. This led me to look into the potential of social jargon (science terms/terminology) in the SC approach and how it can enable or constrain SC use in under-resourced schools in the Zambezi Region.

5.3.3 Terms revealed from data

Science language used by Indigenous communities is not the same as that in WMS. However, in some cases the terms used were similar to WMS but in many cases they were found to mean something different. The constraints which social science terms present are displayed in the following Table 10. To see if they could support the SC approach, some WMS language terms specific to naming are displayed but in social science terms used by the Indigenous communities. An example is the term beer which in Indigenous communities refers to all alcoholic beverages. Also, the term speed is used in such a way that one cannot distinguish it from velocity but WMS has a term for each concept or construct. The science teachers who were working as members in our community of practice co-constructed the information in Table 10 below.

Table 10: Science language from the community which can support the SC approach

School X	
Teacher A	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Distance	Associated with measuring and is a scalar quantity
Displacement	Associated with measuring and is a vector quantity
Velocity	Associated with measuring and is a vector quantity
Speed	Associated with measuring and is a scalar quantity
Teacher B	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Mass	Associated with measuring and scalar quantities
Weight	Associated with measuring and vector quantities
Force meter	Instrument for measuring force in Newton's Law
Scale balance	Instrument for measuring mass in kilograms
School Y	
Teacher C	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Beer	Product of fermentation and low content alcohol made from barley, wheat and others
Wine	Product of fermentation and low content alcohol and made principally from grapes
Spirit	Product of fermentation and high content alcohol
Teacher D	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Coke	Product of dry distillation of coal
Coal	Natural occurring source of energy formed from dead plants subjected to pressure and heat
Charcoal	Product of dry distillation of wood

Wood	Natural occurring source of energy not subject to heat or pressure
School Z	
Teacher E	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Distilled water	Water in which dissolved and suspended particles are removed
Pure water	Only suspended particles have been removed
Radioactive and other processes such fermentation, distillation, milk turning to sour are taken as things	They are all processes not things
Teacher F	**Other ways of understanding the cultural science language**
Some suggested cultural science language reflecting science	
Capacitor stores a certain amount of electricity	A device used for storing energy
Heat energy in a resistor is produced by electricity	A device for regulating the flow of charged particle.
Half as referring to anything which is not a whole example 3/4; 1/4 and 1/2	Precision as an attribute is important in science teaching

5.4 Brainstorming

Brainstorming was done to verify whether the information obtained in the community analysis reflects science and can support the SC approach and how can it be used in science teaching and learning in schools. I circulated Tables 8, 9 and 10 to each participating teacher. Teachers were tasked to tick agree or disagree against each activity. The acronyms CP (cultural practice), CA (cultural artefacts) and SJ (social jargon) were used. The result of this brainstorming activity is revealed in Table 11 below.

Table 11: Comments of participants on activities, artefacts and jargon selected

Name of teacher	**Comments on what the teachers selected**		
	CP	CA	SJ
A	√	√	√
B	√	√	√
C	√	√	√
D	√	√	√
E	√	√	√
F	√	√	√

By circulating Tables 8, 9 and 10 ensured that the participants' statements were reflected correctly in this study. Another advantage was that participants who were previously unaware of the potential of science to support the SC approach in the activities mentioned could read about it.

To ensure that visits to sites were fruitful to the learners, I selected a teacher and checked what was suggested in the community. This allowed the teachers to prepare for the visit and the learners to gain the full potential from what was on offer. To ensure that the teacher offered sound classroom talk during the visit, we planned the lessons together and this formed part of the expansive learning cycle as discussed in Section 4.2.3 and 4.3.2. Some of the pictures which were taken during these initial encounters are discussed below.

5.5 Audio-visual techniques

The selection of pictures below illustrates the cultural practices identified by teachers who participated in the study. Only pictures which I thought prominently reflected science were selected.

Figure 14: Using *mapukuta* to process metals

The figure above shows a man treating metal using heat. The *mapukuta* as it is known in the Indigenous communities in the Zambezi Region is also used for extracting metal~~s~~ from ore~~s~~. Impurities are burnt away and what remains is a malleable and ductile material which can be hammered into shape to produce tools or jewellery**.** This device was used by one of the teachers to support engagement of the SC approach in an under-resourced school. In addition to metallic artefacts, Indigenous communities also use wooden artefacts as shown below.

Figure 15: Traditional wooden spoons for separating solid and liquid substances

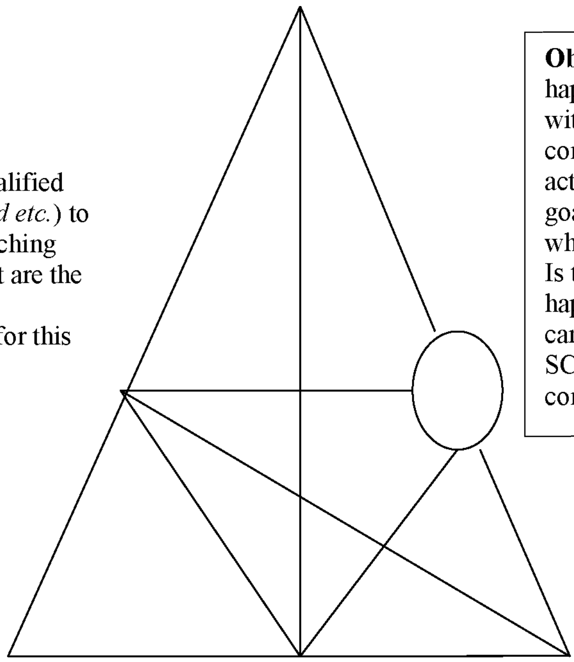
The wooden artefacts are used by Indigenous communities for separating solid and liquid materials. Separation is a concept taught in Physical Science but it is handled theoretically. Bringing these artefacts into a classroom add a concrete dimension to the teaching and learning. All these artefacts are appropriate tools which I mentioned in Figure 8 showing the second generation activity system where relationships within the elements are revealed.

5.6 Activity system lens in relation to data that emerged

The data presented above answered research questions in the exploration phase. Each of the research questions is answered using the second generation activity system view in Figure 14 below. Sub-questions shown in each section of the component were constructed in order to facilitate answering these research questions in the exploration phase. What follows is a discussion of data which answered research question 1 in Section 5.5.1. This is followed by a discussion of data answering research question 2 in Section 5.5.2.

Mediating Artefacts: What are the physical and/or mental tools used to engage SC when teaching pressure and science concepts? Are the tools in use well suited to the goal(s)? How have these tools changed over time? In what ways are the tools in use constraining or influencing the way the work is done? Do subjects (teachers) have sufficient skill to use the available tools effectively in relation to applying SC cognition when mediating pressure concepts? What other tools could be needed for the work? What knowledge and skills are needed for teachers to engage SC in mediating concepts in pressure? Are they present? Can they be sourced? From where? How and by whom? How willing are they (subjects) to try new tools?

Subjects Are teachers qualified *(informed, skilled, focused etc.)* to engage with SC when teaching pressure concepts? What are the different kinds of skills/knowledge needed for this pedagogy?



Object: What can we *observe* happening in relation to engaging with SC when teaching pressure concepts? How well suited are the actions we can observe to the goals of application/use of SC when teaching pressure concepts? Is there is a misfit? If so why is it happening? What actions/activities can be (re)focused towards use of SC when teaching pressure concepts?

Rules: What are the formal and informal (cultural) rules that promote or constrain teachers from engaging with SC when teaching pressure concepts?? To what degree are these explicitly stated? Are there problems with these rules? What are the other structures that shape the way the work is done?

Community: who else is interested/affected when SC is applied to the teaching of pressure concepts? How can they be brought on board?

Division of labour: Who does what in the teaching and learning process? Does this matter, or is it merely a sensible division of labour? In what ways does the division of labour constrain or enable SC when teaching pressure concepts? Is there any need to share the work in a different way? Why and how?

Figure 16: Components of 2nd generation activity system and how they answer exploration research questions

The components in Figure 14 are the physical and/or mental tools that can be potentially used to engage SC when teaching science concepts. Further, I briefly addressed the sub-questions: Are the tools in use well suited to the goal(s) of education? How have these tools changed? As well as the question do subjects (teachers) have sufficient skills to use the available tools effectively in relation to applying SC cognition when mediating science concepts? Each component is discussed in relation to how it allowed science teachers to engage the SC approach or how each enabled or constrained the engagement of the SC approach. What follows is data revealing how the SC approach is engaged in relation to Figure 14 above.

5.6.1 Data revealing how SC approach is engaged

From the data presented, indications are that physical and mental mediating artefacts shown in Figure 14 as components of an activity system are used to engage the SC approach by schools which are near technological facilities reflecting WMS. The schools which were not near the social and cultural structures hardly engage the SC approach. The two Physical Science textbooks use examples of some social and cultural resources which are not pertinent to the Zambezi Region.

An example is that of a picture of a double decker bus illustrating that it is not stable since its centre of gravity is high. A culturally-relevant example of this concept used by Indigenous communities in this region would be wooden stools which accommodate stability. Such cultural examples were not taken on board by the teachers in under-resourced schools. Other authentic examples to engage the SC approach such as an analysis of pulley systems at a borehole are mentioned in the Physical Science textbooks, but teachers in under-resourced schools do not take learners to those sites. Instead, they opt for examples which do not reflect the prevailing social and cultural context of the region. This means that the tools which reflect WMS are not suitable as they lack the cultural and social contexts so important for learning which Vygotsky (1978) encourages.

Science teachers as the subjects revealed in an activity system shown in Figure 14 do not entertain real life observations to cause changes in the object. The real life observations are the facts which Peirce (1955) suggests are useful when generalizing about observed phenomena in order to come up with a hypothesis. Failure to include real life observations limits science teachers in under-resourced schools from using the SC approach in their practices. As key players in the development of the object, science teachers are not able to lead in activities encouraging the emergence of practices with theories to explain empirical observations in Indigenous communities that match those in WMS. Abductive process applies a different context or worldview to explain a given phenomenon. This accords with the premises of social realism in which any view is considered valid since there is no one way of understanding reality.

In view of the activity system, science teachers as subjects do not operate in isolation. Their activities should receive constructive interference from the community of practice. The community of practice on the other hand is perfected by virtue of having its members participating in the division of labour regulate how their practices must be anchored. Rules which are in the analyzed curriculum documents suggest how the science teachers can bring about changes in their practices. However, even though these rules are dialectically related to each component in the activity system, science teachers do not seem to take note of this.

5.6.2 Data revealing enablers and constraints of SC engagement

Selecting situations only reflecting WMS and ignoring the ones from the culture of the learners constrains engagement of the SC approach. Failure to select the right examples from the Physical Science textbook or adapt those in the curriculum reveals teachers' failure to engage with pedagogical styles responsive to their region and this act as constraining factors to the use of the SC approach in under-resourced schools. This is also reflected in Table 7 which reveals data from the school curriculum using the DAFOR scale. Revelations were non-numerical concepts, engaging SC activities, engaging IK practices, and manifestation of social realism rated in the rare category and manifestation of sociocultural theory was rated in the occasional category. So for teachers to have the necessary skills to select appropriate examples for their school science, they need empowerment so that the non-numerical concepts are all in the dominant category of the DAFOR scale.

For practising teachers like those who participated in this study, the skills can be developed using workshops conducted by a knowledgeable individual. For those still in training to become science teachers, their programs should include these non-numerical concepts. When science teachers do not use observed facts related to relevant circumstances they miss valuable opportunities to apply reasoning from which hypotheses can be drawn. Such hypotheses could blend IK with WMS and so facilitate SC (Peirce, 1955). Failure to do so acts as a constrainer to engage the SC approach in under-resourced schools. Instead teachers are expected to analyse the situation in which they are immersed and then use the situation to solve the anomaly in which they find themselves. This is also emphasized in CHAT as it reveals that existing situations need to be used in order to come up with a solution to an anomaly.

Enablers revealed from the activity system are those found in the curriculum documents analyzed. An extract such as "*The community around the school can be an important support and resource, as well as a source of knowledge*" from NNCBE (2010) suggests that it is revealing alternative ways to engage the SC approach if anomalies such as the absence of resources are noticed. Also, the interactive nature revealed in the activity system act as an enabler since this property ask teachers to cooperate with other components in order to ensure that SC engagement is enabled.

The presence of audio-visual materials in the displayed data acts as an enabler in the engagement of the SC approach. This applies to the audio-visual materials displayed in Figure 14 and 15 which embody science concepts.

5.7 Concluding remarks

When looking at the displayed data one would note that there are some activities in Indigenous communities which reflect science and which can be used in a SC approach. Showing a concept in its visual form is an indicator of activities where Indigenous communities create their own tools. The tools suggested were the same tools which were found suitable as LTSMs in the classroom.

The displayed data leads to the next stage of data presentation in Chapter Six. The focus of Chapter Six is data generated in the Second phase where ELC was engaged.

CHAPTER 6: EXPANSIVE LEARNING ANALYSIS

> *Data display enhances the reading and comprehension of articles, providing the readers with additional data representation and highlighting the authors' data analysis* (Verdinelli & Seagnoli, 2013, p. 377).

6.1 Introduction

Displaying the data not only enhances the reading and comprehension of passages but presents the information systematically so that the reader can draw conclusions supported by the sociocultural and social realism theories discussed in Chapter Three of this thesis. Data generated from brainstorming allowed me to take the necessary action. The objective of this chapter is to display the data generated during expansive learning using the instruments described earlier so that data can be analysed in Chapter Seven and analytical themes that are constructed as a result will aim to answer research questions 3 and 4.

To achieve this end, data from the experimental test is presented. Experimental test data are data obtained when teachers interacted with the selected cultural practices, cultural artefacts and terms during the expansive learning cycle (ELC). We first piloted the proposed activities before using them in their teaching practices. To ensure that the science reflected in the cultural practices, cultural artefacts and social science jargon and that research questions 3 and 4 were addressed, we planned the lessons together. Thereafter, we consulted other experts to ensure that the planned activities were aligned to the SC approach. This also ensured that the tenets of ELC were implemented.

With the view to answering research questions 3 and 4:

- What expansive learning and mediation tools can the study develop to support the use of SC in the teaching of science concepts through the use of pressure in IK and other science practices
- What insights can be obtained from a SC-driven pedagogy?

To ensure that research questions 3 and 4 were answered, some research sub-questions were devised taking into account the stages in ELC that addressed the two research questions in Phase two. These research sub-questions are shown in Figure 17 below.

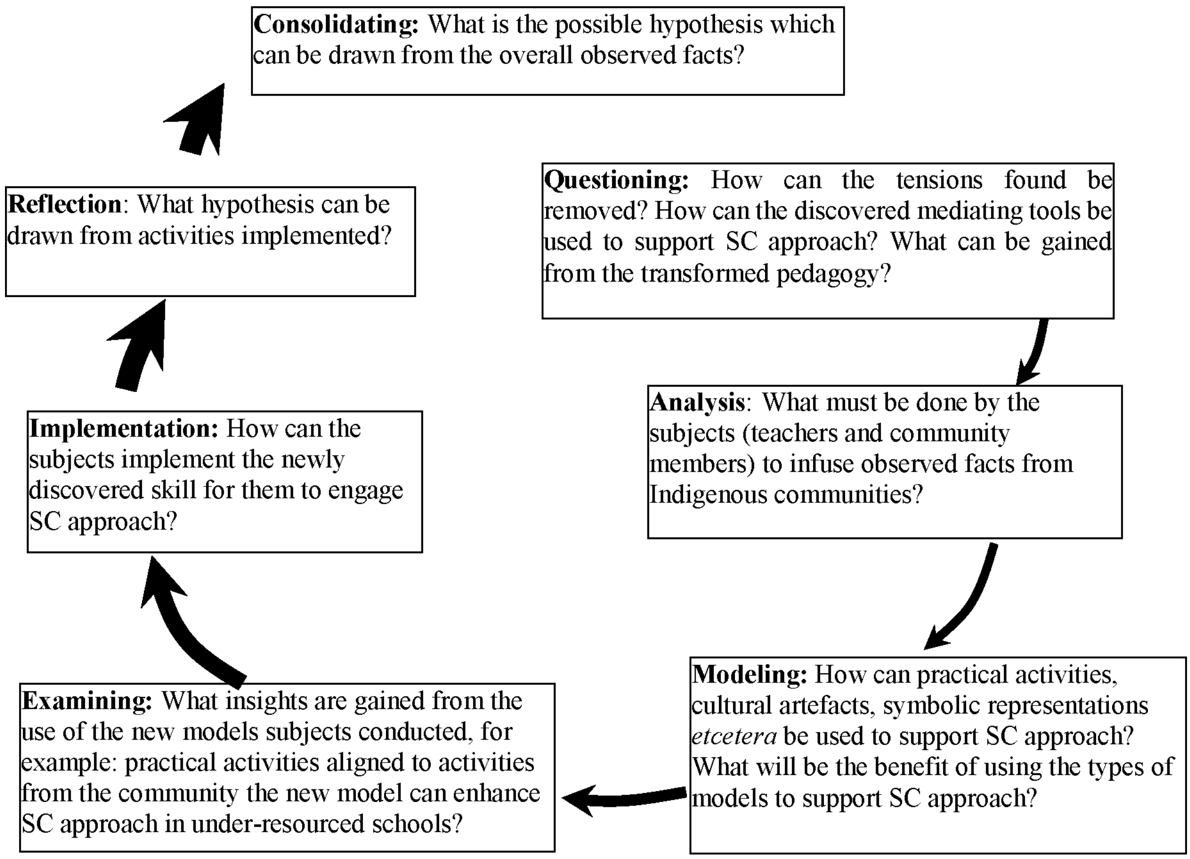


Figure 17: Expansive learning cycle with sub questions to answer questions in Phase two

As stated in Section 5.5.2, as a result of the teachers selecting situations that only reflected WMS the engagement of the SC approach was inhibited. This also repressed the epistemological transfer of the intended WMS since the science concepts taught lacked the cultural context the learner could have used as prior knowledge as Breidlid (2013) suggests. Using ELC while engaging the sub-questions indicated in Figure 17 resulted in a solution to the problem. That is, a solution in which the epistemic therapeutic nature of IK emerged (Baloyi, 2009) to facilitate epistemological transfer. The following section aims to discover how mediational tools can be developed and how to bring the related insights to the surface.

6.2 Cultural practices answering research questions 3 and 4

To ensure that the participating teachers understood what they were required to do, the cultural practices related to pressure suggested by me were presented to each participating teacher before they engaged ELC examples. Each teacher was supplied with the apparatus shown in Figures 19 and 20.

In this study practical activities were introduced to verify, negate, or authenticate the cultural practices that supported the SC approach. Goodwin (2005) suggests that when conducting a practical activity, one starts with a hypothesis. Peirce (1955) refers to analysis and inference of observed facts (in the empirical layer) in order to make them applicable to other circumstances by the formulation of a hypothesis as abduction. In the case of this study, the science teachers' questions aimed at formulating a hypothesis were: *How can cultural practices, artefacts and social science jargon from Indigenous communities support the SC approach in under-resourced schools? Do the results make sense? Can we make sense of the practical activity results?* The sub-questions in Figure 17 assist in answering the above questions as they facilitated the search for patterns.

In conducting the practical activity with the science teachers, I made sure that we used local materials. I also made sure that the cultural practice under investigation was tested by each teacher as it occurs in the environment. For example, when testing the effect of soot on water, soot (unburnt carbon) with teachers, specific volumes of water were placed in a recycled two litre transparent container with a thermometer inserted to measure the temperature. The control for this experiment used an equal volume of water from the same source and a similar thermometer was inserted. Figure 18 below illustrates how the research team investigated the science concepts that Indigenous communities apply in cultural practices related to the Albedo effect.

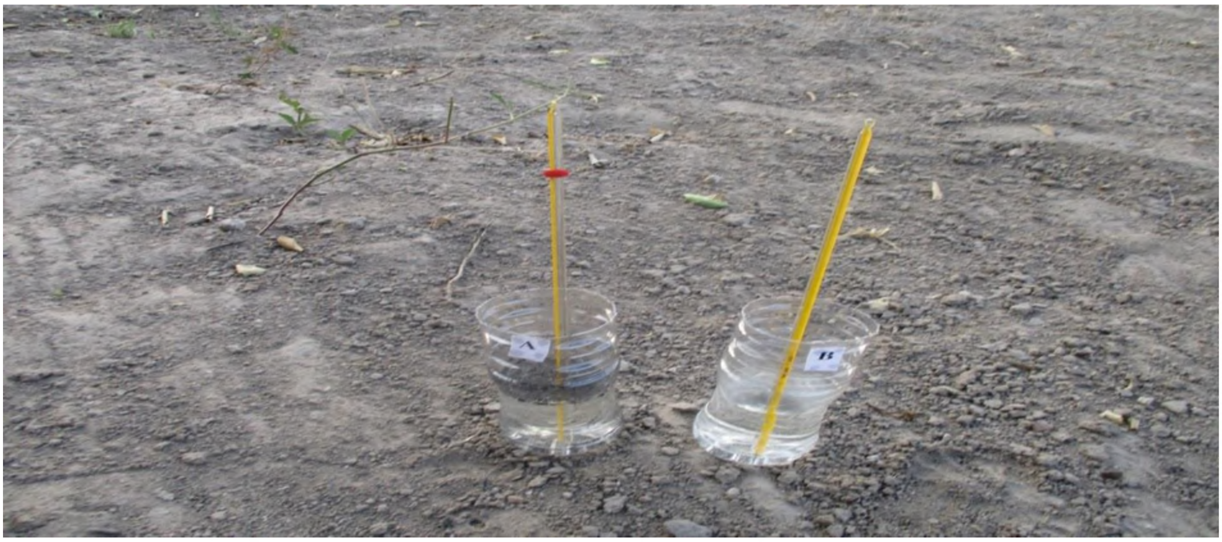


Figure 18: **Verifying the application of the Albedo effect in Indigenous community cultural practices**

In conducting an experimental test to demonstrate the effect of soap in water on evaporation, local available materials were also sourced and used. Each teacher poured a specific volume of a soap solution into a container with a wide surface and placed a thermometer in it. For the control, an equal volume of water without soap was poured into a similar container with a thermometer. After eight hours, the remaining volume of water from the two containers was measured and discussed. Figure 19 below illustrates the setup of the apparatus used to verify how Indigenous communities apply science concepts in cultural practices related to the Marangoni effect.

Figure 19: **Verifying the application of the Marangoni effect in Indigenous community cultural practices**

Thus selected cultural practices, artefacts and terms were analysed by the participating teachers. These were subjected to an experimental test to probe their suitability for use in the SC approach in under-resourced schools.

As the teachers did not have access to sophisticated apparatus such as that found in a well-equipped laboratory since these were rural under-resourced schools that lack such apparatus instead of using thermometers in the practical activity the teachers were told to measure the volume of water left after the experiment. This is the same technique used by indigenous people. Indigenous communities come with knowledge related to the rapid evaporation of water when they see that a pond contaminated with soot or soap dries faster than an uncontaminated one. Indigenous ways of measuring form the basis of formal methods of measurement. The nature of these activities required that I video recorded the experiment in order to record all that transpired.

After some preliminary analysis of data the teachers started seeing some relationships IK and WMS. It is interesting that one of the two teachers who were not able to continue with the study asked me about the results of these experiments.

> *"I heard that the experiments my colleagues conducted conform what we see in WMS. The reason Indigenous communities engage such practices is the fear to be affected when a natural phenomenon fail to provide or a natural resource is depleted through failure to use it sustainably or observe regularities of nature and then apply in their daily lives" teacher who left before completing the research" teacher who did not complete the study.*

From this statement, it could be surmised that a word had spread that the experiments had indeed reflected science. The narrative of the teacher echoes with what the Afrocentric worldview that it is about, considering the affective part of knowing (Hawkins & Thompson, 2007).

The four beakers used were recycled 2 litre plastic soft drink containers. This aligned with the NNCBE (2010) recommendation that recycled material be used in order to obtain LTSMs (Chapter Five). The teachers measured the temperature in each container at hourly intervals during the day until dusk and then they measured the quantity of water at the end of the day. The temperature measurements were averaged and are presented in Table 12 below.

Table 12: Temperature and time variation of a sample of water with soot in Beaker A and without soot in Beaker B (control)

Time (Hrs.)	Beaker A (temperature ^0C)	Beaker B (temperature ^0C) [control]
08:00	24	24
09:00	36	31
10:00	37	35
11:00	40	37
12:00	41	40
13:00	42	40
14:00	40	36
15:00	38	33
16:00	35	31
17:00	31	27
18:00	28	25
19:00	27	23
20:00	26	19

In the above table, the first column represents the average temperature measurements of a sample of water with soot taken at hourly intervals. Column B represents the average temperature measurements of water not contaminated with soot, which served as the control.

Table 13: Temperature and time variation of a sample of water with soap in Beaker C and without soap in Beaker D (control)

Time (Hrs.)	Beaker C (temperature ^0C)	Beaker D (temperature ^0C)
08:00	24	24
09:00	33	32
10:00	35	34
11:00	37	36
12:00	39	37
13:00	40	38
14:00	40	38
15:00	38	36
16:00	36	34
17:00	32	30
18:00	30	28
19:00	29	26
20:00	25	19

In the above table, the first column represents the average temperature measurements of a sample of water with soap taken at hourly intervals. Column B represents the average temperature measurements of water not contaminated with soap, which served as the control. The changes noticed in the volume of water are reported in Chapter Seven. When the participating teachers completed the above practical activity, I asked each teacher to come up with new ways to incorporate their ideas from brainstorming into classroom practice in order to make the SC approach possible. These discussions were circulated to all participating science teachers and reflections related to the conducted practical activity aimed at answering sub-research questions in Figure 17 above were as follows.

The practical activity which the participants and I engaged in removed the tensions which constrained SC engagement in under-resourced schools. Another insight was that cultural practices, artefacts and social science terms from Indigenous communities are mediating tools. This helped to provide responses to the research sub-questions in Figure 17 a response to research questions 3 and 4.

6.3 Data from cultural practice teachers subjected to practical activity

When all the teachers accepted that the lesson plan addressed the tenets of the SC approach, each teacher then proceeded to present the lessons which I videotaped. This helped to check that activities discussed during our expansive learning cycle (ELC) were used. The perceptions of the teachers on the use of culturally-related ideas to support the SC approach were obtained through interviews and reflections which the teachers wrote after the exercise. Data that emerged from the experimental test is discussed and presented in Section 6.3.1 below. Thereafter, data obtained from the interviews and reflections is also displayed.

6.3.1 Relating a blast furnace to *mapukuta*

I accompanied teacher A and learners from school X to visit a community member. The reason for the visit was to discuss the *mapukuta* (Figure 14 and Figure 20 a and b) to see how the processing of metals to make tools such as axes, hoes, drilling of holes for parts of ploughs could be related to the example of a blast furnace found in the recommended textbook. Data which were obtained is presented in Table 14.

Table 14: Data obtained during ELC while engaged in the analysis of mapukuta

Tools for mediating learning which were observed	**Relation of tools observed with science concepts in recommended textbook**
Fresh air supply to the burning point	In a blast furnace fresh air is also supplied but is hot
Coke supplied as a source of heat	In a blast furnace charcoal is also supplied but at a certain stage it is turned into powder for the purpose of increasing the rate of burning
Flame changes colour	A hazy red, growing to brighter yellow as the temperature went up, and ultimately produced a bright white glow and this can be used to determine the temperature at which the *mapukuta* is burning using a colour temperature scale
Metal poked into the fire becomes incandescent producing different colours as time increases	Also a range of different colours produced at different temperatures
Hammering the metal object without breaking	Heating in a *mapukut*a made the metal ductile and malleable
Use of tree bark to handle the hot metal when hammering	Insulating concept when a hot body is handled

The data tabulated in Table 14 above is supported by the diagrams below. The diagram shows how the community member handles a hot object when he intends to hammer it into shape. When asked why he does not use his bare hands to hold the hot material, he had the following to say:

> *"The heat from the mapukuta moved into the metal. The metal is no longer like it was before. It is at the same temperature with the temperature in the mapukuta. I need something to protect my hand or else the heat in the metal moves in my hand and I get burnt" (mapukuta owner).*

(a)

(b)

Figure 20: (a) Community member lifting hot metal from the *mapukuta* using a pipe insulated with a bark of a tree. (b) A community member hammering the metal using a hammer to turn it into a tool

Although the participant as well as the owner of the *mapukuta* (one with a cap with an assistant wearing red and white striped shirt) had elementary science literacy useful as narratives, they were in a position to talk cultural science language. Narratives in cultural science language I believe have a potential to be translated into science classroom situations. Heat is animated as it is taken as if it has organs to move and it is not a surprise as this is supporting the axiological perspective in Afrocentric philosophy (see Section 2.7). Also, this manifests the cosmological focus in the Afrocentric view of structure of reality that matter is animate, inanimate and interconnected (Hawkins & Thompson, 2007). The bad effects of heat are seen as those in which injury is inflicted on an individual if not protected but its beauty is that it can ease the hammering of a metal into a desired shape (Hogue, 2011). Similar activities which involved ELC were also done with teacher B at school X. What follows is what emerged when teacher B conducted his lesson after ELC activities with the researcher.

6.3.2 Community members' behaviour in relation to electrical current teaching

Teacher B had an opportunity to introduce the concepts of electrical conduction starting from cultural practices which learners use to avoid lightning. For example, lightning is about community members are discouraged from taking cover under a tree. The concept of lightning was then related to conduction of charged particles.

The teacher introduced the idea of electrical conduction by first discussing how community members protect themselves from being struck by lightning. When the teacher probed the consequences of standing under a tree when there is a thunderstorm, a number of explanations emerged from the learners. Some of these reasons are tabulated in Table 15 below.

Table 15: Using Analogy to teach discharging using an earth wire

Question from teacher	Response from learners	Analogy in conduction
Why is a person struck by lightning if he takes shelter under a tree when there is lightning?	The tree acts as a path for the flow of particles coming from the cloud to the ground	Tree is a conductor of charged particles
Does a person get struck by lightning if he takes shelter under a tree which is dry?	The tree is hard, the flow of particles is reduced	A hard tree is more resistant to the flow of charged particles
Why do those charges or particles move from the cloud into the ground?	The cloud is saturated with particles which are charged so it wants to shade off excess once it finds a path where they can pass through	A cloud is at a higher potential than the ground where the charges will be carried
If a tree can take the charges in a cloud into the ground, what is the function of a metal rod protruding above the highest building in an area?	It has the same function as a tree	It discharges the cloud so that the house is not struck by lightening

After obtaining the displayed data from school X, I then proceeded to School Y. I engaged in ELC activities with each of the two participating teachers.

6.3.3 Teaching friction using cultural practices

At school Y the two teachers were teaching the concepts of friction and charcoal making. Teacher C had a classroom talk which started with how traditional people made fire in the past. From the discussions a number of ways of making fire were mentioned by the learners. From the discussion the concept of friction was introduced and the factors which determine friction were highlighted through analysing the different ways of fire making to the learners (Appendix 3T3E). The table below shows what emerged.

Table 16: Traditional methods of making fire

Types of fire making	Structure of devices	Factors of friction enforced
Hand drill	Vertical spindle in circular motion inserted in a hole made in a fireboard	All parts of the spindle in contact with the fireboard
Bow drill	Vertical spindle with a knob at the top is inserted in a hole in a fireboard and circular movement achieved through use of a bow wound around the vertical spindle	All parts of the vertical spindle are in contact with the section of the hole in the fireboard and angular velocity is faster than in the hand drill
Pump drill	A vertical spindle with a weight at the base and a horizontal stick	More angular velocity and presence of a weight at the base increases friction

	attached to the spindle with a rope on it to induce movement	
Fire saw	It has a wooden saw rubbed on a heat fireboard	Large surface area of the two are in contact
Use of a lens	Based on concentrating energy from the sun to a point	Not based on friction

The table above shows some methods used to make wood fire and the variants were further analysed to find factors influencing friction. These were found to be dependent on the unique design of each tool. The two diagrams below Table 16(a) and (b) show the method which is used to make fire by taking advantage of friction.

(a) (b)

Figure 21: The hand drill technique used for making fire with two adults demonstrating and two youngsters under apprenticeship looking on (image (a) adapted from *http://www.gateway-africa.com/howdidthey/traditional-fire-making.html*)

Even though the two pictures were taken from different Indigenous communities they still support what the literature has stated. That is, learners are apprenticed in cultural activities undertaken in the community and they are suitable for modelling as suggested in Figure 17. In doing so, learners gain useful knowledge. This is the authentic prior knowledge which a teacher can use to contextualize teaching during the SC approach.

Teacher D at school Y opted to explore how wood is traditionally turned into charcoal and then used that knowledge to teach dry distillation of wood. She pointed out that the use of charcoal by many people in the area was a clear indicator that community members who supplied those in peri-urban settings have in-depth knowledge of how wood can be changed into a product which burns with a blue flame for heating purposes and not for illumination which is yellow. She also suggested that the production of spirits from a mixture of fruits was a good example of knowledge in the community which could be used in a SC approach.

Although in this case fractional distillation is the process used by Indigenous communities, the two can be discussed one after the other. The photograph below was taken at the site which the teacher and I visited during ELC in order to establish how this cultural activity and the related artefacts could be used during teaching. To gain more insight we tasked the woman who was using the cultural artefact in Figure 22 to explain how her model of a fractional distillation process works. She had the following to say:

> *"It works when I supply heat to the earthenware pot and makes the contents of the pot to change to gas. An earthenware pot does not wear out quickly as compared to a pot which is made of metal which can yes quickly absorb the supplied heat. However, a metal pot you can use it for only few encounters but contents quickly boils and release the gas I am more interested in. The pipe from the earthenware pot to the cooler does not necessarily need to be that same as the one in the cooler. The cooling system requires a metal pipe which allows heat to move from the gas and leaves water in the pipe. Also, I need to keep changing the water in the cooler since when it is too warm, it allow the contents to escape as gas" community member..*

Figure 22: Cultural practices involved in spirit production where fractional distillation is used

The narrative from the woman reveals that the cultural science language she uses can be aligned to WMS. The description could also be important to a learner who is an apprentice so that he or she could relate the process of fractional distillation in IK to that in WMS. A learner or a teacher can adapt the IK view used in fractional distillation to make sense of the science phenomenon or process. What follows is the data which emerged in her practice while teaching dry distillation or carbonization as it is sometimes called when done at lower temperatures.

Much can be achieved by exposing learners to ideas that are related to WMS to IK.

Table 17: Ideas emerging after using cultural artefact in teaching dry distillation

Tools for mediating learning which were observed	Relation of tools observed with science concepts in recommended textbook
Charcoal	By product in dry distillation
Gases emitted during wood processing into charcoal	Similar to gases which are condensed when WMS standards are used
Gaseous products are in two parts	There are gases which can be condensed to liquids and some are a tarry residue, soluble tarry liquid, water and acetone and some which cannot be condensed under these conditions and are emitted as carbon dioxide and carbon monoxide
Colour of the flame	The flames are a mixture of yellow and blue

Charcoal as the main by product shown in the above table was then used to light a fire. The students were asked to compare this fire with fire coming from wood which is not processed. The diagram shows a sack full of charcoal used to demonstrate colour of the flame coming from (a) charcoal (b) wood. The wood pieces used to bring a flame were from the same wood that was used to make charcoal.

(a) Charcoal (b) Wood

Figure 23: Samples of charcoal and wood were taken from sack (a) and (b) respectively

The method of charcoal production in Figure 23 (a) was discussed by the learners using their experience from their communities. Classroom talk revealed that charcoal is produced in Indigenous communities by partially burying fresh glowing embers in sand. This was then related to dry distillation, a concept discussed in WMS. Learners were tasked to investigate how the charcoal is produced and supplied to vendors at the market and had this to say when they reported to the teacher:

"Indigenous community members are reluctant to take us to the sites where charcoal is produced but shared how. According to them, the process is like dry distillation. The fear according to the Indigenous community member is the process done does not sustain the forests in the area. Indigenous communities see the cultural practice as easing the destruction of valuable trees" Learner reporting to teacher C.

The narrative shows that the Indigenous community member values the materials which are around them as this is part of their Ubuntu philosophy (Le Grange, 2012). They are what they are because of their environs. The visit the learners paid helped to develop some environmental issues which could not have been developed if the SC approach incorporating IK was not used. After observing the successful engagement of ELC at school Y, I then proceeded to school Z.

6.3.4 Materials and cultural practices used in the community

Only one teacher at school Z had managed to reach the stage of this research where ELC was engaged. The other teacher, F gave excuses whenever approached about issues related to this research. However, teacher F did ask me to explain how the cultural activities, cultural artefacts and social science terms selected at his school could be used to support the SC approach.

This allowed me to proceed to engage ELC activities with teacher E in areas where learners were asked to visit a hut constructed using local available materials such as grass for thatching, wooden poles for walls and clay for plaster. The learners were asked whether the hut offered insulation to the inhabitants. The other activity implemented with his learners was to examine cultural artefacts used for cooling liquids during the hot season in terms of how these could be included in the SC approach to contextualize teaching and learning of science concepts. Table 18 below documents what emerged.

Table 18: Ideas Emerging After Using Local Materials Used In Hut Construction

Tools for mediating learning which were observed	Relation of tools observed with science concepts in recommended textbook
Grass collected locally	Insulating material
Wooden poles	Poor conductor of heat and does not allow lower temperatures to pass through easily
Clay for plastering the walls	Poor conductor of heat and does not allow lower temperatures to pass through easily
Floor smeared with cow dung	Hardens in order to prevent dust from rising
Window	Provides aeration
Seeds of various plants suspended from internal roof These are darkened by smoke from the wood fire	Methods of preservation to ensure that seeds will be preserved since the smoke acts as an antiseptic

The picture of an earthenware pot smeared with wet mud is shown in the diagram below. This was brought into the classroom. This served the purpose of LTSMs.

Figure 24: Earthenware pot used for cooling

Some science knowledge reflected in the earthenware pot was the hardening of the pot with fire aimed at reinforcing the properties of the material. Reinforcing the properties of a material is also done in WMS but the term used is 'allowing'. Allowing comes about as a process used to enhance the properties of a material. Heat curing was then found to be analogous to allowing or serving the same purpose. Other data which emerged which was found to be suitable to use for mediating purposes is shown in Table 19.

Table 19: Tools used for mediating learning

Mediating tools	Concepts in science related to the mediating tools
Baked clay is a porous, semi-permeable material	Membranes found in chemistry are porous and some are semi-permeable
Wet sand used to plaster the external walls of the earthenware pot becomes dry	Latent heat is absorbed from the contents and in doing so the internal temperature in the earthenware pot is lowered
Contents in the earthenware pot are preserved longer because of the lower temperature within the pot.	Cooling effect of the earthenware pot

In the table above, a phenomenon of cooling is observed because of the ability of the earthenware pot to allow heat to pass through its walls. The teacher had also opted to explore hide tanning. As one of the practices raised during brainstorming he explained that traditional tanning methods prevent environmental pollution. When I found that hide tanning has the potential to engage SC, I asked him to give a class in which he discussed ways of safe-guarding the environment.

As well as interviewing the participants engaged in ECL, I also obtained data from using audio-visual techniques.

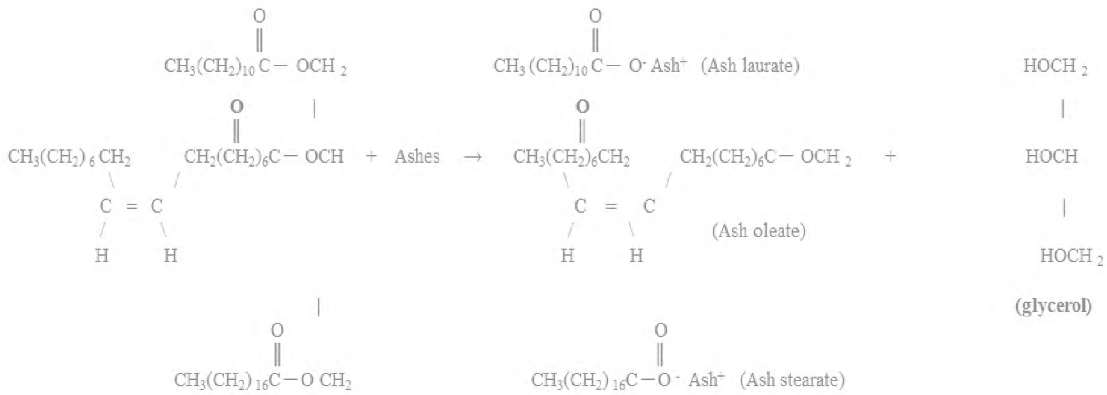
6.4 Data from audio-visual techniques

The teacher asked if I could assist him through ELC involving hide tanning and observe the lesson. He had already taken a picture of a hide shown in Figure 25 below tanned using cultural practices. I discovered that an alkaline substance (ash) and not salt had been used in the process.

Figure 25: A hide waiting to be tanned using cultural practices friendly to environment

The teacher explained that treating the hide with ash differed from treating it with chromium which has an effect on fish and even human beings. The hide was smeared with ash from a hard wood tree and it took only two days to dry. To ensure that it remained flat and stretched during the drying process, the hide was secured with wooden pegs. When the hide was dry, forest products such as bark from a *mopani* tree was then smeared on the hide and wringing done to soften it after fumigating the hide with smoke from a wood fire.

The teacher explained that the traditional methods of curing hides are important in SC as learners learn the properties of alkaline substance in concrete way to supplement the abstract information provided by the text. Taking learners to a site where a hide is being processed allowed them to see the properties of ashes behaving as an alkaline hygroscopic (ability to absorb water from the surrounding) substance. In this case ashes were the alkaline substance and they were also found to be wet during the process of hide preservation. The failure of the hide to rot when salt was not added was an indication that ashes behave like alkaline substances. The reaction of ashes with fats on the hide is referred to as saponification or hydrolysis. This process converted the biotic material to salts as shown in the equation below. The other product glycerol, is also shown in the equation below. They are the salts responsible for preserving the hide.



In his reflection, the teacher pointed out that the concept of hydrolysis (saponification) of fats with ashes (alkaline) can be taught using SC approach if cultural practices related to hide processing are embraced by teachers. A discussion of the salts formed namely ash laurate, ash oleate and ash stearate equips learners with Chemistry language. If the metallic element in the ashes is known this substitutes the prefix ash the name of the element is used instead.

The three above-mentioned products are all salts. Indigenous communities do not only use ashes for curing hides. They also use a mixture of ashes and water to remove the fats from cooking utensils. I had witnessed this practice in my own home when I was a child. My two sisters used to clean cooking utensils spoiled with fats ashes. When I was growing up in those years I never knew why ashes can be used to clean cooking utensils with fats. Water alone is ineffective in removing fat, but in combination with ash it forms a salt which dissolves fat in the same way as soap does.

When teachers embrace the science reflected in cultural structures ~~to~~ and use it in the SC approach, they immerse science learners in a community of practice. McLellan (1994) and Herrington and Oliver (1999) (Section 2.2.1) encourage teachers to adopt practices which provide authentic contexts that reflect the way knowledge is used in everyday real life. This is supported by Lave and Wenger (1991) who consider those who are entering a community of practice as legitimate peripheral participants even though they might be novices.

The teacher also pointed out that hide tanning as practiced by indigenous communities does not use substances which harm the environment. The three salts formed are friendly to the environment. This reinforces the Ubuntu idea which values and protects the environment.

6.5 Data from interviews

To obtain data which could be used for triangulation purposes, interviews were conducted with the remaining teachers who participated in the study. The interview questions probed some of the concepts which were discussed in Chapters Two and Three. Table 20 below shows the data that emerged from the interviews.

Table 20: Data emerging from interviews

Interview questions	Responses emerging	Relation of emerging ideas with concepts discussed in the chapters
1) How does the use of cultural practices, artefacts and social science jargon in the community can assist science teachers in under – resourced schools to engage situated cognition?	-Very useful as it allows a learner to engage in a classroom talk as he uses knowledge acquired basing on his cultural capital. -Useful but science teachers engaging them need to make some modification of the practices and equipped with subject content knowledge good enough to detect science in them.	-SC is possible in under-resourced schools
2) If it does assist, how does it achieve this and if it does not achieve this what are the challenges which come with it?	-Schools are under-equipped, under current situation equity, quality, democracy and access are not achievable. The use of such approach enable addressing the goals.	-Addressing the goals of education
3) Have you engaged in situated cognition in your approaches when teaching science concepts before?	-Not often, if SC is engaged, it is engaged in too few places reflecting science in the region but reflect western science.	-Sociocultural activities engaged are at a different cultural plane
4) If you were engaging or not in situated cognition before this research what enabled or constrained you to engage the situated cognition approach?	-Learners cannot afford to pay the transport to view areas where SC can be engaged as the places are far in other regions. -When using practices Indigenous communities engage in which reflects science, the community member should be invited to school and explain his views which the teacher and learner will then use in their science concept discussion.	- Science knowledge is only in those areas which are applying contemporary technological development -Some science jargon coming with the community member might be useful for a classroom talk

There was a need to triangulate the data from interviews with data from other sources, the participating science teachers were tasked to write reflections on the use of cultural practices in their practices.

6.6 Data from reflections

The data generated from reflections was found to be very useful in stage six of the ELC. Data generated from reflections answered research questions one to four. This explains why this stage of ELC is important. The data which emerged is tabulated in Table 21 below.

Table 21: Data emerging from the teachers' reflections

Excerpt	**Claim supported**
1. Learners in our region fail because the examples we use to contextualize are not those they interact with in their culture. If we then include the cultural practices reflecting science we might improve pass rate in our region.	Cultural translation
2.Usefulness of using local indigenous examples reflecting science lies not only in providing some tools to use when conducting practical activities but also comes with the benefit of allowing a learner interact with what occurs in his social and cultural plane.	Sociocultural
3.Even though the distance to sites where practices reflecting science will be closer, school management should play a pivotal role in sourcing transport, seek permission from Indigenous communities to use such knowledge and give science teachers permission to proceed as this avoids tension which can arise.	Tensions in CHAT
4.One of the challenges learners encounter is to relate what the teachers are saying with what they already know. This challenge can be eliminated when teachers' science language is blended with social science jargon a learner already knows. The terms teachers will use improves the way they will explain science concepts.	Pedagogical content knowledge
5.The challenges faced by the learners when the teachers explain science concepts is that teachers only consider those examples mentioned in the curriculum which uses one knowledge source to explain science concepts. Other views of how science is understood by learners, the learners' community or the teachers are not used. This perpetuates the sole use of one knowledge source.	Social realism

The excerpts in the above table came from what the teachers wrote in their reflections. Teacher A who was more convinced that knowledge from cultural practices and artefacts is helpful in improving scientific literacy had this to say when we were travelling from the *mapukuta* site:

> *"What we must do is to construct a shade in one of the informal locations near the outskirts our town. Land is cheaper there. We stock the shade with cultural artefacts, document all cultural practices and support the writing with pictures of indigenous communities in action. We sometimes arrange to take learners to other regions where technological infrastructure is in vain. Why have we not been seeing that the encounters reflecting science revealed in technological structures reflecting WMS in other regions can be substituted by our local cultural examples? They are accessible and still address the same problem. One knowledgeable community member stand in to explain to learners who will visit the site" (teacher A).*

Teacher A, as I have highlighted that she was the most experienced teacher in our community of practice (Lave & Wenger, 1991; Lave, 1998). As a result, she realised the power of the cultural practices and artefacts useful in epistemologically transferring ideas conceived in Indigenous communities.

6.7 Concluding remarks

In this chapter I presented the data that were generated during the ELC. These are related to the Phase two data-generating instruments discussed in Chapter Four. The aim of this study was *to explore and expand situated cognition in teaching science concepts at the nexus of indigenous knowledge and Western modern science* in under-resourced schools. To pursue this aim, practices reflecting pressure were discussed with participants, these discussions sparked ideas of using other cultural practices depicting science. These ideas were discussed with the teachers and practical activities on them carried out. They introduced cultural practices which support the use of the SC approach in under-resourced schools in the Zambezi Region of Namibia. The data displayed in Chapters Five and Six are analysed in Chapter Seven which follows.

CHAPTER 7: DATA ANALYSIS, INTERPRETATION AND DISCUSSION

Data analysis begins as soon as the researcher begins collecting data and serves two related purposes: to make the researcher totally familiar with the data, and to help in structuring and organizing data into meaningful units (Shaw, 1999, pp. 64-65).

7.1 Introduction

This chapter analyses and discusses the data that emerged from encounters with the science teachers who explored how cultural practices, artefacts and terminology can be used in under-resourced schools to engage SC. As Shaw (1999) suggests in the epigraph, analysis begins immediately the researcher begins collecting data. For this research, the process started when I collected data on cultural practices related to pressure concepts. The results were then used to trigger the interest of the participants who conducted a community analysis on practices reflecting science. This was followed by interpretation and discussion supported by sociocultural theory and social realism. Using ELC, the practices which the science teachers suggested during brainstorming were then subjected to an experimental test after scrutinizing the science embedded in them. When the modelling of new practices with science teachers was completed, teachers proceeded to use the new theoretical ideas in the SC approach.

Besides community analysis, brainstorming and engaging the tenets of ELC with the data generated in Chapter Five, other data generating tools were used such as document analysis, interviews, reflections, audio-visual evidence and an experimental test. The order used to display data was based on whether the instrument generating data is for exploring or for ELC. The order of the data was based on whether its primary purpose was for exploration. Other data generating instruments were employed for miniature expansive learning cycles. The same order in which the data were presented was used in this chapter to analyse, interpret and discuss in order to answer the questions stated in Chapter One.

In the process of analysis, interpretation and discussion I ensured that the goals of this study were satisfied, mainly;

- To explore how science teachers in rural schools use the SC approach in teaching science concepts; and

- To develop meaning-making skills in science with reference to how science concepts can be taught using SC in under-resourced schools through incorporating appropriate examples of IK.

What follows is first an analysis and interpretation of the data displayed in Chapter Five. That is, analysis and discussion of the findings of the exploration done in Phase one. The next analysis will be that of data from Chapter Six in which the miniature expansive learning cycles were engaged using data generating instruments mentioned in Phase two.

7.2 Responding questions in the exploration phase

In the following section I discuss data which emerged from document analysis and how it answered research questions in the exploration phase. The documents analysed were those used in the curriculum in grade 11 Physical Science teaching. Also, included in this section is the discussion and interpretation of data that emerged from community analysis and brain storming.

7.2.1 Responding questions in the exploration phase using data from the textbook

The author of the recommended textbook, Clegg (2005) does use examples of cultural practices which are relevant to the Namibian situation. For example, salt processing is done in Walvis Bay, a rusting chassis in Damaraland, neutralizing a field using lime and others which are displayed in Table 3. These are good, but are they accessible to learners in the Zambezi Region located hundreds of kilometres away from these examples?

This fulfils the sociocultural aspirations of the NNCBE (2010) which states that the cultural and social aspects in a learners' environment should be used. The cultural and social aspects from a learners' environment are the meaning-making tools and teaching resources Vygotsky (1978) supports but only for learners living in the regions where they are found. This makes it difficult for teachers in the Zambezi region to use them in their practices to contextualize teaching. To support this Chisholm and Leyendecker (2008) point out that the learner-centred approach is a failure as teachers in Namibian schools do not engage in it on account of a lack of resources.

The teachers in those areas where the cultural and social structures are situated can easily apprentice the learners in the process of learning (Collins, Brown, & Newman, 1989). Enosi (2010) posits the IK view by suggesting that when learners undergo formal learning they are apprenticed and equipped to continue the activities of their communities. This is not the case with teachers in the Zambezi Region. They only have access to such sites if the economic status of their learners allows them to do so and in most cases it is not possible to engage the SC approach in distant regions.

Clegg's (2005) aim in using these examples in the textbook was to act as guidelines to ensure that teachers see and know them. Thereafter the teachers should provide similar examples of cultural practices within the learners' communities which embody the same phenomena. To achieve in order to engage the SC approach teachers should search for real-life empirical observations of learners (recontextualize) as suggested by Danermark (2001) and relate them to WMS. However, teachers struggle to bring contextualized examples from the learners' community as they restrict themselves to examples depicting WMS in other areas. Instead cultural translation is needed as suggested by Bhabha (1994). Thompson (2013) views this as a process of adapting the curriculum to the region where it is used.

So teachers are encouraged to culturally translate the theories of learning and the approaches which are recommended in the NNCBE (2010) Bhabha (1994). Also, the material in Clegg's (2005) textbook and other science textbooks should be used to create a hybrid curriculum Aikenhead (1997) so that the Science that is taught is accessible and of a high quality. The recommended textbook offers a hybrid curriculum suitable for learners located near the technological infrastructure mentioned in the textbook. However, teachers in the Zambezi Region need to communicate science concepts to their learners which respect their conception of the world and communicative habits and practices (Thompson, 2013).

The textbook example such as the use of lime to neutralize the soil in commercial farming areas is an unfamiliar practice to learners in the Zambezi Region. In the learners' community ashes are used instead. The use of ash to neutralize soil should be mentioned in and discussion pertaining to the use of limestone as an acid-neutralizer. An Afrocentric hybrid curriculum should be developed (Mukwambo, et al. 2014) as it combines the recommended textbook examples with the learners' IK.

There are other examples of cultural and social structures in the textbook that do not depict the Namibian situation. One such example from Clegg (2005) is displayed in Table 3. In this example the author maintains that uranium mining in Gabon is not sustainable. Namibia also has uranium mines so it would be preferable to select mines from the learners' community so that understanding of the concept of sustainability is understood. Various community cultural practices such as how Indigenous communities apply pressure concepts and address sustainability can also be used in case studies as Conole (2008) suggests. In this way one of the premises of the SC approach such as grounding teaching in the actions of everyday situations is achieved (Lave, 1988).

Not only cultural practices depicting science but also cultural artefacts were used which were outside the Namibian situation. Aikenhead (1999) reveals how Aboriginal adults who are members of a community of practice were brought into a classroom but this is never done in schools in the Zambezi Region. If Science teachers did this, they would be able to cross knowledge practice boundaries from the everyday to mesh with the knowledge embedded in WMS.

To illustrate the use of beams as support structures Clegg (2005) considered the Victoria Falls Bridge. In the Zambezi Region, a bridge across the Zambezi River is geographical closer and would make this concept more accessible to learners using the SC approach. Sometimes learners observe phenomena which they explain using IK, the danger is that it could be suppressed if it is in conflict with the WMS worldview. The conflict exists as they try to reconcile their IK worldview and WMS but this is an opportunity as a disequilibrium condition which Dewey (1934) mentions as necessary to enable knowledge construction. This is also supported by Ogunniyi and Hewson's (2008) contiguity argumentation theory as it creates tensions in a learner's cognitive system. By using examples of a bridge in the learners' environment teachers could engage the SC approach in which social science jargon is embraced as the structure is accessible.

Engeström's (1987) second generation activity system displayed in Figure 8 and Figure 9 features the questions to ask in order to explore how science teachers in rural schools use of SC in teaching science concepts encourages the use of language as a mediating tool. In the case of the science teachers in this study, it was found that they did not use social science jargon which allows learners to use language in order to develop verbally (Vygotsky, 1978). Thus social contact developed during the interpsychological plane while apprenticed in IK was not accessed. They preferred to use WMS language which dominates the curriculum materials. In doing so they failed to align their teaching practices to the perspectives of the SC approach which is a social process that plays a role in meaning making (Lave, 1988).

The absence of science jargon in which the author starts by clarifying some science concepts misused in the community is a clear indication that teachers are constrained to use the SC approach as the social tools are not embraced to complement WMS with IK. Schmidt and Stricker (2010) suggest that this is imperative. This is one of the secondary contradictions manifested where learners are denied the use of indigenous ways of understanding nature gained in communities of practice during traditional apprenticeship programmes (Enosi, 2010; Rogoff, 1995). In other words the formative cultural and historical activity system they experienced during informal learning is considered an irrelevant cultural and historical activity system in formal schooling. That activity system is presented in Figure 8 where two systems are shown with one representing the activity of a science teacher and the other representing the Indigenous community activity. They are seen as isolated, yet according to Kuutti (1996) the two activity systems influence each other and other activity systems in their vicinity. The belief that they are not related constrains the engagement of the SC approach in under-resourced schools.

Document analysis in this research revealed that science teachers only engage in SC when they visit areas with technological infrastructure far from schools where they teach. As they do not translate the science language in the recommended textbook to suit the social science jargon learners are equipped with from their communities, this becomes a constraining factor from engaging the SC approach (Wolf, 2008).

7.2.2 Responding questions in the exploration phase using the supporting textbook

In all three schools featured in this research the teachers used "*Physical science: Namibian senior secondary certificate: Ordinary level*" (Kachinda, et al., 2009). Possibly this science textbook has more examples reflecting science which learners experience in their communities. Some of the cultural practices appear in Table 4 in Chapter Five such as the use of a seesaw to teach momentum, the stability of a curved stool used in the community depends on height, the higher the stool the less stable it is because the centre of gravity is elevated. These authors also use a double decker bus as an example to reveal its unstable structure on account of its raised centre of gravity, which is not very relevant to most learners.

Ideas of conduction and insulation are depicted by using a pot with a wooden handle. Learners are familiar with wood as an insulator as they traditionally protect themselves from heat using wooden materials. The use of social science jargon in Kachinda, et al. (2009) is better than that in Clegg (2005). In Kachinda, et al.'s (2009) textbook, the authors illustrate pressure concepts used at a borehole. Cultural artefacts in the diagrams are those found in the learners' community. Even though these authors include diagrams of an open borehole where ropes and pulleys are used the science teachers did not take learners to such sites to ensure that their practices engage the SC approach. This will be revealed in the analysis of how science teachers in under-resourced schools engage the SC approach which is a response to question one.

In view of this data one can say even though there are some suggestions on how to infuse some science from the community into the science currently taught in schools teachers still lack agential character (Morris & Adamson, 2010). Teachers should not embrace a pre-packed curriculum uncritically but as agents of transformation they should infuse the existing curriculum with IK (Bhaskar, 1989).

7.2.3 Official curriculum data in relation to exploration phase questions

The official curriculum document encourages teachers to engage the SC approach (Table 5). The community around the school can be used to support the teaching of science concepts as according to Lave and Wenger (1991) (Section 2.2.1 to 2.3.1) this fulfils the idea of a community of practice supporting the construction of knowledge.

A community member could be invited into the classroom, the school could visit the site where the community member is applying science or the teacher could bring the artefacts used in the community into the classroom. In Canada Aikenhead (1999) engaged the SC approach by bringing Aboriginal adults to explain valuable Aboriginal knowledge which acted as prior knowledge and which meshed with WMS. In the case of science teachers in schools, research was conducted to facilitate understanding of how IK and WMS can complement each other. as shown in Figure 8 they do not bother to bring knowledgeable Indigenous community members or take learners to sites where these communities apply science concepts. This reinforces the idea that in any social system there is social stratification (Bhaskar, 1998) manifested as division of labour. Often teachers dissociate themselves from the indigenous community of practice as they feel their knowledge is inferior to the WMS they engage with at school.

The division of labour allows the members of the community of practice to gain more knowledge as they interact with the environment, gain talent and at the same time perfect the tool they use. Thus members in a community of practice learn and develop and also develop the tools they use to interact with the environment. Shared development in the tool and the user is also supported by Leontèv (1981), Miettinen (2006) and Blunden (2010). Blunden (2010) used CHAT and concluded that people engaging in any activity are continually shaping and being shaped by social contexts. Thus people who might be more knowledgeable can assist in teaching practices. Failure to recognize this constrains the engagement of the SC approach in science teachers' practices when indigenous community members are not brought on board to share their store of valuable knowledge to complement WMS.

From what was extracted during community analysis it was seen that a number of cultural practices are available in the community of the learners. These only wait to be detected and used in the teaching of science concepts. This is evident from Tables 8 to 10 obtained during brainstorming and Figures 14, 15, 21, 22, 23, 24 and 25 obtained using audio-visual techniques.

The official curriculum sees the use of science in the community as extending the boundaries of the classroom into the community as suggested in the NNCBE (2010). Miller and Gildea (1987) support this idea as they suggest that real examples need to be incorporated when teaching. This is one way of extending the boundaries of the classroom where the teacher investigates Indigenous community activity systems reflecting science and complements this with WMS. This approach was successfully implemented by Gerdes (2007) in Mozambique to improve mathematics literacy.

Although the official curriculum acknowledges that the activity system of science teachers is not divorced from the activity system of community members, before undergoing miniature ELC the teachers regarded the activity systems as separate from each other. The two activity systems are networking and receive influence from other activity systems (Mukute & Lotz-Sisitka, 2012) and this need to be taken into account to bring about changes in science teaching practices.

Other themes derived from the analysis of the official curriculum are: cultural translation, sociocultural theory, Africanisation and Ubuntu and IK. Mukwambo, et al. (2014) recommended that using examples from the official curriculum alone is not responsive to the Africanisation of the curriculum where a hybrid curriculum emerges when sociocultural activities from learners are used.

The indigenous community activity system reinforces the Ubuntu philosophy through ensuring that the environment is not polluted or destroyed. This is observed when biodegradable materials such as ash and forest products (Table 8) are used for hide tanning and preventing global warming by not using soot-contaminated containers to draw water (Figure 27). This is supported by mechanistic materialism which is a base of social realism and CHAT (Figure 5) which suggests that each person is an essential part of the whole (Blunden, 2010). On the other hand if the activity system of the teacher is not infused with IK, this could promote practices are not environmentally friendly.

This might lead to contradicting the object in the two activity systems and violating what Ubuntu advocates. According to Meyers (2007), these contradictions are catalysts which are responsible for bringing social change or continuity known as morphogenesis (Archer, 1988). I refer to the contradictions as catalysts since they maintain their structure during interaction and only disappear when tensions do not exist. Failure to weave WMS and IK allows the contradiction to keep interacting within the two activity systems until a point when a social change occurs. The social change occurs when the teachers change their teaching practices and align them with the principles of the SC approach to prevent cases in which results shown in Table 1 change for the better.

The derived themes from the official curriculum support using what the community has at its disposal to engage SC. The sociocultural theory on which the (NNCBE, 2010) is anchored emphasizes social, cultural and communication factors as important in teaching and learning activities (Table 9). Leontèv (1981) and Miettinen (2006) also regard cultural and social factors as important in influencing development. Some statements like, "Children are always exploring their social and material environment, and learn through communication with others - playing, experimenting, experiencing things, and by reflecting on them" are a reflection of what teachers should do in their practices (NNCBE, 2010).

The need to have science teachers' practices aligned to Africanisation and Ubuntu, supported by Mukwambo, et al. (2014) requires the official curriculum to emphasize the need to take the given examples merely as guidelines which should be replaced by examples found in the learners' environment since these reflect the prevailing social and cultural systems (Scott 2013). Scott (2013) like Case (2013) argues that considering sociocultural theory is made up of the two afore-mentioned systems the NNCBE (2010) emphasizes and encourages teachers to use both. One of the constraints is that the NNCBE (2010) does not explicitly say that the examples which it provides are merely guidelines which should be replaced by the social and cultural systems in the learner's environment. This failure to be specific by the NNCBE (2010) could be the reason why teachers only use the examples from WMS and neglect to use science from other cultures.

Properly applied, an African-centred curriculum is sensitive to addressing global warming as shown in the indigenous community practices concerning pressure discussed earlier. Using the view of CHAT (Section 2.3.2), the secondary tensions between the two activity systems become apparent. Whereas the activity system of community members helps to curb global warming, that of science teachers accelerates it. An African-centered curriculum which fuses IK with WMS is important in fusing the two worldviews.

The secondary tensions between the two activity systems are not the only ones which are manifested in the third generation activity system. Primary contradictions between components in an activity system were also observed. Official curriculum falls under rules in the activity system of teachers and also under instruments. These rules teachers follow without making any changes. However, a curriculum is just a guideline and need not be rigid but should be adapted to suit the needs of the beneficiaries. I pointed out in Section 2.1 that the NNCBE is flexible as it allows teachers to introduce innovations into the curriculum. Innovations such as infusing IK into the curriculum are referred to as cultural brokering (Stairs, 1995) (see Section 2.5).

7.2.4 Grade 11 Physical Science syllabus answering Phase two questions

Unlike data from other curriculum documents, the data from the grade 11 Physical Science syllabuses does not suggest how the SC approach can be implemented in schools. Table 4.4 shows that there is nothing in the syllabus which suggests that a teacher needs to engage in the SC approach. The activities of everyday situations that foster the SC approach are not part of the ideas related to cultural practices, artefacts and jargon (Lave, 1988).

It is the teachers' responsibility to contextualize concepts during teaching and learning using the SC approach which must not be absent in teaching activities. Absence of the SC approach should rather be seen as a shortcoming which creates tension around whether to engage the SC approach or not. This should remind teachers that a curriculum document is a guideline which should be adapted to meet the needs of the learners.

A further focus on the activity system of science teachers reveals that the grade 11 Physical Science syllabus is explicit about what teachers should do in order to embrace SC in under-developed schools. It is in the nature of all curriculum documents to be implicit or explicit (Connelly & Clandinin, 1988).

In Indigenous communities the activity systems of community members are explicit and learners participate as apprentices in such knowledge construction programs (Enosi, 2010; Rogoff, 1995). Being both implicit and explicit in those two activity systems allows contradictions to surface. The expectation is that everything should be explicit so that the SC approach can be engaged to ensure that knowledge gained is actively constructed (Hale, 2013).

7.2.5 School curriculum data in relation to questions in the exploration phase

The themes which emerged when the school curriculum was analysed were: engaging SC activities, engaging IK practices, manifestation of sociocultural theory and manifestation of social realism. These themes are some of the concepts or constructs on which the SC approach is anchored. For example, Schwandt (1997) views phenomena perceived in the environment as reality. SC on the other hand emphasizes the use of social systems (social realist view) and cultural systems (sociocultural view). Vygotsky (1978) suggests that they are part of the meaning-making tools in the learner's environment which can be used to support teaching.

These themes were considered as non-numerical concepts. On account of them being non–numeric, they were analysed using the DAFOR scale. Table 7 shows how they were located in relation to the parameters of the scale. Sociocultural systems on account of being considered as meaning-making tools (Case, 2013; Leontѐv, 1981; Wertsch, 1981; Engeström, 1999) as emphasized in CHAT are important for mediating learning (Section 3.2.3.4). These were occasionally seen. This was when the science teachers indicated areas where the science concepts were applied but were not in context since they were located in social and cultural activities that were alien to the learners. Aikenhead (1994) suggests that to address context science teaching and learning should initiate from what the learner knows (Section 1.2). This anchors the learning in prior knowledge when teaching (Mukwambo, 2013). A good example is where teachers used learners' prior knowledge from the community on pressure concepts and augmented this with pressure concepts found in WMS.

The absence of contextualized learning tools creates obstacles if the teachers are equipped only with content knowledge (CK), pedagogical content knowledge (PCK), pedagogical technical content knowledge (PTCK) and curriculum content knowledge (CCK) (Shulman, 1986 in Section 1.5). These knowledge types according to Shulman (1986) and Lave (1988) are applicable to support WMS but not IK. To remove the obstacles teachers should also have pedagogical indigenous content knowledge (PIC), technical indigenous content knowledge (TICK) and content indigenous knowledge (CIK) (Mukwambo, 2013 in Section 2.6) as the lack of these types of knowledge constrains the engagement of the SC approach by science teachers in under-resourced schools.

Engaging SC activities, engaging IK practices and the manifestation of social realism were rarely observed. The engagement of activities using the SC approach was infrequent since science teachers had planned visits to places where science concepts are applied only once throughout the year. This further constrained the use of the SC approach in science teaching in under-resourced schools. This follows their understanding that-the schools where they teach lack the technological infrastructure reflecting science thus necessitating visits to other regions. Similarly, IK was not brought into their practices as a tool for mediating learning.

Failure to infuse IK practices to facilitate the SC approach failed social realism attempts to utilize knowledge in the communities of practice (Lave & Wenger, 1991; Wenger, 1998). There was therefore no discernible progress made towards achieving social justice. Wenger (1998) views failure to engage culturally contextualized practices as a barometer of the absence of the implementation of social justice.

Teaching that is located exclusively in WMS and not infused with IK which reflects indigenous ways of knowing nature has an overarching negative impact since it does not address the challenges which the community faces. Table 1 showing the low percentage marks attained in the Namibia National Examination is a reflection of the challenges faced by community members since knowledge that they can usefully be ploughed back into the community is not acquired. Learning might not be taking place as SC is not engaged or might only be engaged in places where the school has an environment with an infrastructure to support it so cognitive conflicts occur which hamper learning. According to Piaget (1977), a learner experiences cognitive conflict contradictions encountered in the process of accommodating science concepts. If examples are not culturally contextualized by the teacher, the chances are that these contradictions remain in the cognitive system of the learner. Examples such as how global warming is curbed through IK practices can help to alleviate the contradictions a learner encounters.

7.2.6 Data from the community analysis in relation to the exploration phase questions

To explore how science teachers in rural schools engage the SC approach in teaching science concepts, teachers were first exposed to cultural practices reflecting pressure concepts. The technique of modelling was used since models are a pre-requisite to ensure that the SC approach flourishes (Farmer, et al., 1992; Brandt, et al., 1993; Rogoff, 1995). Using the model of pressure they implemented the ideas which emerged during brainstorming. Each teacher selected a particular concept to work on. This process completed in Phase one served to generate data which were then used in Phase two during the miniature expansive learning cycle.

The cultural practices selected revealed that they reflect science as attested in Table 8 to 5.8. Each suggested activity is displayed and shows how it can benefit science teaching. However, teachers were cautioned that cultural practices, artefacts and the cultural science language selected or to be used in SC approach only revealed the empirical level of reality. This level of reality surfaces data based on observable experiences only (Bhaskar, 1993). Suggestions were to gain more insight about the knowledge surfaced and one thus needs to do a thorough analysis since the empirical level reflects what is happening in the other levels of reality (it is a subset of the real level which is also a subset of the actual level); the actual level (concerned with mechanisms) and the real level (concerned with the structure generating the mechanisms) (ibid). This might have led Khupe (2014) in her study conducted in South Africa not to see and then show how the activities in an Indigenous community can benefit science teaching.

To facilitate the process, only a few activities were selected and each teacher and the researcher subjected it to the stages of ELC as mentioned in Chapter Four. The purpose was to introduce an intervention as Engeström (1987) perceives ELC as having a mediation nature.

The *mapukuta* selected at school X by teacher A for example, was found to be useful to support the SC approach when teaching concepts related to a blast furnace. Activities carried out when using a *mapukuta* to process ore or heat treat metals cannot be dismissed by WMS as not reflecting science. These activities came about as a result of Indigenous communities perceiving regularities in natural phenomena as the basis of knowledge (Chambliss, 1989). Also, the similarity of the *mapukuta* and a blast furnace in how they work is a clear pointer that the *mapukuta* is the base of the mechanized blast furnace which came as a result of men using existing historical circumstances (Blunden, 2010). Figure 5 reveals the factors and theories which shaped CHAT. Regularities observed were evidence enough to illuminate that epistemological transfer is possible through use of an IK worldview which focuses attention on culture. This was only when the observable experiences (manifested from the empirical level of reality) are understood as reflecting the structure (representing the real level of reality) generated as the result of the mechanisms or processes from the actual level of reality.

Some of the similarities are that air is blown at the point where the metal or the ore is burning. The colour of the flame in a *mapukuta* differs from that of an ordinary wood fire used for cooking. In this respect it is similar to a blast furnace at a mining site. The temperature of the flames is not measured using an ordinary thermometer but through the use of colour of radiated flame (pyrometry) since colours are indicative of temperature. The major difference is that in a blast furnace activities are mechanized whereas in a *mapukuta* everything is manual and the risk of being burnt is higher. A *mapukuta* itself is a historical artefact developed by man and advances the cognitive skills of the developer or user (Leontèv, 1981; Miettinen, 2006; Blunden, 2010). The similarities unearthed from the activities of a *mapukuta* and blast furnace are a revelation that a science teacher at an under-resourced school can use to engage the SC approach.

Teacher B at school X failed to present her ideas during ELC as she was assigned to other activities by the school management.

Teacher C at school Y who opted to use traditional fire making ideas to teach friction highlighted that the different devices used for fire making are suitable for teaching the concept of friction. Pictures obtained revealing the historical development of the activity of fire making show that friction depends on (a) the condition of the surfaces in contact and (b) the weight of an object. As a result of these beliefs ancestors in Indigenous communities shifted from one fire making device to another as their experience showed them better and faster ways of producing fire. Appendix 3T3E shows the different artefacts developed and how teacher X used them to teach the concept of friction in Physical Science.

Shifting from one tool to another is a clear manifestation of the ideas found in mechanistic materialism which is a component of social realism. In mechanistic materialism the understanding is that development starts with quantity and then quality follows. In the case of fire making, tools used for teaching friction and the factors determining it showed that one of the developed tools was of a better quality and this enabled the teacher teach to friction concepts (Appendix 3T3E).

In case of fire making using friction, some youngsters were able to assist (Figure 21) as they are part of the community of practice (Lave & Wenger, 1991). The presence of youngsters at a site supports what Collins, et al. (1989) state that apprenticeship programs are imperative. Enosi (2010) and Rogoff (1995) agree that learners should undergo apprenticeship, but they do not mention the importance of programs where learners participate in the indigenous community's culturally related activities. However, the evidence is confirmed in this study as shown in Table 16 which serves as a foundation to engage the SC approach in under-resourced schools which are located in communities still practising these cultural activities.

Teacher D at school Y opted to teach fractional distillation by explaining activities in the community which are similar to fractional distillation using convectional laboratory apparatus (Figure 22). Aikenhead (1994) and the NNCBE (2010) encourage science teaching starting from a science related activity found in the community. When we visited the site where the apparatus for processing spirits were in operation Teacher D said;

> *"What we have been doing is a waste of time and financial resources. We visit places which are far for the purpose of engaging SC approach but here in our region we can still do it if we use cultural practices which reflect science. Fractional distillation of a mixture of fermenting substances done at community level can still allow learners to understand the science explanation done at a place where contemporary infrastructure applying fractional distillation. I think there is a need to find all cultural activities reflecting science and then recommend them to science teachers so that we use them for teaching science" (teacher D).*

The same teacher conducted another lesson using an idea from the brainstorming session. The idea of her bringing charcoal to teach the concept of dry distillation was prompted by the fact that her ELC had been a success. Teacher D elected to teach another concept which cropped up during the community analysis which showed that cultural practices were useful in the SC approach. She reported that charcoal was produced locally and if teachers visit these cultural sites learners would be immersed in a culturally authentic context involving dry distillation (Miller & Gildea, 1987). Teacher D observed that the use of activities from the community take the microsystem, mesosystem, exosystem, and macrosystem into account. Bronfenbrenner (2005) emphasizes the importance of the learner's bio-ecological environment as an influence on development.

At school Z revealed that the materials used for hut construction in a community depend on a particular environment. In the Zambezi Region the materials used for construction of huts were environmental friendly which reinforces the Ubuntu philosophy. The need to use materials which the environment can support is important as alternatives might be expensive and could corrode within a short space of time. When materials corrode they could contaminate the environment. Munyai (2014) points out that chromium use in hide tanning or electroplating materials is not kind to the environment. The use of regularities (Chambliss 1989) or patterns (Peirce, 1955) still plays a role in revealing knowledge which can be used in the SC approach when the encounter is related to WMS. The teacher pointed out that even though he visited the area for his learners to see the mediating tools related to the concept of materials there is always a need to visit places outside the Zambezi Region. This will enable learners to see how materials used in one region may not be suitable for another region.

An example is the coast of Namibia where metallic materials are not suitable. In the humid, salty coastal air these materials corrode rapidly. The average learner in the Zambezi region would not be aware of this. The mediating tools such as wooden materials or asbestos that withstands the harsh coastal conditions are compared since the mediating tools are used as LTSMs as recommended by Czerniewicz, et al. (2000) to support teaching in under-resourced schools.

In exploring pedagogical practices to address how the SC approach can be engaged in under-resourced schools, teachers were encouraged to suggest cultural artefacts which reflect reality as they represent events seen, but where the mechanisms are not readily observable (Bhaskar, 1998). These are analysed and discussed below.

7.2.7 Data from cultural artefacts in relation to questions in exploration phase

To develop meaning-making skills as proposed by Vygotsky (1978), cultural and social products (Case, 2013) that bring historical significance and important cultural values in science teaching concepts facilitate the engaging of SC in under-resourced schools. Using the perspective of incorporating appropriate examples of IK, teachers suggested some cultural artefacts which reflected science. Some of these artefacts are displayed in Table 9These were then used for modelling which allowed the teachers' practices to adopt the characteristics of the SC approach as supported by McLellan (1994) and Herrington and Oliver (1995) who are critics and analysts of Lave's (1988) theory (Section 2.2.1).

Cognitive modelling as suggested by Jonassen (1999) took place as the learners were taken to certain sites. Teacher A drew a *mapukuta* (which she used as a mediating tool) and used it to model how materials can have their property changed when heat is supplied to this cultural artefact. Teacher C who taught friction using traditional fire-making techniques also modelled using a chart illustrating variations of fire making techniques. By presenting these concepts to the learners it enabled he teachers to target their ZPD (Vygotsky, 1978) and Bandura (1977) which is essential for successful learning. This is also supported by Engeström (1991) and by the supported activities which were carried out in miniature in the ELC**.** The learners were asked to point out which diagram they thought had the greatest friction (Appendix CP1). In addition the teacher also had a hand drill used for starting fire to use as a model in the class. That is a cultural artefact used as a mediating tool.

Teacher D brought a sack of charcoal made locally. She also had a small plastic bag full of coke which he took from the school laboratory. These two served as mediating tools of the concepts she was teaching. The presence of the mediating tools assisted in improving her PCK (Shulman, 1986).

Learners were not sure of the distinction between coke and coal, charcoal and wood. They observed what colour flame was produced when each burns in oxygen as LTSMs (Czerniewicz, et al., 2000) as mediating and meaning making tools (Vygotsky, 1978). Accepting that artefacts from the community reflect science, allowed this teacher to use these models of energy. The learners were asked to observe the colour of the flames that radiated from the sources.

Teacher E took learners to a site where they engaged with SC. Even though they did not have a thermometer he asked two learners to conduct a practical activity. One learner was asked to enter a hut made of local materials – grass for roofing and poles for the walls plastered with clay soil. The other learner was asked to enter a hut where the roof and walls were made of corrugated iron. They then discussed their experiences with those who had remained outside. The two, after cognitive modelling, which (Bandura, 1977) emphasized is linked to cognitive apprentice came up with different results (Section 2.4.1). The one learner reported that it was very hot in the corrugated iron hut, while the other learner reported that it was cool inside the hut made of clay and thatched with grass. Taking these responses, the teacher infused ideas from science of insulators of heat, and poor and good conductors of heat.

According to Teacher E, insulators were analogous to *muchimbam*i (*salvinia molesta*) mentioned during brainstorming (Table 5. 3.2.1). The aquatic plant (covering fish in a dugout canoe below) is used by fishermen when they transport their catch to the market (Figure 26).

Figure 26: ***Salvinia molesta* (*muchimbami*) used to insulate fish from heat (adapted from *http://joel-muller.blogspot.com/*)**

In the fishing grounds as there are no ice cubes to preserve the fish, *salvinia molesta* is used to insulate the fish from the heat from the sun. Thus the fish reaches the market still fresh. Relating to the properties of local materials allowed the teacher to soft scaffold (Brush & Saye, 2001) the learners in order to attain their ZPD (Section 2.3). Van Lier (1996) advocates soft scaffolding which allows the teacher to use cultural practices the learner knows.

Stott's (2016) and Valsiner's (1997) ideas of considering the ZFM and ZPA was embraced as all the systems influencing development mentioned by Bronfenbrenner (2005) were used to facilitate learning. If other learners contributed materials and ideas from their communities for the afore-mentioned activity, then a multicultural approach in teaching science is achieved. The cultural artefacts which were used by the participating teachers acted as mediating tools during the process of science teaching.

7.2.8 Data from cultural jargon in relation to questions in Phase one

Many terms in science are misused in the community such as those terms displayed in Table 5. 3. 3.1. Sometimes, according to the community those concepts or constructs are labelled as terms in that particular language. According to Mukhtoraliyevna (2016), one word is used for all the strands in the category because an equivalent does not exist in that language. The cause in most cases is cultural differences. For example, the word beer exists in some communities. These communities do not use words like spirit and wine. Therefore, when such terms are used in scientific language their meaning might not be immediately understood. In such cases visiting a site, bringing a knowledgeable community member into the classroom or bringing the appropriate artefacts when teaching the premises of SC (Lave & Wenger, 1991) is useful, as teacher D demonstrated.

In the case of teacher D who conducted a lesson on fractional distillation, a distinction between spirit, beer and wine was made. According to her, beer is a product of fermentation. Fractional distillation produces spirits. Demonstrating using the cultural artefacts (Figure 22) enabled the teacher to engage an SC approach to address misconceptions in science language within the community. However, the initial process in spirit making is fermentation and distillation follows later.

The social term which is misused is according to Vygotsky (1978), the social contact which allows one to be more aware of one's environment. Social contact plays a role in the intrapsychological level (Section 3.2.1). It is important for the teacher to allow learners to assimilate or accommodate science concepts by paying attention to social science jargon formed in a community of practice during informal learning.

So, when engaging the SC approach using cultural perspectives, it is imperative that encounters in which these concepts are misused are brought into ~~a~~ classroom talk (Lemke, 1990). It is in the classroom talk where the teacher can facilitate cultural transmission and assimilation, Aikenhead (1997) (Section 2.5) to foster deep understanding. In doing so, science concepts learnt in a particular community of practice will present themselves in any one of Ogunniyi and Hewson (2008) five categories in the contiguity argumentation theory (Section 1.2). Contiguity argumentation theory enables learners to construct proper conceptions of science concepts if the teacher starts by analysing misconceptions such as the one described below.

Another example of a misconception emanating from misuse of science jargon is when a "capacitor" is referred to as storing electricity or a charge. The learner has the science language but what needs to be transformed to allow for proper understanding is that electricity cannot be stored since electricity is a flow of charged particles. So, in a capacitor charged particles are static and this allows one to refer to the static charged particles as electrical energy. This will allow a learner to see that a capacitor stores electrical energy. Discussions of this nature allow one to highlight other concepts that are not used properly in informal education. These can be transformed into useful science knowledge which then allows access to science in the same way one would access it when engaged in a WMS community of practice.

Another instance where terms are used incorrectly is when Indigenous communities of practice use the term 'weight' instead of 'mass'. Ogunniyi and Hewson's (2008) contiguity argumentation theory can also be used to make a distinction between 'distance' and 'displacement', and between 'velocity' and 'speed'. These scientific terms are not used correctly in the indigenous community activity systems in the Zambezi Region. Clarification of these concepts was done during the miniature ELC and during brainstorming (see Table 10).

When the teacher at school Y brought the two materials used as sources of energy and their purified form, the difference between coal and charcoal and between coke and wood became clear to the learners. The practical activity she conducted-allowed learners to see that when wood and coal burn they produce a yellow flame suitable for illumination. A yellow flame is associated with incomplete combustion which produces soot. Cultural practices in pressure analysed from the view of Indigenous communities are elements which accelerate global warming. This is also supported by Ramanathan and Carmichael (2008), Prayetton (2009), and

Chen (2012) who used a WMS perspective to explain how soot contributes to global warming. This insight allowed the teacher to incorporate global warming in the lesson. This would not have been possible if a SC approach using social and cultural structures had not taken place.

On the other hand, coke and charcoal produced a blue flame which was very hot and suitable for heating. What followed was an explanation that this process does not contribute to global warming since complete combustion takes place. The social science jargon mediated science concepts and enabled contextualized teaching to address scientific literacy.

7.2.9 Data from brainstorming in relation to questions in Phase one

When I started this study I expected that only a few suggestions relating to practices reflecting science in the community would be forthcoming. Also, I expected the teachers who participated in the research would only report on practices on pressure which I had used as exemplars to sensitize them. Evidence to the contrary is reflected in Table 11. Each mark under each column is a manifestation that teachers A, B, C, D, E and F all managed to select a cultural practice (CP), cultural artefact (CA) and social science jargon (SJ). All the teachers identified cultural activities which reflect science found in the community.

Some tensions as suggested by Meyers (2007) were experienced when the teachers were asked to select jargon in the community which reflected science. Another challenge was how to obtain the object shown in the activity systems since each component is dialectically related to the other (Ratner, 2002; 2006). The reason for this is that in order to detect the jargon, one needs to be well versed in science or have a high scientific literacy level. Other challenges were when we investigated whether the selected jargon which the learners acquire was used properly in the community. This also required the teachers to have a detailed understanding of WMS to know which science term is misused.

Lack of depth in science creates tension when there is a need to come up with pedagogies which are culturally responsive (Brown, et al., 1989; Lave & Wenger, 1991). This tension arises since CK is needed for teaching. The tensions weaken the activity system since all elements are in a dialectical relationship and have a dialectical causative effect on each other (Archer, 1995). The tension radiating from the teacher who is the subject will affect the rules in the curriculum, it might prevent the teacher from interacting with community members in practice, and result in a failure to achieve the task assigned.

A lack of depth in science terminology in order to detect jargon in the community means that a teacher might not use the appropriate mediating tools which are one of the requirements for the SC approach to flourish. In such instances, the object of the activity system is not achieved. This is then manifested in the form of high failure rate as evidenced in Section 1.5 where I displayed a table on how learners perform in national examinations. Absence of CK on the part of the teacher means that the teacher might not have the other knowledge types mentioned by Shulman (1986).

Another manifestation of the existence of cultural practices revealing science that can be used in the SC approach are pictures. I took photographs to find out whether what the teachers described did exist in their communities. Some of these photographs are shown in Figure 14 and Figure 15 in Chapter Five.

Data generating instruments such as experimental tests could not have been brought into this research without data generated during exploring in Phase one. Data generated during Phase one gave the participating teachers an opportunity to participate in the stages of the miniature expansive learning cycle, using, questioning, analysis, modelling, examining, implementing, reflection and consolidation Engeström (2007) advocates the interventionist nature of these activities. Also, the same data allowed me to obtain reflections from other teachers and also to hear their opinions during the interview process. The analysis of data from exploration data generating instruments appears in the following section.

7.3 Data from sites supporting SC in relation to questions in Phase two

Even though teachers had pointed out areas where science concepts are applied in the community during brainstorming, not all had managed to take their learners to the sites they had mentioned or to use all the ideas gained during ELC in their practices. Those who did not visit the sites with their learners merely referred their learners to these sites. The teachers therefore drew on pedagogical indigenous content knowledge and examples from the learners' culture and they were able to immerse the learners into contextualized authentic activities (Collins, et al., 1989) in (Section 2.3.2). This was on account of questioning, analyzing, modelling, examining, implementing, reflecting and then consolidating the ideas they had contributed during brainstorming sessions.

Because of its interventionist character Engeström (1987) the DWR discussed in section 6.1 allowed experimental tests to be conducted with the participating teachers. This served to explore what was happening in the real level of reality (finding components and their relationships) and then establish the mechanism of the cultural practices used in the intervention. The activities subjected to experimental tests pertained to the culturally related issues that arose during brainstorming. These were mainly related to a *mapukuta* the blast furnace, teaching the concept of friction using activities related to fire generation, fractional and dry distillation activities in the community and properties of materials in the community and their use. The data emerging from experimental tests shows that all the activities selected from the community reflected science concepts in WMS.

The results were similar to those obtained when pressure cultural activities were subjected to experimental tests. The concepts that emerged compared with those in WMS. Below is an analysis of data emerging from an examination of cultural practices reflecting pressure.

Although the central focus in this section is to answer research questions in Phase two, some responses were also relevant to research questions in Phase one. This is due to the fact that these phases are intertwined and serve the same purpose.

7.3.1 Data from cultural practice on pressure in answering Phase two questions

When the values in Table 12 generated by the participating teachers were plotted, it was revealed that the temperature in beaker A ascended faster than the temperature in beaker B (Figure 27). The temperature in beaker A reached a maximum value while the temperature in beaker B lagged behind. At sunset the opposite was true. Temperature in beaker B descended faster while that in beaker A lagged behind. This complies with what I stated that water contaminated with soot retains heat. These findings are confirmed by Beaudoin's (2014) studies in the Arctic region. These results are used to explain anomalies experienced by farmers in America. A science teacher needs to adapt these situations to an African context, such as the Zambezi region. Adapting this information is what Bhabha (1994) referred to as cultural translation.

This is why the Albedo effect as it is known is a threat to global warming (Section 2.4.2). The community members use this knowledge of the Albedo effect but science teachers do not take cognizance of this as evidenced by the absence of cultural translation Bhabha (1994) and Thompson (2013) in the school curriculum. To further support that water with soot retains more heat compared with water without soot, the graph in Figure 27 shows that beaker A remained at a temperature of 25^0C while beaker B remained at a temperature of 19^0C.

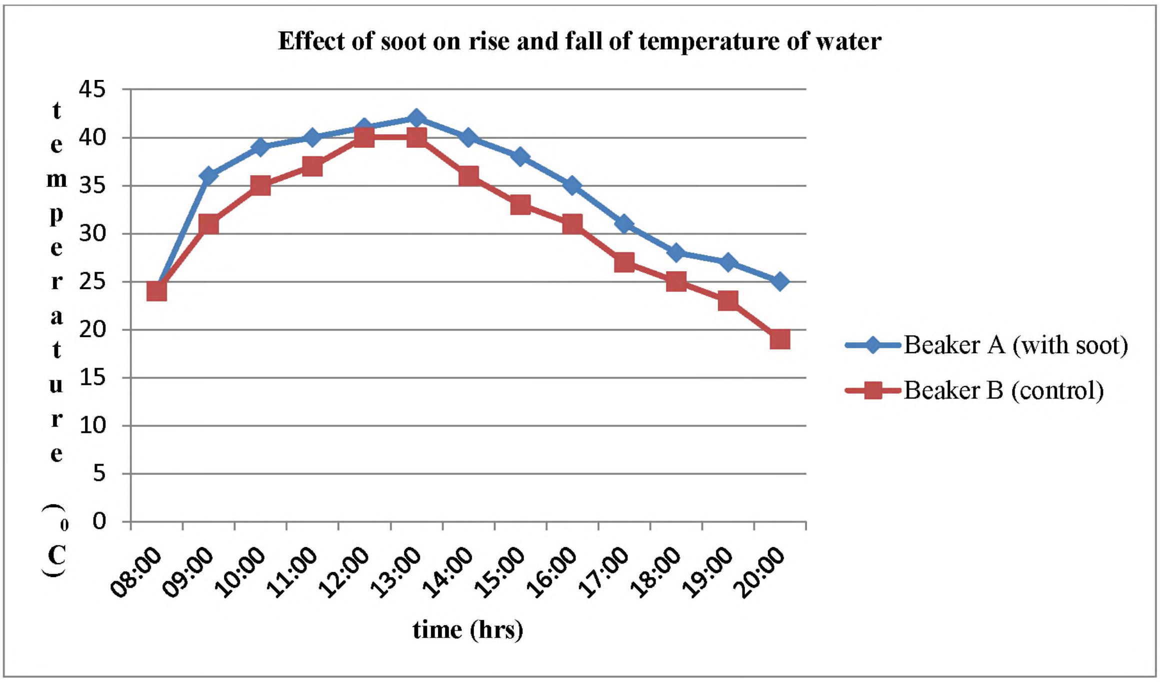


Figure 27: Albedo effect manifested in cultural practices in pressure

To further support that more water is lost from a beaker with soot-contaminated water, the data reveals that even though there were 100ml of water in each beaker, very little was left 62ml and 68ml respectively.

The same situation observed with beaker A and B was observed with beaker C which contained a soap solution and beaker D ordinary water. During sunrise, temperature in beaker C rose faster while that in beaker D lagged behind. During sunset the opposite was true. The temperature in the control beaker fell faster than the temperature in beaker C. Also, more water was lost in beaker C than in beaker D. Only 67ml was measured in beaker C while beaker D had 68ml. This conforms to Gonzalez's (1987) theory that pressure gradient exists if two liquids with different vapour pressure are mixed. The diagram below in Figure 28 shows how the temperature and time interval are related. These results are analysed using IK views reflecting tenets of WMS.

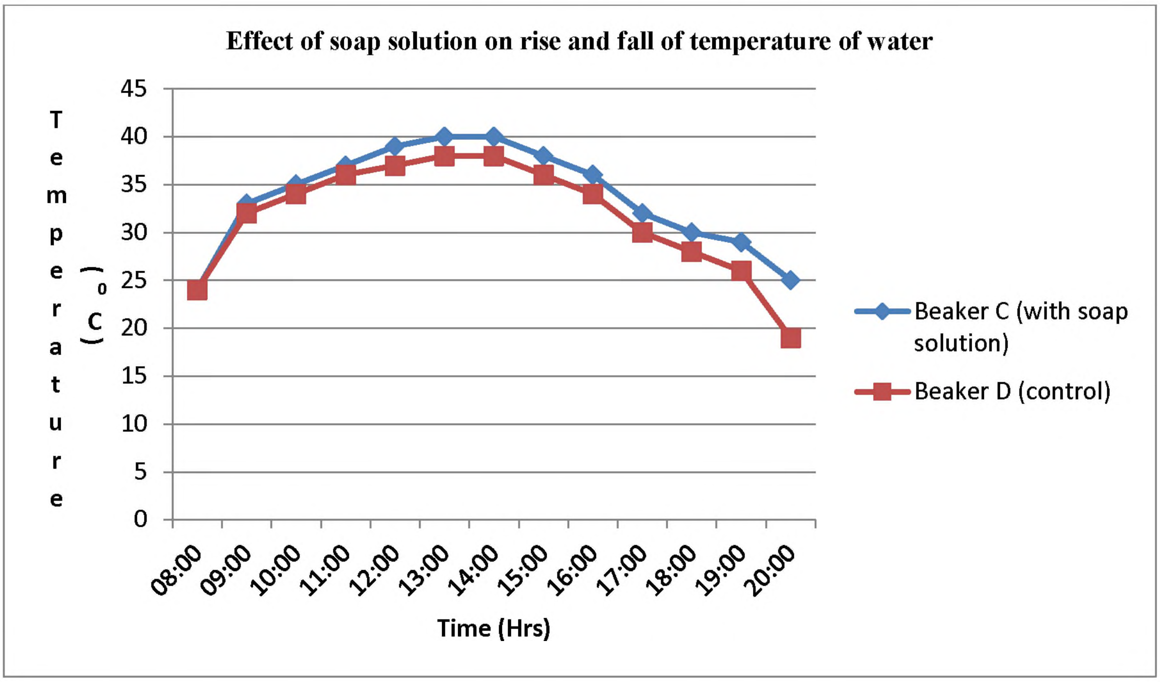


Figure 28: Marangoni effect manifested in cultural practices in pressure

In most cases Indigenous communities do not perceive causal relationships. Their knowledge is gained through observing regularities associated with the events Chambliss (1989). Yin (2003) refers to the events as "real-life events" (p. 2). Indigenous communities do not talk of the mechanism which according to realism is an explanation of the makeup and behaviour as components of reality (Putnam, 1999). The Indigenous communities analysis of regularities also yielded another phenomenon which can be used in the SC approach in under-resourced schools to link with knowledge found in WMS.

The results obtained in the two previous figures paved the way for the science teachers to use cultural practices as the starting point in practical activities. The experimental test on pressure cultural practices inspired agency and this produced the data I analyse below (Bronfenbrener, 1979; Bhaskar, 1989; Wadsworth, 2004; Morris & Adamson, 2010).

Two teachers who had initially opted to participate in the research were not able to take part as they were delegated duties to do outside the region. Because of time constraints it was impossible to wait for them to implement the ideas they had tested and transformed into a cultural responsive pedagogical practice.

Teacher D at school Y engaged with new ideas but did not visit the site with students but visited the site herself and brought back materials to use with learners. The remaining three teachers visited the site where science concepts are applied in the community with their learners. The analysis and discussion of data done above has focused–attention on answering research question one: *How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching science concepts?* Less attention has been paid to research question two: *What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts?* To redress this anomaly data generated is discussed and analysed in relation to the components of the second generation activity system shown in Figure 9. In doing so sub-questions indicated in that figure can be answered and then synthesized to answer the second research question. This will then lead to a better understanding of the enablers and constraints of the SC approach. With this in view the diagram presented in Figure 9 is presented again but with responses to the sub- questions presented before as shown in Figure 29 below.

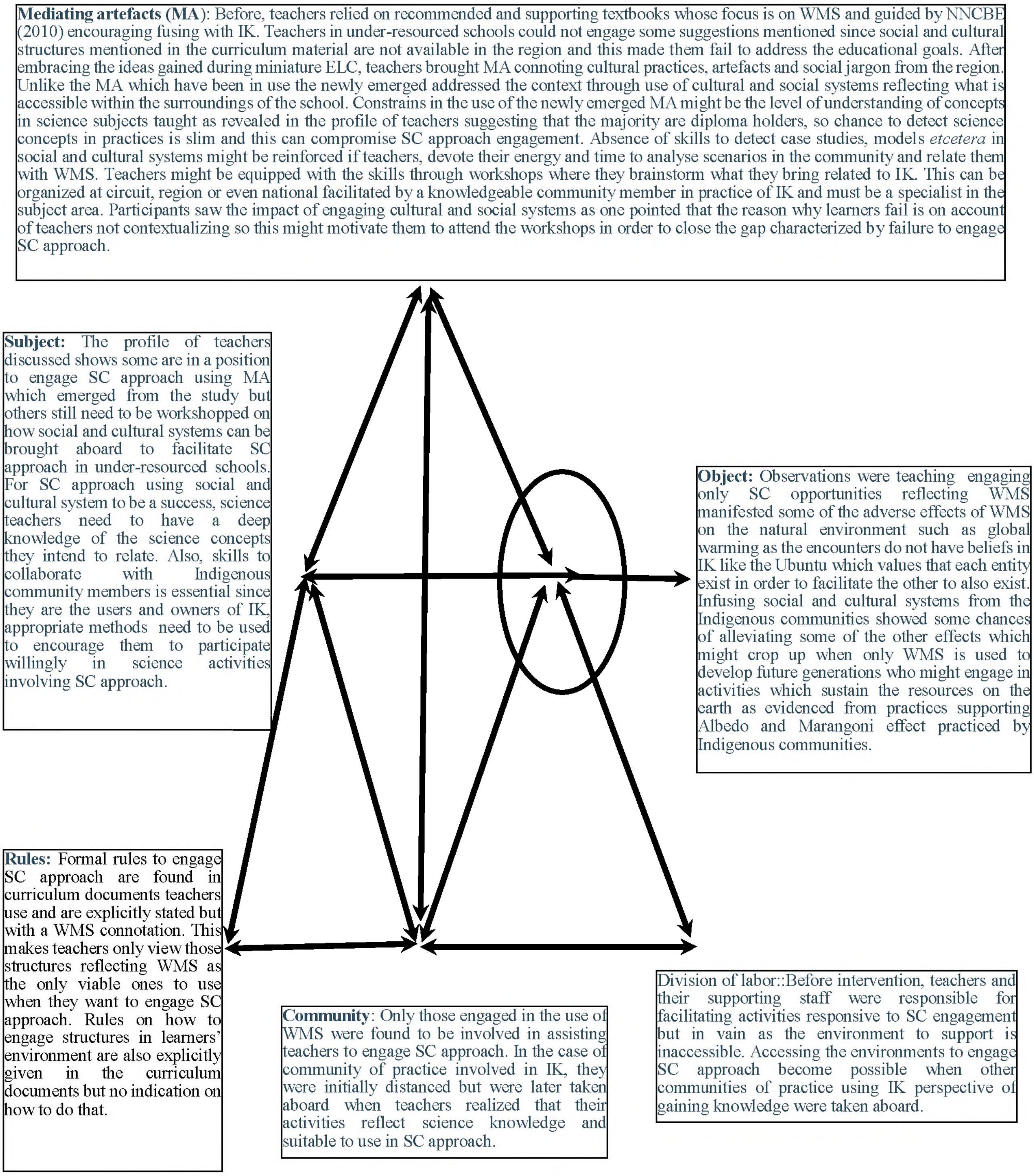


Figure 29: Data generated in relationship to components of the second generation activity system

In view of the diagram above each of the components is discussed in relation to how the components will assist to answer research question two and also to achieve the goal of the study *To explore and expand how science teachers in rural schools use the SC approach in teaching science concepts.* As stated before components are dialectically related Plakitsi (2013). This means that what happens to one component will affect the other. The six components constituting CHAT are discussed below.

Mediating artefacts

The data obtained served as mediating artefacts which can be used when science teachers engage with the SC approach. To best understand how the data achieved this, one needs to understand the types of mediating artefacts (Conole, 2008). The types of mediating artefacts are presented in the diagram below together with data generated which belongs to each type of mediating artefact.

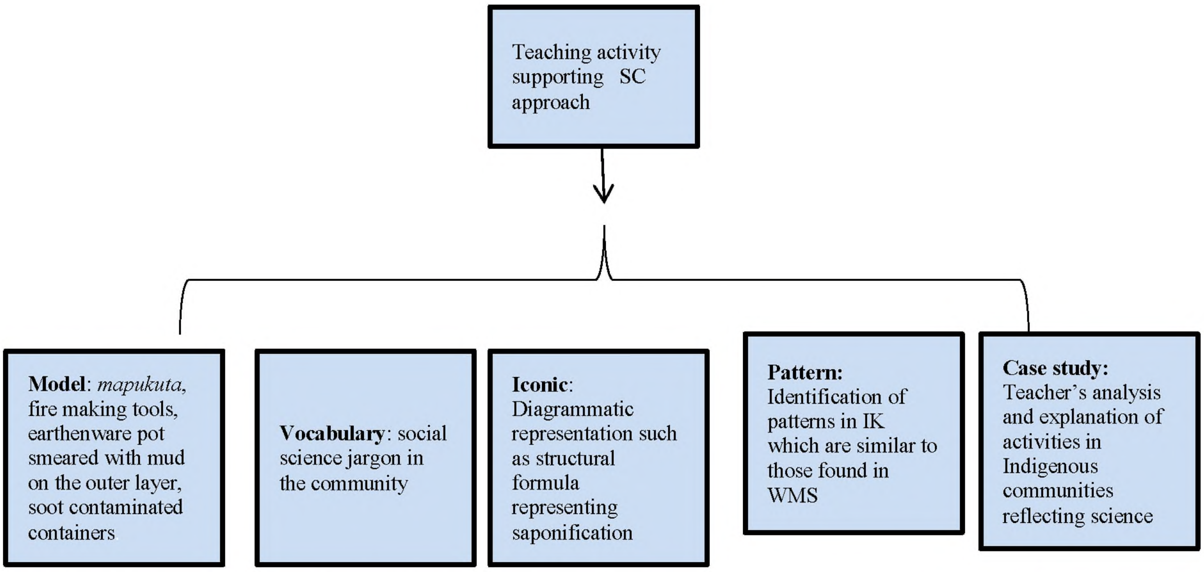


Figure 30: Types of mediating artefacts in relationship to those that emerged *(Adapted from Conole, 2008, p. 191)*

7.3.2 Data answering questions in Phase two after engaging ELC

As some of the instruments found in both phases of the study play the same role, this served to show in this interpretivist and interventionist (Seale, 1999) study that the data obtained is reliable and can be used in under-resourced schools to engage the SC approach. For example brainstorming, interviews and audio-visual techniques are common in both phases. This section of the study analyses and discusses data which was generated in order to answer research question three and four.

Teacher A from school X took learners to the site where the community extracts, purifies and manufactures tools using a device known as a *mapukuta*. Teacher C at school Y visited a site where fire is produced using the understanding that friction generates heat which can be harnessed to make fire. Teacher F at school Z visited a homestead and referenced the materials used to construct the huts when teaching properties of material and their use. The data from the teachers is discussed in relation to the two activity systems shown in Figure 31.

Even though I analysed the data which emerged from the visits using two activity systems, it does not mean that the two activities exist in isolation (Meyers, 2007). Other activity systems interact with those two under study (Section 3.2.3.4). Activity systems exist in a network influencing each other (Engeström, 1987). Other activity systems which might have influenced the two activity systems presented in the third generation in Figure 10 are that of the curriculum planner, the researcher, and administration activity system of the school. Figure 10 presented before is now presented below in Figure 31. Unlike Figure 10, Figure 31 shows according to Rogoff, (1995) and Enosi (2010) that learners are apprenticed in both activity systems and have one aim. The aim is to gain knowledge in both communities of practice. In addition the teacher's activity system and the community member's activity system are related in that they aim to facilitate the learning process towards the same object.

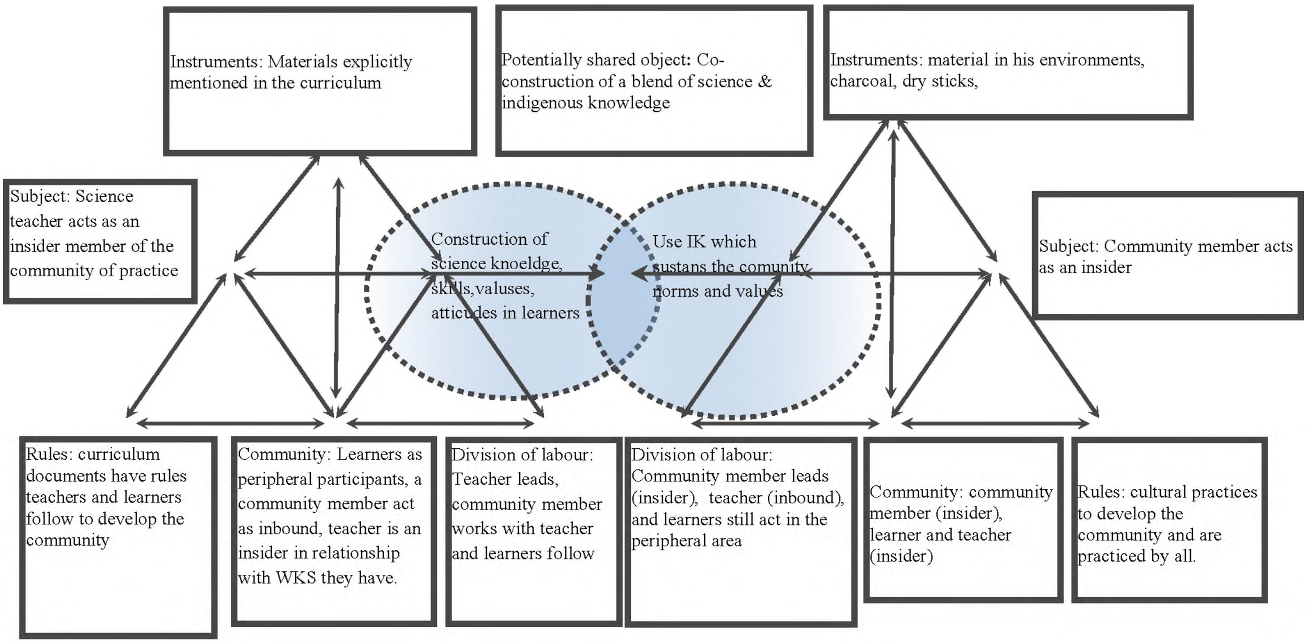


Figure 31: Elements in the components of a teacher and community member activity system when morphogenesis of teaching practices prevail

In the activity system in Chapter Four, members' participation was restricted to certain components of the activity systems. The diagram above paints a different picture. All members appear in each and every grouping. Also, the upper components of the activity systems indicate that those instruments are both the same. However, the curriculum document is not explicit, it just states that the cultural ideas used need to be embedded in the cultural context of a learner which according to Aikenhead (1999) facilitates cultural border crossing. In short, teachers need to include examples from the learners' environment.

This is supported by the fact that the activity systems are social systems which relate to each other through social interaction and that they constitute social reality (Archer, 1988, 1995). Failure to recognize the interaction which exists between the activity systems leads to morphostasis. According to Archer (1995), this promotes teaching practices which do not change. Recognition of the interaction of the activity systems after engaging miniature expansive learning cycles with the six teachers promoted morphogenesis. The changes in the practices of Physical Science teachers when they incorporated social and cultural structures in a learner's environment to support the SC approach in under-resourced schools, illustrates Archer's morphogenesis (1995).

Morphogenesis which occurred after ELC was engaged displaced monocultural pedagogical practices with multicultural pedagogical practices. Thus the two knowledge systems were observed to co-exist through the teachers' use of cultural practices, artefacts and jargon (Schmidt & Stricker, 2010). This promoted the SC approach as evidenced from the four remaining teachers who embraced the tenets of SC in their practices.

Evidence of the coexistence of knowledge systems is in the fact that the four remaining teachers engaged in practices in which the two knowledge systems were recognized as expected by the NNCB. Teacher A at school X found that activities in a *mapukuta* can be related to activities in a blast furnace. Teacher C at school Y taught the factors influencing friction through a study of developments in fire making tools. Teacher D at school Y who conducted a lesson on distillation and dry distillation conducted some practical activities in which she demonstrated the differences between various sources of energy

In so doing Teacher D aligned her practice to NMEC (2010) guidelines which viewed the poor symbols and low pass rate (Table 1) as due to a lack of contextualizing teaching. Teacher D used an example in which some activities in a social system contributed a major role in enabling under-resourced schools to address the quality of their teaching by employing practices similar to those teachers teaching science concepts in well-resourced schools.

Even though teacher F and B could not present the activities aligned to the SC approach, their activities did introduce a morphogenesis to NNCBE. Giddens (1984) structuration theory maintains that an activity must not be divorced from the social context in which it occurs. The case of winnowing is an example. The fire they used while winnowing allowed those facilitating the activity system to separate the components through exploiting convectional current and this acted as a mediating tool. The activities introduced by participants after engaging in miniature ELC mediated learning. Through use of the different mediating tools (Table 14, 17, Figure Table 16 and 22) the different strands of the curriculum were engaged. This made it possible to create the same potentially shared object. Blindly following the formal curriculum does not allow similar objects to be formed from the different activity systems and when such a scenario exists contradictions are created.

The important mediating tools (Vygotsky, 1978) to develop meaning making came from the Indigenous communities and the SC approach. In using these, equity and access which the Namibian curriculum advocates are met (UNICEF, 2011). Further evidence of morphogenesis when the SC approach is engaged through the use of cultural social systems comes from interviews and reflections.

7.3.3 Data from interviews answering questions in Phase two

From the interviews it emerged that after ELC teachers in under-resourced schools supported one another and devised practices consonant with the SC approach (Table 20). Question one of the interview aimed at answering research question three. The teachers pointed out that the cultural practices and artefacts which they infused with WS were useful mediating tools which allowed for cultural border crossing.

Factors constraining the engagement of SC in under-resourced schools were the need for teachers to explain the unobservable mechanism of the phenomenon Indigenous communities use (Bhaskar, 1998). This also needed to be related to ideas from WMS. Indigenous communities focus on the empirical level in which observable events are seen (Bhaskar, 1993), the make up or behaviour of the components (Chambliss, 1999) causing these events is unknown to them. In order for teachers to give the correct science explanations in indigenous practices, they need to be well equipped with subject content knowledge as the actual science in IK is not known in the communities.

Question two of the interview also suggested constraints encountered when teachers want to engage the SC approach in under-resourced schools. The response was schools are under-resourced and this impedes the engagement of the SC approach in schools. This resonates with Tjipueja (2001) who mentions that lack of resources hampers the achievement of the goals of the Namibian education system. Itibari and Zulu (2006) agree that scarcity of resources is a constraint.

Factors enabling the use of the SC approach are the activities which were selected from the communities which enabled a cultural adaptation of the curriculum materials. This is not an ordinary adaptation but one which takes into account that the cultural, social, economic factors of a learner are taken on board (Wadsworth, 2004). So cultural practices address the cultural factor, the social factor is addressed by embracing the social science jargon in the community and economic factors are addressed by allowing the use of social and cultural systems reflecting science in learners' immediate environments (NNCBE, 2010).

After ELC practical ways of infusing ideas were discussed. The practices were discussed which promote development since according to Bronfenbrenner (2005) development is possible if all the systems in a learner's bio-ecological environment are present. Further enablers were the fact that the teachers used pedagogical indigenous content knowledge PICK (Mukwambo, 2012) which uses IK views while constructing WMS knowledge. This allowed the phenomenon to be explained in the classroom talk using IK perspectives. This could not have materialized otherwise since the use of science language linked to WMS alone does not promote learning as learners are challenged by the language.

Before engaging miniature learning cycles which this study used on account of time constraints (Engeström & Sannino, 2010) the participants were not able to engage the SC approach. Various factors prevented them from doing so such as the SC approach can only be done with contemporary technological infrastructure, learners cannot afford the transport and there is limited infrastructure to support the SC approach in the region. The data from interviews is further validated by data from the reflections the teachers wrote after their lessons.

7.4 Data from reflections answering questions in Phase two

Insights from excerpts in Table 21 show that the failure of students to obtain better symbols (Section 1.5) in Science is attributed to the failure of teachers to use contextualized examples. Even if learners visit sites to see the concept they have learnt in action, because the ideas presented are not contextualized they still end up with inert knowledge (Hale, 2013). Cultural translation (Bhabha, 1994) is made possible when teachers use indigenous community-based practices to engage the SC approach when teaching Science.

Another insight is that local indigenous examples reflecting science provides mediating tools when conducting practical activities and allows a learner to interact with what occurs in his social and cultural plane (Vygotsky, 1978). Thompson (2013) sees it as a way of solving problems related to adaptation whereas Chisholm and Leyendecker (2008) regard this as providing LTSMs which are tools. The use of tools which are social and cultural from Indigenous communities as advocated by the NNCBE (2010) prepares for a learner-centered and SC approach responsive to socio-cultural theory (Thompson, 2013; Chisholm & Leyendecker, 2008).

7.5 Concluding remarks

The expanded data analysed and discussed in this chapter anticipated the findings and recommendations. Data generating instruments such as practical activities could not have played such an important role in this research if data from document analysis, brainstorming, and community analysis was lacking. Its presence gave the participating teachers a chance to participate in ELC. The data generated during ELC with the participating teachers included reflections and opinions. The findings of this study are presented in Chapter Eight which follows.

CHAPTER 8: FINDINGS FROM THE STUDY

Findings are drawn from systematic analysis of material, rather than from preconceptions (Malterud, 2001, p. 485).

8.1 Introduction

This chapter focuses on the findings of data presented in Chapter Five and Chapter Six and analysed and discussed in Chapter Seven. The systematic analysis of data in Chapter Seven allowed facilitated objective interpretation and findings (Malterud, 2001). Research questions which guided this study are presented then analytical statements that consolidate themes that emerged from the data are discussed against the relevant literature and theoretical frameworks.

8.2 Research questions

The main research question was: How do Physical Science teachers engage SC in teaching science concepts at the nexus of indigenous knowledge and Western modern science? To answer this question the following sub-research questions were formulated:

- How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage SC in their practices when teaching science concepts? [interviews, community analysis, document analysis, brainstorming and reflections were used to answer this question]
- What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts? [brainstorming, audio-visual evidence, reflections, and interviews were used to answer this question]
- What expansive learning and mediation tools did the study develop to support the use of SC in the teaching of science concepts through the use of IK practices? [brainstorming, reflections, and interviews were used to answer this question]
- What insights were obtained from an SC-driven pedagogy? [experimental test, audio-visual evidence, reflections, and interviews were used to answer this question]

Even though pressure concepts were the focus in the literature reviewed, participating teachers were not restricted to this concept. Suggestions on how pressure concepts can be taught using the SC approach came from the researcher. The intention was to engage ELC activities with the teachers in order to detect the science in cultural practices related to pressure concepts which I used as a unit of analysis (Engeström, 2001). This equipped the participating teachers with the skills to connect IK and WMS during science practices. Through this, other science concepts emerged. These were investigated and used as units of analysis in order to find how they could be used to support the SC approach in under-resourced schools. Using the data generating instruments mentioned in Chapter Four some data were generated, analysed, discussed and formally expressed as statements of findings.

8.3 Analytical statements

The analysed data, discussion and research questions were used to construct the analytical statements reflected in Table 22. The analytical statements served as a yardstick to show that participating teachers discovered how Physical Science teachers can engage SC in teaching science concepts at the nexus of indigenous knowledge and WMS.

Table 22: Analytical Statements

Source of data	Themes	Analytical statements	Theories/literature	Research questions
Interviews, community analysis, document analysis, brainstorming and reflections	Lack of cultural translation of IK ideas Agency of teachers to enable a hybrid curriculum to be engaged	SC approach engaged when teachers arrange a scientific excursion to other regions	Sociocultural, cultural translation, SC, WS and IK, top-down and bottom-up curriculum	1
Brainstorming, audio-visual, reflections, and interviews, document analysis	Learners serving apprentice programs in IK are not recognized Lack of recognition of IK constrains its use in the SC approach	Monocultural perspective used to explain science constrains use of IK in SC approach.	Constructivism, social realism, IK and modelling	2
Brainstorming, reflections, and interviews	Mediating tools PICK, TICK	Engaging IK practices in the SC approach promotes a hybrid curriculum	ZPD, PCK, CK, Top-down and bottom-up curriculum, sociocultural, cultural translation	3
Experimental test, audio-visual, reflections, and interviews	Cognitive apprenticeship, scientific literacy. SC approach is in favour of learner-centred approach	Science situations in IK used in SC approach promote scientific literacy	SC, multicultural, PICK, TICK, social realism, authentic context	4

The analytical statements were found to be related to some concepts and constructs, and theoretical and conceptual frameworks discussed in Chapters Two and Three respectively. The analytical statements answered some research questions as shown in the table and discussion below.

8.3.1 SC approach during excursions to other regions

During brainstorming some of the teachers agreed with Ritchie and Coughlan's (2004) view that both types of scientific excursion, that is the curriculum-based and the extracurricular based excursions, are constrained by time and financial resources if they are to be realized in other regions.

Allowing teachers to use social and cultural systems in the learners' communities to engage SC removed the constraint associated with lack of finance. Time is also reduced when infrastructure reflecting science within the surroundings of an under-resourced school is used. The SC approach contextualizes and makes it accessible to most learners. In addition the important goals of education are achieved (Itibari & Zulu, 2006).

Interviews were conducted after the teachers had executed the ideas constructed during miniature ELC in their classrooms. These interviews revealed that the use of cultural practices, artefacts and terms provided the necessary infrastructure for the SC approach. According to Rena (2007), infrastructure plays a pivotal role in delivering quality, equity access and democracy if teachers in under-resourced schools in Namibia engage the SC approach. Cultural practices, artefacts and jargon are embedded in students' prior knowledge and everyday experiences which Rivet and Krajcik (2008) view as catalyst for contextualizing teaching and learning..

Document analysis revealed that teachers need to engage the SC approach using resources available in their communities (Section 5.2.3, Table 5 and row 4). Teachers viewed the NNCBE (2010) as a prescriptive curriculum (Morris & Adamson, 2010) as they indicated that they had implemented the curriculum without making any adaptations. Suggestions from document analysis showed that science teachers are encouraged to engage the SC approach by drawing on community members with expertise in the relevant science concepts. Aikenhead (1999) used this approach with Aboriginal adults to engage SC using social and cultural systems.

The NNCBE (2010) encourages science teachers to engage social and cultural systems (sociocultural) and the social system (social realism) (Sections 3.2.1 and 3.2.2 respectively). However, teachers did not act as agents of change. The teachers could have confidently adapted the NNCBE (2010) to produce a science pedagogy responsive to under-resourced areas using cultural practices, artefacts and jargon whose nature is seen by Sillitoe (2000) as adaptable and flexible. The failure of teachers to be agents of change means that their science practices induced a morphostasis (Section 3.2.2).

Reflections obtained from science teachers after ELC showed that they only engaged the SC approach using the few contemporary technological infrastructures which reflected WMS. Technological infrastructures are part of social and cultural systems but scarcity and limitation in rural areas made it impossible to engage the SC approach. Science concepts reflected in IK were not used for engaging the SC approach although they are part of the social and cultural structures a learner would have encountered in cognitive apprenticeship (Wineburg, 1989; Tripp, 1993; Rogoff, 1995). NNCBE (2010) labels them as structures in a learners' immediate environment. Regardless of this, science teachers preferred to use examples from Physical Science textbooks. The two textbooks used examples which are not from the cultural context of the learners. In other words, examples were not culturally translated (Bhabha, 1994) to meet the needs of these learners in under-resourced schools.

In brainstorming it emerged that the activity system recognized as reflecting science used a WMS perspective. Meyers (2007) and Mukute and Lotz-Sisitka (2012) view activity systems as networking and not isolated, so this short-changed science teaching. Activity systems, like their components, are dialectically related as Ratner (2002) maintains. This explains why the activity systems in the third generation end up having very different objectives. In reality the objective should be the same as they all aim to facilitate cultural transmission and assimilation (Aikenhead, 1997).

To intervene I tasked the participating teachers to conduct experimental tests to investigate how Indigenous communities interact with science concepts embedded in cultural and social systems, Because these encounters are found in the local communities of the learners, their use in the SC approach enabled the learners to be at the same level as learners in areas where technological facilities are available. The teachers were then in a position to address the goals of education (Section 1.2).

To sum up responses to research question one, it was found that the science teachers only engaged the SC approach when they arranged scientific excursions, where the science concepts are applied in infrastructures reflecting WMS in the region. These visits were limited.

The existence of two knowledge activity systems in which each has a component of division of labour creates contradictions. These contradictions exist between the elements of the division of labour in each activity system. Each member in the division of labour regards the knowledge he produces as being of high value. With these perceptions each would not like to share that knowledge freely and led the NNCBE (2010) using the bottom-up approach (Section 2.1). As the NNCBE (2010) is not a centralized curriculum like the Hong Kong curriculum (Morris & Adamson, 2010) it reflects a bottom-up approach.

Good qualities of IK are hidden within contradictions. Under such circumstances, teachers are not in a position to detect the importance of IK in the SC approach. As a result the teachers valued the infrastructure reflecting WMS and regarded it as more suitable for supporting the SC approach than the infrastructure reflecting the science in IK. This resulted in a monocultural approach in the teaching of science concepts.

8.3.2 Monocultural perspective constrains use of the SC approach

A monocultural approach in teaching occurs when knowledge from only one culture is used in pedagogical practices while neglecting to embrace knowledge from other cultures. A multicultural approach (Mukwambo, 2013) occurs in teaching if teachers behave as culture brokers (Stairs, 1995). A multicultural approach to teaching science allows every learner in the classroom to explain the phenomena under discussion based on observed facts gained and relate these to WMS ideas in the curriculum. That is a multicultural approach promotes metamorphosis (Archer 1995) of teachers' practices. The distinction between monocultural and multicultural approaches highlighted the absence of systems of knowledge.

The absence of social and cultural systems reflecting WMS in the Zambezi Region constrains the use of the SC approach in science teaching (Section 2.2.1). Tjipueja (2001) concluded that the absence of infrastructure constrains teaching but he was referring to all schools in Namibia. In the case of this study which looked into three schools in the Zambezi Region data was generated from the analysis of curriculum materials, the recommended physical science textbooks which have examples of social and cultural systems reflecting WMS. Social and cultural structures of WMS are seen in other cultures in the world and in other parts of Namibia.

The absence of examples reflecting WMS in the school curriculum served as an indicator that social and cultural structures reflecting WMS are absent in the Zambezi Region.

Non-recognition of learners' participation as cadets (Collins, et al,, 1989; Rogoff, 1995) in IK practices constrained the engagement of the SC approach in science classrooms. Acknowledging knowledge gained during cognitive apprenticeship in IK allowed science practices to be aligned to the sociocultural theory of teaching (Section 3.2.1.2). This is encouraged in the NNCBE (2010). Sociocultural theory emphasizes the use of different cultures to promote a learner-centered pedagogy which according to Chisholm and Leyendecker (2008) is not practiced on account of a lack of resources or marginalizing other cultures in a landscape where culture is diverse. Side-lining of systems influencing development facilitated the emergence of monocultural science practices and constrained the use of the SC approach (Bronfenbrenner, 2005). Acknowledging the existence of other knowledge systems as advocated in social realism enabled science teachers to recognize absence as a constraint (Putnam, 1999).

When the absence of structures supporting the SC approach was conceded, the science teachers and the researcher found that some cultural artefacts, practices and jargon embedded within IK enabled the SC approach to be engaged (Section 5.3). The cultural practices, artefacts and jargon which they suggested were used to model (Bandura, 1977) as they engaged the SC approach. They each selected cultural practices, artefacts and jargon to use in science-related situations (Aikenhead, 1997) as the starting point when teaching science. The selected suggestions were then passed through the stages of ELC and finally found their way into the classroom. The subsequent interview revealed that these cultural practices, artefacts and jargon can be used to support SC since the four teachers were successful in conducting the SC approach with their learners.

A follow up video of suggestions showed some of the artefacts and community practices which teachers used later to enable the SC approach. Figures: 15 and 20 reveal the SC approach being applied and proved useful in allowing learners to engage in classroom talk (Lemke, 1990) by referencing their cultural viewpoints.

The monocultural approach to the teaching of science before engaging ELC was the result of an uncritical acceptance of only one source of knowledge, or a "God's eye view" to explain phenomena in the environment (Putnam, 1999). Putnam (1999) further proposes that activities that men engage in reflect part of empirical knowledge and reflect reality and are revisable at any point, yet science teachers' view cultural activities related to WMS as the only one which reflects reality. Even though WMS and IKS are both commodities, WMS is more valued than IKS (Section 3.2.2).

This leads to science teachers explaining concepts using only one cultural lens. This prevents border crossing (Aikenhead, 1999) and also deprive science teachers to use the Afrocentric epistemology whose assumption is that knowledge comes from both what is experienced (the empirical level of reality) and what others experience (Hawkins & Thompson, 2007). The activity systems generating WMS and IK are equally valuable and have the same people participating as I showed in Figure 31 and explained in Section 7.3.2. More value is placed on WMS even though it has its base in IK as Bell (1979) suggests.

This creates contradictions between the two commodities, namely WMS and IK even though they serve the same purpose. My analysis in Chapter Seven illustrates that WMS and IK are competing for a market. This view is supported by Odora-Hoppers (2002) who compared how the two knowledge systems are currently being used. The reason why WMS dominates is because IK has been undervalued for so many centuries. This has assigned low exchange-value and use-value (Section 3.2.2). Instead, IK concepts found in cultural practices which are the mediums of production can act as mediating tools to facilitate the SC approach when science concepts embedded in IK are woven into WMS.

8.3.3 IK practices in the SC approach promotes a hybrid curriculum

An analysis done by teachers of how to find social and cultural systems in the community which support the SC approach in under-resourced schools revealed a spectrum of cultural practices, artefacts and terms (Tables 5.6, 5.7, and 5.8). All were found to be relevant to science taught in. To surface knowledge on how matter is connected, Indigenous communities are interested in how they are affected and the other components of the universe. As they do so, they surface knowledge which addresses axiological issues (ethics and aesthetic) (Asante, 1991). This allows the Indigenous community to come up with cultural practices (the soot case explained in Chapter Two, for instance) which sustain the universe. The epistemological and ontological views used in the Afrocentric framework can facilitate that science teachers see both use-value and exchange-value of cultural practices within an IK connotation (Marx, 1867; Padgett, 2007) despite them not being recognized.

The use-value of cultural practices, artefacts and jargon dominate WMS when used in the Indigenous communities since they are part of the medium of production. As the medium of production they refer to tools for mediating science concepts which could promote a hybrid curriculum (Bhabha, 1994). Even though use-value of IK is currently not prominent, weaving IK into WMS promotes an Afrocentric curriculum (Odora-Hoppers, 2002).

However, the exchange-value is not high as it is only circulated within a community and is unknown to other cultures. For the Indigenous communities who value them as tools they perfect cultural and social systems to meet their current requirements and developmental needs (Blunden, 2010). This encouraged the science teachers using the SC approach to value social and cultural systems as mediating tools since they are developed objects which have also developed the users (Table 8). When some selected community activities were tested for their suitability for combining with WMS, it was found that they did not constrain the understanding of science, instead, they provided authentic conditions for teaching (Collins, et al., 1989).

The science jargon allowed the social and cultural systems to be woven into WMS as shown in Table 10. The table shows some science terms which are used incorrectly in the community. The science teacher explains these in WMS using PICK which the learners know and can understand. This engagement of science jargon used in the community supports the contiguity argumentation theory which Ogunniyi and Hewson (2008) propose. Also, it is preferable to use activities found in the community as mediating tools, since learners have background TICK (Shulman, 1987).

The interviews conducted also revealed that the reliance on PCK and CK from WMS will be limited if IK practices are merged with WMS during the SC approach. The PCK, CK, PICK and TICK can all be used to develop the ZPD. In order to optimize learning at the ZPD (Vygotsky, 1978), one needs to be aware of where the learner is before introducing new knowledge to them. The interview questions given to the teachers revealed that embracing what was found in community analysis and brainstorming the NNCBE (2010) can assume a top-down and bottom-up curriculum (Morris & Adamson, 2010). One of the themes that emerged from the interview question was that the community member as an expert should be invited into the classroom to explain some scientific concepts. ELC made it possible for science teachers to view the NNCBE as a flexible document which can accommodate the sociocultural views of the learners.

The teachers' reflections in Table 20 also show that learners can be asked to relate what they are taught with what they see in the community. This is further support for the idea that cultural practices artefacts and jargon in the community can be used as mediating tools during SC as they are mediums of production.

If community practices are properly analysed to detect science concepts they can be combined with WMS to improve teaching practices. However, the science concepts need a thorough analysis involving ELC. In the process the teacher needs to relate them to WMS concepts. This can then facilitate engagement of the SC approach in under-resourced schools to produce a valuable hybrid curriculum.

8.3.4 Science situations used in the SC approach to promote scientific literacy

One of the insights from a SC-driven pedagogy is that some science situations detected promote scientific literacy. Also, the reflections of the teachers revealed that a hybrid curriculum is obtained. Experimental tests and video recordings of the use of social and cultural systems allowed the teachers to see that the NNCBE is not a prescriptive document. Further insights were that are the goals of education are attainable even in under-resourced schools.

The development of an individual's scientific literacy is through induction into the community of practice of those who are already scientists (Section 2.2.1). In the case of this study, the learners are legitimate peripheral participants in IK and WMS. Lave and Wenger (1991) only consider cultural practices in WMS. In the WMS system learners are inducted by teachers to acquire WMS ideas using the activity system of the teacher mentioned in Figure 31. However, the learners are legitimate peripheral participants in the activity system of community members where they are serving apprenticeship programs (Enosi, 2010; Rogoff, 1995). An attempt to teach WMS alone does not foster understanding as the conditions under which it is offered are essentially decontextualized. Learners in under-resourced schools with an absence of infrastructure reflecting WMS are severely disadvantaged but a hybrid curriculum can remedy this situation.

Interviews and reflections revealed that the exclusive use of WMS and a monocultural perspective on the teaching of science impacted negatively on the formation of identity (Kelly, 2004). In contrast, the combination of WMS with IK allowed a multicultural perspective in the teaching of science concepts (Section 4.5.1.1). The engagement of practices in which cultural practices are used in the SC approach facilitated the emergence of a hybrid curriculum which nurtures scientific literacy. The SC approach is like a seedling you are transplanting. The seedling will bear fruit if care is taken that it is given the right conditions to adapt to the new terrain. This is the same consideration which should be given to the SC approach since in under-resourced schools it needs to be adapted to meet the harsh conditions such as the absence of LTSMs (Czerniewicz, Murray & Probyn, 2000).

Examples reflecting WMS abound in the recommended and supporting Physical Science textbooks. Teachers do not adapt them to accord with learners' experiences during informal learning as Bass (2012) suggests. Yet doing so could place under-resourced schools on the same level with well-resourced schools that are successful in achieving the goals of education. The belief that curricula documents must be followed like a medical doctor's prescription is unsound pedagogical practice (Morris & Adamson, 2010).

Schools in other regions of Namibia are better positioned to relate WMS to daily social activities in learners' experiences since they are near manufacturing plants or activities which apply science concepts taught in WMS. In doing so *quality, access, equity and democracy* are addressed and scientific literacy is developed. However, if teachers in under-resourced schools do not weave IK examples into the WMS-dominated curriculum scientific literacy will remain low in these schools as evidenced from the marks in Table 1. So, to ensure that we do not short-change learners from diverse cultural backgrounds in under-resourced schools by not developing scientific literacy, entwining WMS and IK is imperative as this can ensure that the SC approach is engaged by all schools as the hypothesis below suggests.

Practical activities, case studies, models, vocabulary, diagrammatic representations and patterns based on observed facts from Indigenous communities can be applied to all science concepts in order to engage the SC approach in under-resourced schools. Use of cultural practices, artefacts and social science jargon from Indigenous communities to support SC approach in under-resourced schools has the effect of recontextualizing the teaching and learning of science. This serves as a way of Africanizing the curriculum to not only lessen the hegemonic effect of WMS but also to allow IK to play the same role so that those from different cultures acquire the relevant scientific literacy.

8.4 Concluding remarks

In this chapter it emerged that the SC approach can be engaged in under-resourced schools when teachers arrange scientific excursions to other regions. Before this study the findings showed teachers were engaging the SC approach from a monocultural perspective and this constrained the use of SC in under-resourced schools. To ensure that morphogenesis of practices is achieved, the study proposed that WMS be infused with IK in order to come up with a hybrid curriculum which can be used in under-resourced schools. This demonstrates the morphogenesis encouraged by (Archer, 1995).

These insights were then used to compile a summary of findings, recommendations, reflections and a conclusion which is discussed in Chapter Nine.

CHAPTER 9: SUMMARY OF FINDINGS, RECOMMENDATIONS, REFLECTIONS AND CONCLUSIONS

If you are analyzing an image, examine it as a whole and then reflect on how the individual elements contribute to its overall meaning (Hacker, 2010, p. 20)

9.1 Introduction

This final chapter comprises a summary of my findings, recommendations, acknowledgement of limitations, reflections and conclusions. In compiling the sections which make up this chapter the contents of earlier chapters are examined as a whole (Hacker, 2010). In Chapter Eight the research questions which guided this study were presented to support analytical statements. In this chapter the research questions are presented again in order to support the overview, major findings and their benefits, the limitations of the study, recommendations, new knowledge, reflections and conclusion.

9.2 Overview of the study

The main goal of this study was to explore and expand the use of the SC approach by Physical Science teachers in under-resourced schools in the Zambezi Region of Namibia. To achieve this goal, the following research questions were posed and the following instruments used to generate data, as first set out in Chapter One.

The main research question was: How do grade 11 Physical Science teachers engage the SC approach in teaching science concepts at the nexus of indigenous knowledge and Western modern science? To answer this main question the following research sub-questions were formulated:

- How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage the SC approach in their practices when teaching science concepts? [interviews, community analysis, document analysis, brainstorming and reflections were used to answer this question]

- What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts? [brainstorming, audio-visual evidence, reflections, and interviews were used to answer this question]
- What expansive learning and mediation tools did the study develop to support the use of SC in the teaching of science concepts through the use of IK science practices?[brainstorming, reflections, and interviews were used to answer this question]
- What insights were obtained from an SC-driven pedagogy? [experimental test, audio-visual evidence, reflections, and interviews were used to answer this question]

These research questions determined the context discussed in Chapter One and completed in Chapter Two. In Chapter Two, Namibian curriculum issues were used to anchor the principal concepts in this study, such as the SC approach. SC is discussed as one of the leading conceptual frameworks, together with other supporting constructs such as cognitive apprenticeship, community of practice and authentic context. The study used cultural practices to do with pressure, artefacts and jargon to encourage science teachers to detect the science reflected in them and then find other practices reflecting science to support the SC approach. This prepared the ground for discussing pressure as a concept taught in Physical Science, how it is related to IK practices and how the practices in pressure and other science concepts can be infused in the SC approach.

A number of theoretical frameworks were used to construct knowledge (Section 9.7). Since this study is interventionist in nature, I employed sociocultural and social realism theories (Meyers, 2007; Engeström, 1987; Virkkunen, 2004). Sociocultural theory was important because the study concentrated on cultural practices, artefacts and jargon which are social and cultural structures (Case, 2013). Using social realism allowed for an exploration of social systems separated from cultural systems.

The interventionist character of this study was manifested when CHAT, an analytical tool, was introduced to support the theories and concepts discussed. This served as a useful precursor to the ELC stages which allowed the participants and me to conceptualize and construct transformed pedagogies. The discussed issues then shaped the methodology adopted for the study.

This descriptive qualitative study in which CHAT, DWR and ELC were used employed two phases to generate data. In Phase one the data generated came from exploring. In Phase two the data came from the expansive learning cycle. Six teachers participated in both phases and the research sites were schools in the Zambezi Region. The data generated were then presented in Chapters Five and Six, and analysed in Chapter Seven. Some discussion of the research findings is featured in Chapter Eight. A summary of these findings appears in Section 9.3.

9.3 The major findings of the study

This section highlights and summarizes the principal findings to have emerged from the study. The findings in respect of research questions 1, 2, 3 and 4, are presented in that order.

Findings related to research question 1

The findings for research sub-question 1: "*How do grade 11 Physical Science teachers in rural schools in the Zambezi Region engage the SC approach in their practices when teaching science concepts"* were varied. I found that science teachers in the three schools studied in the Zambezi Region were not able to regularly engage the SC approach. They found it difficult to engage SC on account of the absence of technological resources in the region. Yet they could have managed had culturally and historically-accumulated constructions been used as a base to construct knowledge (Lektorsky, 1984). The teachers did engage the SC approach once a year or once at each level (junior secondary level or upper secondary level) when they organized scientific excursions to visit other regions. These visits operated on the belief that true valid scientific reality exists only when the WMS perspective is invoked.

Before conducting this study, the learners' cultural practices were distanced from their science practices. The responses from research question 1 made it possible to understand the factors that enable or constrain the SC approach to engagement in under-resourced schools.

Findings related to research question 2

The findings for research question 2: "*What factors enable or constrain rural school grade 11 Physical Science teachers' practice with regard to engaging SC when teaching science concepts*?" were as follows. The monocultural view on knowledge constrained the use of the SC approach. Teachers' monocultural practices in the teaching of science concepts effectively divorced them from reality; yet concepts are all shaped by real-world experience and social interaction. Embracing views from other cultures promotes morphogenesis (Archer, 1995).

This resonates with Msila (2007), who says that the current education system needs to be harnessed to IK to give it an African context. Thus, science teaching practice should be regarded as a process of embracing all cultures. In doing so a hybrid curriculum would be created which encourages soft scaffolding (Brush & Sayer, 2001).

It was also noted that materials determine teachers' activities. The materials include those currently at their disposal and that have developed over time. Blunden (2010) suggests that people create knowledge using what history has already created by modifying and adapting it. Figure 5 points out that circumstances transmitted from the past contribute to bringing about change in human activities.

Before this research intervention, the cultural practices, artefacts and terms in IK were considered as of no use-value or exchange-value (Marx, 1867; Padgett, 2007). After valuing their use-value, the teachers used them as mediating tools for sourcing prior everyday knowledge, which according to Furnham (1992) can be used for contextualizing science. In the process when teachers subjected their learners to a miniature ELC they found the mechanisms involved at the real level as essential in the SC approach. In doing so the science teachers did not only develop these cultural practices, artefacts and terms, but they themselves were changed (Vygotsky, 1978). So, a change in one's world-view was another of the enablers which came with engaging the SC approach through the use of cultural practices, artefacts and terms.

The value of considering indigenous cultural practices, artefacts and terms in science teaching is supported by the idea that human thought is dependent on the cultural practices, artefacts and discourse of which they are also components (Blunden, 2010). In view of the findings, science teachers in under-resourced schools became immersed in authentic situations that support the SC approach (Miller & Gildea, 1987), but on account of the mechanisms in the real layer unknown to them, they could not embrace cultural and social systems to change their practices.

Findings related to research question 3

The findings responding to research question 3: "*What expansive learning and mediation tools did the study develop to support the use of SC in the teaching of science concepts through the use of IK science practices*?" pointed to the need for a hybrid curriculum. This was found to be achievable through the use of models, vocabulary, icons/symbols, patterns, case studies and practical activities. All these are supposed to be based on or reflect the science the learner would have come with from his/her community. In doing so science teachers and learners use

PICK and TICK which act as mediating tools (Postholm, 2008; Veresov, 2010). In addition, a hybrid curriculum for learners in under-resourced schools would feature science situations (case studies, patterns, symbols, vocabulary models and practical activities based on phenomenon in their environment), as suggested in Figure 30, based on IK and suitable for use in the SC approach to promoting scientific literacy.

Findings related to research question 4

Finally, insights from research sub-question 4: "*What insights were obtained from an SC-driven pedagogy*?" supported certain educational world-views and theories. For example, a perspective emerged that scientific literacy could be developed through the use of cultural practices, artefacts and terms, when these are incorporated into the SC approach. This view also supports multicultural theory as discussed in Chapter One, Africanisation in Chapter Two, and also the belief that in an activity, the product (the artefact) is developed further and the subjects engaged in the process (the teachers) themselves develop. The miniature ELC transformed the objectives in the activity systems. Initially it manifested a contradictory character since the objectives which emerged were different. Instead of developing only scientific literacy through the activity system of the science teacher, the fusion of these two activity systems brought about a second benefit – that of sustaining the environment. The importance of sustaining the environment is emphasized in the Ubuntu philosophy found in indigenous communities (Mukwambo, et al., 2014). That is, a dual role is played when the two systems are fused and this is one of the beneficial effects of morphogenesis (Archer, 1995). This is evidenced from the fact that practices employed by indigenous communities always ensure that their activities do not endanger the environment.

Other insights that emerged are if cultural practices, artefacts and social terms are not used as mediating tools to facilitate the SC approach in under-resourced schools, science concepts remain abstract as they are not understood during science teaching. She (2005) reveals how learning about pressure was prevented from remaining abstract through the use of an appropriate teaching approach like SC which allows learners to learn concepts in context. Kariotoglou and Psillos (1993) agree that learning concepts in the abstract leads to misconceptions, as evidenced in the activities which they used to contextualize learning.

In this study an example was the use of an earthenware pot to teach evaporation. Evaporation occurring in the artefact takes advantage of the latent heat of vaporization to cool the contents. To facilitate the SC approach a science teacher brings the artefact to model, explores the vocabulary, identifies patterns or constructs a case study, as suggested in Figure 30. The fact that learners have everyday experience of this phenomenon prevents it from being abstract. Failure to use cultural practices in the learners' environment has led both curriculum planners and science teachers to exclude important concepts, such as the latent heat of vaporization, thinking that the concepts are beyond the learners' reach. This creates gaps in the curriculum, or it becomes narrow or shallow as the view of science is narrowed (Kawagley, et al., 1998) in the absence of progression and cohesion. Progression and cohesion (Kriek & Basson, 2008) are undermined when important concepts in science are omitted in the belief that they are not accessible to learners. However, they can be taught using the SC approach if learners' prior everyday knowledge is accessed and science concepts are related to cultural practices.

9.4 The benefits of findings regarding the SC approach in under-resourced schools

I have mentioned that science concepts which are not properly constructed are "inert" (Hale, 2013), and this can lead to a failure of scientific literacy. When science concepts are constructed, the individual who has constructed them is in a position to use the concepts both for his benefit and that of the community. In the case of learners in under-resourced schools, science concepts acquired during learning are inert but with the use of cultural practices, artefacts and discourse, the science knowledge they construct is activated and its relevance is immediately apparent. This was evident when teachers used the cultural and social systems in their community to engage the SC approach and ensured that the concepts were contextualized (Lave, 1988) and authentic (Collins, et al., 1989).

The use of social and cultural systems in their community acquaints learners with various IK strands of science. This is argued by Mapara (2006), who suggests that science-related subjects such as technology, medicine and environmental issues are aspects of the reality that learners experience in their environment. The IK system of a learner has concepts which reflect the strands which make one scientifically literate. Its use to engage the SC approach enables the science teachers to engage Ogunniyi and Hewson's (2008) CAT. If teaching allows them to engage CAT, then there is full cognitive participation in the understanding of science concepts by the learner, which helps the teaching to address the goals of education effectively.

Schools that are under-resourced cannot fully address the goals of education as they are limited in their use of the SC approach and this is manifested as a tension. Science concepts are not accessed by the learner if "cognitive apprenticeship" is not achieved as part of SC (Collins, et al., 1989). When science teachers in under-resourced schools do not engage the SC approach their science practices do not meet the quality required by the NNCBE. Failure to engage the SC approach does not address the social reality in an area. A monocultural teaching practice will only address the needs of a learner with a world-view in harmony with WMS (Hodson, 2009). The inclusion of diverse social and cultural systems thus enables the goals of the Namibian education system to be addressed.

Other potential benefits were evident from the study. Data generated showed that science teachers who underwent miniature ELC introduced some PICK and TICK (Mukwambo, 2013), which were found to be useful in the classroom talk that is important in science teaching and learning (Lemke, 1990). The PICK and TICK acquired were unlike the PCK and TCK advocated by Shulman (1987), which only recognizes WMS culture and does not translate it into the culture of the community where teaching is taking place. A lack of science language cannot make a science teacher a better teacher. The engagement of social and cultural systems facilitated PICK and TICK, which had not been observed in the practice before the benefits discussed in Section 1.9.

Another noticeable benefit of this study is that it revealed a number of aspects of the cultural and social systems which can be used in the SC approach (Tables 5.6, 5.7 and 5.8). The data disclosed the science concepts which science teachers brainstormed for use in the SC approach and how they can be used. Figure 30 suggests the models, vocabulary, symbols, patterns or case studies reflecting the IK worldview that can be used by practising science teachers. This is noteworthy, since many studies point out that the IK which learners have can be infused with WMS, but they do not show how it can be done. Khupe (2014), for example, does not indicate how the science concepts she advocates can be used in science teaching.

9.5 New knowledge generated

The findings in this study suggested ways of closing the gap characterized by failure of under-resourced schools to engage the SC approach. Prior to this study, under-resourced schools could only plan a science excursion once a year and this limited learners' science language development.

The sanctioning of social and cultural systems which Parson (1951) views as an orderly arranged entity reflecting knowledge in a learners' environment allowed teachers to plan encounters with indigenous community of practice, where learners are apprenticed to acquire science terms which the teacher can use as prior knowledge to develop the science language in WMS (Enosi, 2010). The sanctioning of the social and cultural systems of indigenous communities allowed teachers to embrace a multicultural view in science teaching. In doing so, a premise of social realism – contradiction – emerged, which Priestley (2011) believes is instrumental in encouraging a change of practice.

In embracing all the diverse cultures in Namibia it became evident that for knowledge construction, science teachers need to ensure that existing knowledge structures are taken into account in order to facilitate the emergence of new knowledge: existing circumstances transmitted from the past play a crucial role in constructing new knowledge (Blunden, 2010).

So this study revealed the importance of a multicultural perspective in the teaching of science. Prior to this study, engaging a multicultural view in science teaching together with the SC approach was not possible in under-resourced schools. In well-resourced schools learners were often foreign nationals or Namibians whose cultural practices matched the examples in the recommended textbook. This is not true of learners in under-resourced schools.

In addition to devising ways to make science practice multicultural the study also showed how a hybrid curriculum can be created. Relating science ideas found in IK to those in WMS made the cultural translation of ideas possible. This closed the gap created by practitioners who transplanted ideas without taking cognizance of the historical, cultural, social and economic factors that might influence the teaching of science. Wadsworth (2004) posits that such factors can determine adaptation and assimilation.

The analysis of contradiction found in CHAT revealed that IK is not used in science practices because it encounters stiff competition from WMS on the science teaching practice market. However this research showed that the two knowledge systems are both commodities with value (Hodson, 2009). As commodities they have exchange-value and use-value. The use value of WMS often overrides that of IK since it is used internationally while IK is localized (Moodie, 2004). This is also true with the exchange value. Commodities in the marketplace use WMS language. Buyers of these commodities use the science language of WMS.

Also, the CHAT diagram (Figure 31) shows that teachers and learners are involved in both activity systems when new knowledge is obtained, as attested by Rogoff (1995) and Enosi (2010). They serve apprenticeship programmes in each of the activity systems. The failure to recognize knowledge coming from one of the activity systems brings about the contradiction that leads to teachers in under-resourced failing to engage the SC approach.

It is also possible that failure to harmonize the two knowledge systems has possibly resulted in accelerating global warming. This is attested in the Albedo and Marangoni effect when data on cultural practices relating to pressure were analysed. IK ensures that the Ubuntu worldview is exercised, focusing on the relationships between human beings and their surrounding ecosystem (Semali & Kincheloe, 1999).

The participating teachers suggested that the cultural practices of indigenous communities are environmentally friendly. The cultural practices teach knowledge which is not inert, whereas in the activity system of the science teacher that is solely WMS-based, the learner is left with inert knowledge which he cannot apply to sustain the environment.

Harmonizing rules in the teachers' activity system with those in the indigenous community yields a process that is cyclic in character. This is illustrated in Figure 32 below.

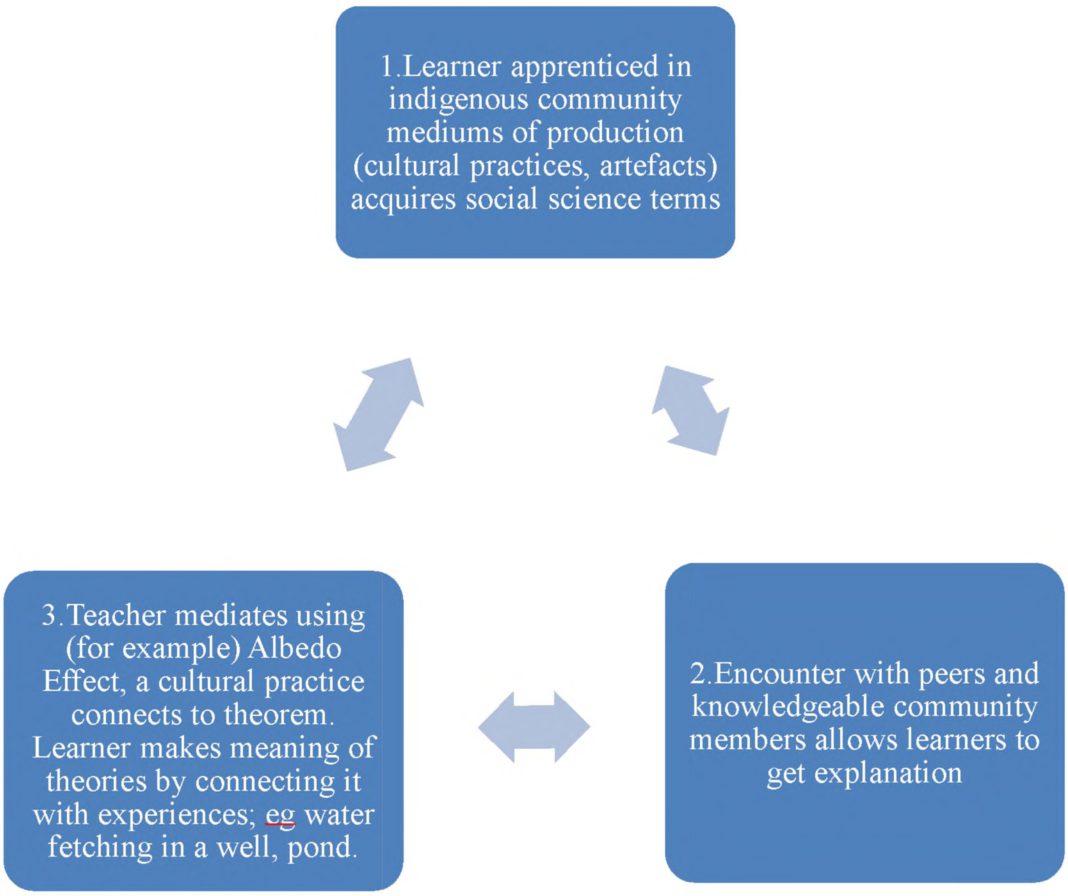


Figure 32: Cyclic nature of activity between teacher, learner and community members

Figure 32 shows that the process of learning is cyclic and dialectic. Knowledge from each stakeholder moves from learner to peer and from peer to teacher and finally back to the learner. Not only do learners learn from teachers, but teachers also construct knowledge from models, patterns or case studies that a learner might introduce if a multicultural view is acknowledged and celebrated. After due explanation, the teacher should be able to detect the science at work, and then use it as pedagogical indigenous content knowledge (PICK) or technical indigenous content knowledge (TICK) (Mukwambo, 2013). When he explains the same case study to peers, the peers learn from the teacher. Social interaction between peers and learner allows the two groups to revisit the case study, and in the process learning takes place. The fact that teaching may take any direction explains why this study revealed that teaching and learning are dialectical processes.

Extrapolating the observed patterns (observed facts) in phenomena subjected to miniature ELC as the emergence of new knowledge facilitated a hypothesis stated at the end of Section 8.3. The new knowledge generated resulted in the following reflections.

9.6 Recommendations

From the research findings it emerged that a community analysis of social and cultural systems exposed some cultural practices, artefacts and jargon which can be used in under-resourced schools to support the SC approach. According to Putnam (1999), it is legitimate to adduce factual beliefs based on empirical evidence as they constitute genuine knowledge. On account of cultural artefacts, practices and jargon being part of knowledge in a community they were successfully woven into WMS. This closed an existing gap characterized by teachers striving to create conditions in which the SC approach can function in under-resourced schools. This resulted in engaging science teachers in the stages of miniature ELC. In the stages, sections in the social and cultural systems reflecting sciences were investigated which were then related to WMS concepts during the SC approach.

Thus it is recommended that in order to ensure that social and cultural systems in the community are expressed in the SC approach it is necessary to expose and analyse them in a community of practice to detect the science ideas reflected. Each of the members in a community of practice can contribute to identifying which science ideas are reflected. This enables aspects of cultural and social systems to be verified as science concepts for use in under-resourced schools. This makes it possible for these schools to attain-the same goals as schools which have an environment conducive to SC engagement.

9.7 Limitations of the study

Kibirige and Van Rooyen (2006) suggest that when using IK one needs to be alert for IK which might contain fallacies. Not all social and cultural systems contain some explanations which can be woven into WMS to facilitate engagement of the SC approach. But, however as suggested some might be used as a launching terrain to correct the misconceptions which learners bring into the classroom as I suggested in Section 2.4.1.

It should be understood that it was not the focus of this study to explore and expand the "truth" of myths related to IK, on the grounds that they are part of social systems that create reality (Mondal, 2016). To reject the use of myth in the explanation of social and cultural systems characteristic of Indigenous communities is a failure to account for other levels of reality (Bhaskar, 1978). Nevertheless, this emerged as a limitation in my study. I had aimed at arriving at explanations and relating them to science use in the SC approach, but it was simply impossible to recommend some cultural practices, artefacts and jargon. These were then discarded in favour of those that were found to have some tenets of science.

This research could not control certain extraneous variables, which fell into two strands as explained in detail in Section 9.4. Extraneous participant variables pertained to the participants' background, mood, anxiety and intelligence quotient. The second strand of extraneous variables which limited this study was the situational or environmental conditions. Factors within the environment such as light intensity, weather conditions and participants' responsibilities at school might have influenced the way the participants answered the questions in the interviews, how they wrote their reflections or their mood when they engaged with ELC.

Certainly extraneous variables were the reason why two participants withdrew from the study. Their withdrawal limited the quantity and quality of data obtained but did not compromise the reliability and validity of the results.

Another limitation to the findings of this study is that the cultural practices, artefacts and terms which were explored and expanded represent a small fraction within a wide spectrum. A number of cultural practices, artefacts and terms still need to be verified to see the WMS which they can support. This will allow science teachers to use them without fear that they are compromising the concepts involved. This means that other research should be conducted and the results distributed or made known to science teachers.

9.8 Reflections

As an interventionist researcher I found that pressure and other science concepts I experienced as essential parts of my belief system when I was growing up, do reflect science. Mondal (2016) maintained that beliefs are typical examples of social systems reflecting reality, as I later discovered in this research when I subjected them to miniature ELC with the participating science teachers. The revelation was that soot-contaminated water reflects concepts in the Albedo effect. That explained why indigenous communities discourage using soot-contaminated utensils and is similar to what Koch and Hansen (2005) revealed when they analysed the Albedo effect in America and Asia. Also, soap-contaminated water reflects concepts in the Marangoni effect. These were useful to support the SC approach in under-resourced schools when teaching science concepts, since the explanation attested to in Figures 19, 28 and in Table 13, concur with studies conducted by Cain (2015) and Gonzalez (1987). This provided the stimulus for the participating teachers to suggest similar social and cultural phenomena in their communities was useful in epistemological transfer in rural under-resourced schools. These were also subjected to stages in ELC and brought to light practices that can be used to support the SC approach in under-resourced schools.

When I started compiling the literature review I found that the SC concept is intertwined with many other concepts which I engaged with to understand how they influence each other. This was later revealed in CHAT, which manifested the same characteristics. For example SC is responsive to constructivism, the socio-cultural approach, social realism, IK, WMS, cultural translation and the Namibian science curriculum. This explains why Shane (1993) emphasized that a curriculum in which the SC approach is used fosters a learner-centred, community-centred and knowledge-centred ethos. The study made it possible for me to see how the dialectical nature (Glatthorn, 2000) of the concepts allows the morphogenesis of science teachers' practices.

I acquired some substantial information when I concentrated on activity systems to analyse my data. This helped me understand and appreciate ELC, key concepts that emerged when one analysed contradictions using CHAT. The use of activity systems to analyse data also acquainted me with secondary and primary contradictions, such as those mentioned in Sections 7.2.1 and 7.2.3 respectively.

Although I managed to generate data in this research it was a challenge. When I engaged the teachers in miniature ELC, it was not easy to work with all six teachers as a group. They were often absent because of responsibilities at school. I had to visit them several times to persuade them to meet with me. Sometimes the brainstorming or experimental groups comprised of fewer than the anticipated six teachers. The information obtained in smaller groups was then passed on to the other groups I worked with. That served to verify whether the regularity which Yin (1993) considers as a characteristic of an extensive and interventionist study involving IK was also observed and noted as true by other participants. This also validated the data generated in terms of Barad's (2007) realist view of validity, which entails that valid explanations are supported by evidence which emerges from the data and which show similarities with what is known.

Another challenge was encountered with Indigenous communities who showed how friction can be used to start a wood fire. I had to travel to remote parts of the forest to fetch the right material as communities have moved over to using matches for making fires.

Furthermore this community was reluctant to share their knowledge freely. They realized that their technology has value and is a commodity (Maila & Loubser, 2003). Consequently they asked for a small fee for demonstrating and sharing their knowledge. They also even asked for a small amount the second time I visited them to sign the letters of agreeing to participate in the study since I had lost the first letters they had signed in 2015. Since my interest lay in gaining the information in order to use it in SC approach I had to comply with their demands.

9.9 Conclusion

This qualitative study which employed a formative interventionist methodology to investigate how grade 11 Physical Science teachers engage SC in teaching science concepts at the nexus of indigenous knowledge and Western modern science, has addressed the stated goal of the study and answered the research questions. I discovered that science teachers learn collectively and are able to identify cultural practices, artefacts and discourse which can be used as mediating tools to support the SC approach in under-resourced schools.

The revelation from this study is that the use of cultural practices, artefacts and terms facilitated change in the science teachers' practice. This morphogenesis (social change) can enable rural under-resourced schools to achieve the goals of education as the epistemological transfer which participating science teachers use in their practices changed as the view was, multiple reality exist as evidenced in embracing the Afrocentric paradigm where the focus was on cultural. It is my belief that when the education goals are sensitively and successfully targeted the high failure rate witnessed in the region might also be addressed.

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Appendices

Appendix 1

Dr. P

14th March 2015

Dear Sir

Ref: Conducting research in schools in Zambezi Region

I write to inform you that I am asking permission to collect data in schools in our region. The data collected is for a PhD study I am currently doing with Rhodes University in South Africa. The tentative title for this study is "*Exploring situated cognition in teaching pressure concepts at the nexus of indigenous knowledge and Western modern science*" In the process of collecting data I abide to the following rules.

I have ensured that all the ethical issues relating to data collection are addressed. That is letters to inform the participants, who are the teachers in our local schools have been handed to them. Also, letters to inform the principals of the three schools have been handed to them. The other letters were handed to community members who are also part of participants. In conducting the research, no participant will be coerced into participation. The data obtained will be managed considering what the ethics of data handling and management require. Finally, I ensure you that in the process of collecting data in the schools, I will not interfere with school activities and neither will I short change the students I teach.

Regards

M. Mukwambo

Appendix 2HX

P. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Principal

X Senior Secondary school

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study at your school

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

Instead I will first come, observe, check how they plan and see if ideas I want implemented are there. I brainstorm with the fellow teachers on how best we can bring such ideas. Community members will be engaged at a certain time of this research. Ideas gained from teachers and community members might help not only the teacher who on a daily basis struggles to apprentice learners to a community of practice. Community of practice engage with theories teachers teach as tools to sustain our community. To the management of the school and me, the ideas I intend to investigate and implement might help us stop thinking that we only need to take our learners for a trip for them to witness what we teach applied in Namibian industries far away from us.

My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TXB

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Physical science teacher

X Senior Secondary school

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 2HY

P. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Principal

Y Senior Secondary School

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study at your school

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 2HZ

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Principal

Z College

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study at your school

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TXA

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Physical science teacher

X Senior Secondary school

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TYC

P.O. Box 157

Ngweze

Katima Mulilo

8th February 2015

The Physical science teacher

X Senior Secondary school

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TYD

P.O. Box 157

Ngweze

Katima Mulilo

8th February 2015

The Physical science teacher

X Senior Secondary school

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TZE

P.O. Box 157

Ngweze

Katima Mulilo

8th February 2015

The Physical science teacher

Y College

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 3TZF

P.O. Box 157
Ngweze
Katima Mulilo
8th February 2015

The Physical science teacher
Y College
Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your circuit

I write in connection with the above theme. I intend to conduct a research with fellow teachers who are teaching Science to grade eleven learners at your school. My activities while conducting research will not disturb the said teachers' daily activities as I will abide to the ethics of doing research and rules of the school. Also, participants will not be coerced into participation.

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Regards

M. Mukwambo

Appendix 4CM1

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Community member

Katima Area

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your community

I write in connection with the above theme. I intend to conduct a research with some community members in your area. This research might assist teachers to come up with alternative ways of teaching learners doing science subjects in our local schools. My activities while conducting research will not disturb the said members' daily activities as I will abide to the ethics of doing research and rules of the community. Further, I clarify that members are not coerced to participate but should do so willingly.

I will first come, observe, and check how they conduct cultural activities which might be useful in science classes. I brainstorm with community members to find the practices and find the knowledge involved and how best we can bring such ideas into science classroom practices. Ideas gained from community members might help not only the teacher who on a daily basis struggles to apprentice learners to a community of practice. Community of practice engage with theories teachers teach as tools to sustain our community. The ideas I intend to investigate and implement might help us stop thinking that we only need to take our learners for a trip for them to witness what we teach applied in Namibian industries far away from us.

My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 4CM2

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Community member

Katima Area

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your community

I write in connection with the above theme. I intend to conduct a research with some community members in your area. This research might assist teachers to come up with alternative ways of teaching learners doing science subjects in our local schools. My activities while conducting research will not disturb the said members' daily activities as I will abide to the ethics of doing research and rules of the community. Further, I clarify that members are not coerced to participate but should do so willingly.

I will first come, observe, and check how they conduct cultural activities which might be useful in science classes. I brainstorm with community members to find the practices and find the knowledge involved and how best we can bring such ideas into science classroom practices. Ideas gained from community members might help not only the teacher who on a daily basis struggles to apprentice learners to a community of practice. Community of practice engage with theories teachers teach as tools to sustain our community. The ideas I intend to investigate and implement might help us stop thinking that we only need to take our learners for a trip for them to witness what we teach applied in Namibian industries far away from us.

My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix 4CM3

P.O. Box 157

Ngweze

Katima Mulilo

8th March 2015

The Community member

Katima Area

Ngweze

Katima Mulilo

Dear Sir

Reference: Seeking permission to conduct a research study in your community

I write in connection with the above theme. I intend to conduct a research with some community members in your area. This research might assist teachers to come up with alternative ways of teaching learners doing science subjects in our local schools. My activities while conducting research will not disturb the said members' daily activities as I will abide to the ethics of doing research and rules of the community. Further, I clarify that members are not coerced to participate but should do so willingly.

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My belief is within our communities our cultural practices, cultural activities and cultural artefacts are embedded with science theories. It is through cooperating with the community engaged with these activities which might make learners understand what we teach.

Regards

M. Mukwambo

Appendix: Interview schedule for teachers before exploration

1. How does the use of cultural practices, artefacts and social science jargon in the community can assist science teachers in under – resourced schools to engage situated cognition?

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2. If it does assist, how does it achieve this and if it does not achieve this what are the challenges which comes with it?

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3. Have you been engaging in situated cognition in your approaches when teaching science concepts before?

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4. If you were engaging or not in situated cognition before this research what enabled or constrained you to engage situated cognition approach?

Appendix: Interview schedule for teachers after ELC

1. Do you think the data we generated in the two phases of this study is true or false?

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2. If true or false, Can you support your argument?

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3. What must be done to include Indigenous communities in the SC approach?

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4. What can constrain or enable the use of cultural practices, artefacts and jargon to facilitate the SC approach in under-resourced schools?

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5. Write some reflections on your experiences since we started communicating with each other. That is comment on whether the ideas we have suggested can be useful in a teaching practice setting where you use the mentioned suggestions to engage the SC approach in under-resourced schools.

Appendix: Interview schedule for indigenous community members

1. How did you come to understand the science ideas you apply in cultural activities?

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2. Do you think the ideas you use in cultural practices or the one you use to come up with cultural artefacts depicting science can be useful in schools for a teacher to relate them to Science he teaches?

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3. How do you think to contribute in science teaching and learning with the ideas you apply in your everyday activities?

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4. What advantages or disadvantages can be brought by allowing you to take part in science teaching with ideas you use in everyday situations which are related to science?

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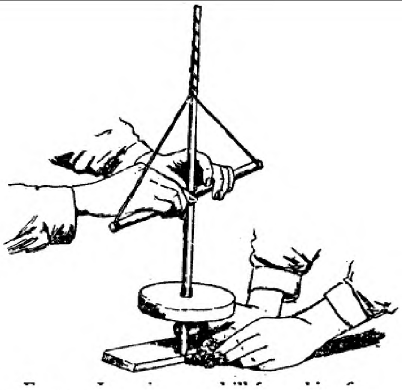
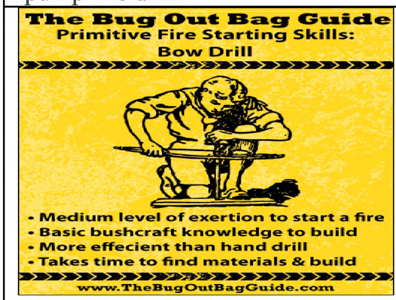
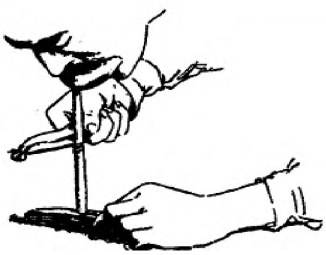
Appendix: 3T3E

Structure of mediating tool	Mechanism to produce friction for fire making	Comparison
 **Figure 33** pump fire drill	Downward motion creates pressure to increase friction. In advanced pump drills some weights are placed on top of the circular structure to reinforce pressure so that there is a great deal of friction.	Pressing the device downwards increases the weight which determines the frictional force. The harder one presses done the faster the fire comes out. This type of device showed that the frictional force depend on the weight with which the operator applies to the two horizontal arms.
 **Figure 34** Bow drill	The string of the bow is wrapped once around a vertical spindle. Pressure to increase friction is achieved by pressing the top of the spindle when set in motion by moving the string of the bow.	The use of both hands and both knees all pressing down still emphasizes that weight is a contributing factor in friction
 Figure 3 Mouth fire drill	The spindle is moved using the string of a bow wound once. Pressure is exerted using the mouth which also allows to hold it in position	The use of two hands also assisted by the mouth still shows that weight is important determining factor of friction. The mouth is used to press the device downwards and in doing so more weight is added which is a factor required in friction

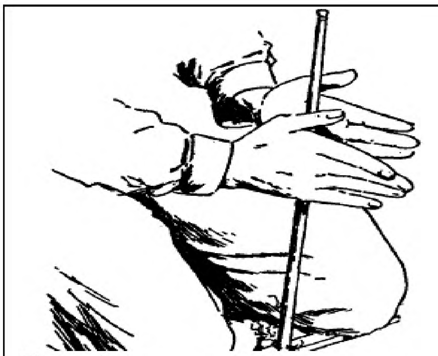
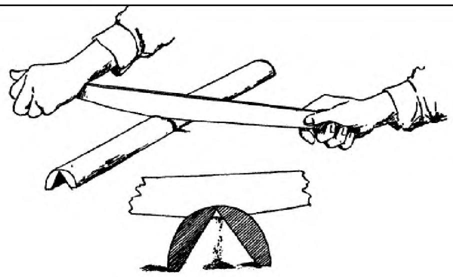
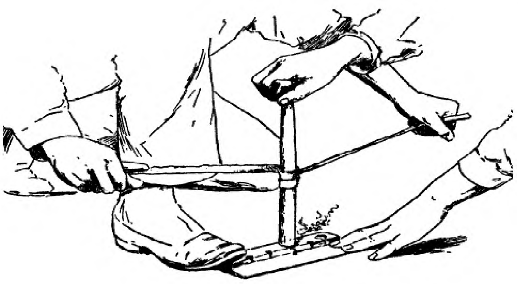
 Figure 4 Hand drill	Only the hands are used to press down to increase pressure while rotating the spindle to produce circular motion. Fire produced easily in dry climates or when used is completely dry	Even though the operator aim to exert more weight, his posture and the way the device is made reduce friction. This makes this device difficult to use when one intends to generate fire
 Figure 5 Fire saw	A sharp-edged piece of bamboo is rubbed on the convex surface of another piece on which a small notch is first cut. At the start rubbing is slow and gradually picks up. The use of both hands allows the operator to exert maximum pressure	The use of both hands with all the weight of the operator exerted onto the device illustrated that weight determines frictional force.
Two handed fire drill  Figure 6	Is similar to a saw drill. Instead of a bow, the two ends of the string of the bow are held by two hands of the operator and is wrapped once around a vertical spindle. Pressure to increase friction is achieved by another operator pressing the top of the spindle when set in motion by moving the string of the bow.	The requirement of more than one operator all pressing the accessories down still illustrated that weight is a factor which contribute in determining the amount of friction
 Figure 7 Fire plough	Two sticks rub together with one of the flint moved horizontally against one with a groove which is stationary	Presents of a split in the horizontal wood important to show that oxygen is needed for the glowing embers to produce fire. Also, the way the activity is down still reveals that a greater amount of weight determines the friction. The posture of the operator illustrate that weight is a factor determining friction.

Figure 1 to 7: Traditional fire making devices used to show that friction depend on weight at school Y. *(adapted from Hough, 1890, p. 359-372)*