


Metacognition within Physical Sciences Classrooms in Two KwaZulu-Natal Districts

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Thesis submitted in fulfilment of the requirements for the degree
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Graduation: Oct 2019

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DECLARATION

I the undersigned, hereby declare that the work contained in this dissertation **METACOGNITION WITHIN PHYSICAL SCIENCES CLASSROOMS IN TWO KWAZULU-NATAL DISTRICTS** is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

A handwritten signature in black ink, appearing to read 'D. J. ...', is centered on the page.

Signature

28/02/2018

Date

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Acknowledgements

“Important achievements require a clear focus, all-out effort and a bottomless trunk full of strategies. Plus, allies in learning”

(Carol Dweck)

I acknowledge with gratitude the following people who have played a great role in this endeavour:

- The participants of this research, if not for them, this research would have not been possible.
- My patient and caring supervisors, Dr ON Morabe and Prof EA Breed, who have been true mentors throughout this research. Their expert advice, support, and encouragement have made it possible for me to complete this thesis.
- My wife Cairistine for her constant support, love, understanding, and patience.
- The support of Mrs MC McInally and the teachers of Monifeith High School in the Angus Council.

ABSTRACT

For South Africa to become a leader in science and technology, it needs to produce many world-class scientists. South African education falls short of that goal because most learners are indigenous learners and those pursuing science as a field of study are relatively few. Furthermore, many of these indigenous learners who study Physical Science are under-achieving. Many studies show that raising attainment in science depends crucially on the promotion of metacognitive skills. The research proceeded on the reasonable assumption that low levels of metacognitive ability may be a primary reason for the indigenous learners' substandard performance in Physical Science. To improve the status quo and start to meet the goal of producing world-class scientists, this should be addressed as a matter of urgency.

The objective of this research was to analyse the state of metacognition of learners in South African Physical Science classrooms to infer and exhort workable teaching and learning strategies to improve learners' metacognitive skills, which might improve their Physical Science results. To this end, the research enquiry was conducted as follows: Assessment of the current level of metacognition in a sample of Physical Science classes at two KwaZulu-Natal districts of South African schools; relating the observed level of metacognition to the attainment scores of the Physical Science learners in the sample.

The research question was answered through a triangulation model of mixed methods design, addressing both learners and their teachers. The respondents completed a Metacognitive Awareness Inventory, a Science Attitude Questionnaire, and a Metacognitive Awareness Inventory for teachers. Data sets were extracted from the analysis of the questionnaires, curriculum documents, science notebooks, examination results, interviewed with respondents, and observed lessons. The research results were viewed through a socio-cultural lens, concentrating on the impact of culture on metacognitive awareness. The results indicated a low standard of metacognition in the selected samples, which led to conclusions that formed the basis of the proposed workable solutions to the research problem.

OPSOMMING

Om 'n leier op die gebied van wetenskap en tegnologie te word, moet Suid-Afrika 'n groot aantal wêreldklas-wetenskaplikes oplewer. Die Suid-Afrikaanse onderwys skiet tekort in die bereiking van hierdie doelwit, aangesien die meeste leerders inheemse leerders wat wetenskap as vakgebied volg, relatief min is. Boonop is 'n groot aantal van hierdie inheemse leerders is en dié wat Fisiese Wetenskap as vak neem, onderpresteerders. Verskeie studies toon dat verhoging van prestasie in die wetenskap grootliks afhanklik is van bevordering van metakognitiewe vaardighede. Die navorsing het voortgegaan met die redelike aanname dat lae vlakke van metakognitiewe vermoë 'n primêre rede kan wees vir inheemse leerders se substandaardprestasie in Fisiese Wetenskap. Om die status quo te verbeter en die doelwit te bereik om wetenskaplikes van wêreldgehalte op te lewer, moet die bevordering van metakognitiewe vermoëns dringend aangespreek word.

Die doel van hierdie navorsing was om die stand van metakognisie van leerders in Suid-Afrikaanse Fisiese Wetenskap-klaskamers te bepaal, werkbare onderrig- en leerstrategieë om leerders se metakognitiewe vaardighede te verbeter af te lei, en die gebruik daarvan aan te moedig, wat moontlik tot die verbetering van Fisiese Wetenskap-uitslae kan lei. Die navorsingsondersoek is soos volg uitgevoer: Assessering van die huidige vlak van metakognisie in 'n aantal Fisiese Wetenskapklasse by twee KwaZulu-Natal distrikte van Suid-Afrikaanse skole; bepaling van die verwantskap tussen die waargenome vlak van metakognisie en die prestasie van die betrokke Fisiese Wetenskap-leerders.

Die navorsingsvraag is beantwoord deur gebruik te maak van 'n triangulasiemodel van gemengde metodesontwerp, wat beide leerders en hul onderwysers betrek het. Die respondente het 'n Metacognitive Awareness Inventory, 'n Science Attitude Questionnaire, en 'n Metacognitive Awareness Inventory for Teachers voltooi. Datastelle is onttrek uit die ontleding van bogenoemde vraelyste, asook uit kurrikulumdokumente, leerders se notaboeke, eksamenuitslae, onderhoude met leerders en onderwysers, en lesse wat waargeneem is. Die navorsingsresultate is deur 'n sosio-kulturele lens besigtig, en het gekonsentreer op die impak van kultuur op metakognitiewe bewustheid. Die resultate het gedui op 'n lae vlak van

metakognisie by die geselekteerde deelnemers, wat gelei het tot gevolgtrekkings op grond waarvan werkbare oplossings vir die navorsingsprobleem voorgestel is.

Key Words: metacognition; Western science; Physical Science; culture; indigenous learners

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Table of Abbreviations

BACEIS	Behaviour, Attitudes, Cognition, Environment Interacting Systems
CAPS	Curriculum and Policy Statement
CHAT	Cultural-Historical Activity Theory
DCO	District Circuit Officer
MAI	Metacognitive Awareness Inventory
MAIT	Metacognitive awareness inventory for teachers
NCS	National Curriculum Statement
NWU	North-West University
OBE	Order of the British Empire
SACE	South African Council of Educators
SAQ	Science Attitude Questionnaire
SDL	Self-directed learning
SEM	Strategy evaluation matrix
SI	Standard International (Unit)
TARGET	Types, Authority, Recognition, Grouping, Evaluation, and Time
TIMSS	The International Mathematics and Science Study
USA	United States of America
ZPD	Zone of proximal development

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CHAPTER 1

ORIENTATION

1.1 Introduction and problem statement

The world is in crisis (Clark & Clark, 2011:xxi; Haney & Malekin, 2001:7). Currently, we must contend with global health disasters, poverty, war, famine, water shortage and refugees (WEF, 2015). The rapid growth of humanity's scientific, medical, and technological knowledge could help to solve these problems (Gutmann, 2009:70). The developing countries believe that scientific knowledge and advanced technologies can provide solutions to most of the problems that we face (Dahlman, 2008:29; Lockheed & Levin, 1991:130; Riley, 2001:54). Similarly, to advance in science and technology, South Africa needs to produce many world-class scientists. However, in South Africa the number of indigenous learners pursuing mathematics and science at the university level is comparatively low; many of them drop out of university before the degree course is over (Holtman & Rollnick, 2010:109). Furthermore, many indigenous South African learners have shown poor participation and success in science, engineering and technology (Holtman & Rollnick, 2010:109). This hinders South Africa's progress in our scientific and technological advancement.

An important key is to develop aspiring scientists at the school level, but often this doesn't happen in South Africa. For example, from the 184,383 learners from South Africa who wrote Physical Science in the 2013 National Senior Certificate (matriculation) examinations, merely a quarter attained a mark of 50% and above, and just 14.4% achieved above 60% (Barry, 2014). Recent studies have shown that South Africa ranked 47th out of 63 countries in the latest World Digital Competitiveness Ranking, because of an ineffective education system that neglected maths and science (BusinessTech, 2017). Research done by the South African Institute of Race Relations (IRR) revealed the number of learners who wrote both maths and Physical Science in matric has declined over the better part of a decade (BusinessTech, 2018). Students' admittance to Higher Education institutions depends on the matric examination marks, which could be the reason for the low number of students studying in science and technology. Moreover, the examination marks is not measure of success in terms of holistic cognitive and metacognitive skills, but this is how the system works in South Africa.

1.1.1 Trends in International Mathematics and Science Study used to compare science achievement of South African learners to the rest of the world

South Africa participated in the Trends in the International Mathematics and Science Study (TIMSS), which evaluates the attainment of science and mathematics knowledge of grades four, five, eight, and nine learners. TIMSS assess selected countries around the world. South Africa participates at grades five and nine respectively. TIMSS in principle measures the effectiveness of the implementation of mathematics and science within the national educational system (Bofah and Hannula, 2015:2; Martin et al., 2015:85; Pedersen, 2013:3).

The credibility of TIMSS results is reinforced by the outline of achievement in mathematics and science in their different content areas (Gronmo & Onstad, 2013:102). As compared to national testing, learners in South Africa tend to focus more on what is emphasised in their national curricula instead of having a broader understanding of mathematics and science as a whole. Even though there is a disparity between the content and questioning techniques of TIMSS and the national testing in science and mathematics, the TIMSS offers a broader comparison in evaluation by the different content areas. This evaluation is compared with the national results as well as the results of other countries, to give a broader picture of the learners' ability in mathematics and science.

To ensure validity and reliability, TIMSS were prepared in English and translated in 30 languages and was checked multiple times (Eckert, 2008:204). To increase the reliability and validity, TIMSS questions were constructed to make use of efficient words to assess accurately the knowledge of the learner, thereby making the test universally accessible (Eckert, 2008:204). Vast resources used, high level of expertise involved, and the openness of the development and data gathered, promoted its international credibility (Eckert, 2008:204).

Despite the work put in to ensure the credibility of TIMSS, it was found to favour some cultures more than others. Research showed that high achieving countries in the TIMSS had high content standards and expectations for learners learning; and a unidimensional pedagogical approach which was content focused (Roth et al, cited

in Eckert, 2008:205). This study still viewed the inclusion of TIMSS study in this research as crucial because South Africa has no rigorous system which measures the collective psychometric and motivational constructs of the learners in mathematics and science comparable to TIMSS (Bofah and Hannula, 2015: 2-3). Moreover, the data gathered gives insight into the relationship between affects and achievement which informs teaching practise and comprehensive consequences for educational interventions (Bofah and Hannula, 2015: 2-3). The TIMSS has a cross-cultural perception (Leung and Zhang cited in Bofah and Hannula, 2015:3), which is one of the focuses in this study.

Twenty years of data analysis of the results of TIMSS concluded the following:

- Despite the greatest improvements made in science and mathematics education being in the last ten years, learners from different backgrounds showed unequal progress (Reddy et al., 2015:VI);
- South African learners acquire science and mathematics skills more slowly than those in competing countries (Reddy et al., 2015:4);
- Three-quarters of South African learners fail to acquire the minimum set of mathematical and science skills by grade 9 (Reddy et al., 2015:5).

Analysis of the average achievement scores of South African school learners in the TIMSS (2011), compared learners according to their pre-1994 racial categorisation and their TIMSS mathematics and science test results (HSRC, 2011:9). The House of Assembly (HOA) administered white schools were the best performing group, while the former House of Representatives (HOR) administered Coloured, and Department of Education and Training (DET) administered Black schools which performed the poorest (HSRC, 2011:9). Learners from the ex-African administrated schools are indigenous learners who come from black ethnic groups in South Africa. Lewin (1990:1) noted that despite a huge increase in learners studying science in developing countries, evidence suggests a great majority do not reach a minimal number of the goals set in the science curriculum. It is notable that despite the majority of science learners in South Africa performing poorly in mathematics and

science, the few that do well in science are comparable with the top achievers internationally (Reddy et al., 2015:6).

1.1.2 Metacognition as a key to success in science education

The reality is that many South African schools are in impoverished communities that lack basic resources, which may well be the cause of poor science and mathematics results (Reddy et al., 2015:8). The South African government lacks the resources to overcome this obstacle and it needs to look at additional solutions to the problem in science education (Hamburg, 1997:110-111).

Successful science education requires, among other aspects, that learners possess appropriate learning skills (McGunnis & Stephanich, 2007:307). Studies have shown a strong link between academic success in science and metacognitive awareness (Akin, 2016:392; Jayapraba, 2013:165-166; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Thomas, 2012:132). Across science education and education in general, metacognition is a useful predictor of the academic success (Thomas, 2012:132). One reason for the poor achievement in science by indigenous learners in South Africa might be insufficient metacognitive skills.

Research shows that science learners with well-developed metacognitive skills perform better because they can plan the approach to a problem, and properly express themselves scientifically while planning and conducting a scientific experiment (Zohar & Dori, 2012:189-192). Thomas (2015:632) states that successful science learners constantly adapt their metacognitive skills to suit the demands of their challenging learning environments. Metacognition is a higher ordered thinking skill which requires experts to promote. Investment in improved resources in metacognition in South African science classrooms might improve the results in science. It is financially achievable compared with attempting to change the impoverished socio-economic conditions in which many of the South African learners find themselves. The intention of this research was to analyse the state of metacognition in South African Physical Science classrooms to infer and exhort effective strategies to improve these learners' metacognitive skills, which might improve their Physical Science results.

Modern science is the basis of the Physical Science curriculum in South Africa, with its roots in the Western world (Cobern, 1996:287). Physical Science, as described in the National Curriculum Statement (NCS) of Physical Science, is the physical and chemical phenomena that result from scientific enquiry, and by the application of scientific models, theories, and laws (DBE, 2011:8). According to Cobern (1996:287), science education has a major cultural influence, and therefore the science studied in South African schools can be described as Western science education. However, the link between Western-based philosophy and modern science is unacknowledged by many in non-Western learners' cultures (Hwang, 2011:3). Many non-Western learners find it difficult to adapt to the Western philosophy of science (Hwang, 2011:3). Tobin (2009:56-57) states that in African countries, science is a secondary culture of indigenous learners. Cultural beliefs in the developing world make Western science difficult to accept or understand. The researcher feels that it is crucial to the research to explore the cultural perceptions of indigenous learners studying Physical Science, which has Western culture embedded in it.

Work done by Lesh & Doerr (2013:293) suggests that metacognition is content and context dependent. Studies done by Magiera (2008:42) suggest that metacognitive skills can improve as a greater understanding of the content and context of the problem is reached. The dependency of metacognition on content and context and the conflict between Western science and non-Western science culture makes it difficult for non-Western learners to improve their metacognitive skills.

The analysis of the South African Physical Science curriculum adds clarity as to whether the curriculum is content driven, or skills driven. If it is highly content driven, it hinders the progress of the indigenous learners' metacognitive awareness due to the factor of time and effort needed to develop higher ordered thinking (Efklides, 2006:6). This is seen as problematic in this study. The cognitive demands of Physical Science are high (see section 2.7.) and this affects the learner's motivation in investing time and effort in metacognitive activities (Thomas, 2012:135).

This study views the classroom-based investigation of metacognition in the study of Physical Science as problematic. It is accepted that the test or examination results are a key indicator of success in the study of Physical Science at school level. This thesis perceives “learning” as a score on the Physical Science examination. In that case the nature of the examination, what is being sought from the examinee (and, more importantly, what then is rewarded with marks) by the constructor of the exam is obviously of vital importance. This is even more so when metacognition is involved. Part of the investigation will look into the extent in which metacognition is motivated during the lesson and rewarded.

Meta-activities require a lot of mental efforts and high motivation which some learners do not want to pursue, thereby not reaching their true potential of metacognitive awareness (Alias & Sulaiman, 2017:35). Learners make judgements of time and effort needed for processing a meta-task and feel unpleasant if the task is difficult (Efklides, 2006:6). Effort put into the meta-tasks determines the success in metacognitive awareness (Vrugt and Oort, 2008: 124). There are many demands on learners studying Physical Science and they may feel that time and effort spent on meta-task is futile if the examination’s measure of success is determined by marks attained in the examination. The learners strive for high grades and may feel that the cognitive demands of the meta-tasks utilise too much of their time and effort. Furthermore, the learners may not find a link to the meta-tasks and the examination. Learners are generally not be rewarded for the efforts involved in the meta-activities.

Moreover, a major problem lies in the average science teacher having no notion of metacognition, and the ones who do lack the resources such as time and effort to promote metacognitive awareness effectively (Georghiadis, 2004:379). The researcher considers this as problematic and will take this into account during the research.

South African indigenous learners, according to the definition inferred from key concepts, mean the African descendants of South African territories and African cultures. The problem is that learners from African cultures are performing poorly in Physical Science (Barry, 2014). Developing metacognitive skills at school level is

crucial in addressing the problem of the large gap in Physical Science results between learners from different cultural groups. Research suggests four ways to develop metacognition in the classroom (Zohar & Dori, 2012:71-72):

- Assess learners' cognitive knowledge and self-regulatory skills before instruction commences;
- Activate metacognitive awareness through prior learning activities such as brainstorming ideas, analysing mind maps and encouraging group discussions;
- By teachers using explicit metacognition instructions during problem-solving activities;
- Promote metacognitive knowledge and regulation through active reflection and dialogue.

This research evaluates the state of metacognition of indigenous learners in Physical Science classrooms in South Africa. If the metacognition of the indigenous learners is poor, it could well be a reason for indigenous learners' poor performance in Physical Science and should be addressed as a matter of urgency.

Academic success in learning science is attributed to good metacognitive skills (Akin, 2016:392; Jayapraba, 2013:165-166; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Thomas, 2012:132) and research shows that improving metacognition improves success in learning science (Hartman, 2001:198; Jayapraba, 2013:165-166). If indigenous learners improve their metacognitive skills, their science results are expected to improve. This could lead to more indigenous learners studying science at an academic level and thereby producing more world class scientists in South Africa, which is not the case currently (Holtman & Rollnick, 2010:109).

1.2 Definitions and overview of keywords

For this study it is necessary to clarify the following key terms:

1.2.1 Metacognition

Early researchers such as Flavell (1976:232) state the metacognition process is the knowledge that learners have about their cognitive processes, products of those processes, and other information relevant to learning. Livingston (1997) refers to metacognition as advanced thinking which involves active control over thinking processes engaged in learning, or put in simple terms, it is thinking about the cognition process. Work done by Young and Fry (2008:1) describes the two subcomponents of metacognition as metacognitive knowledge and metacognitive regulation (see figure 1.1). Metacognitive knowledge refers to what is known and not known about learning content and processes, while metacognitive regulation is the adaptation and implementation of cognitive activities that make learning successful (Elen, 1995:71-72).

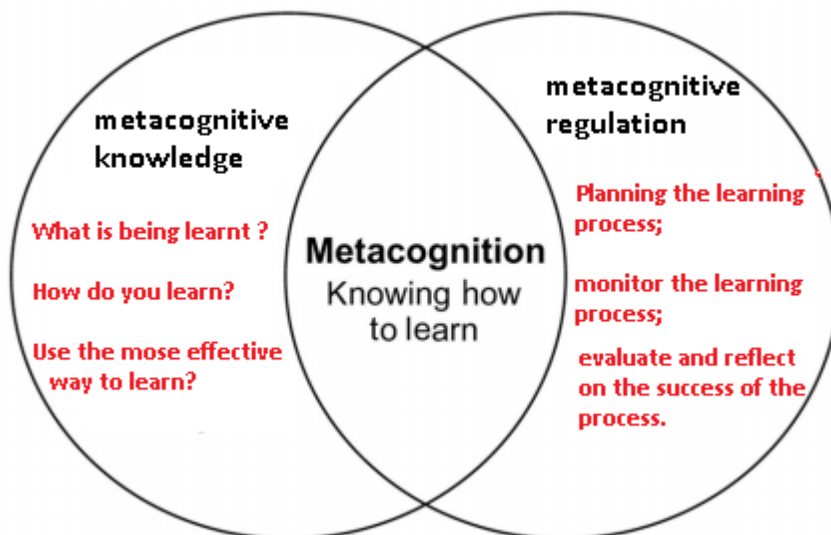


Figure 1.1: Metacognitive knowledge elements and regulation (adapted from Young & Fry, 2008:1)

In this study, metacognition was viewed as an integral element of the problem-solving process, in which learners' use acquired knowledge and strategies on how to solve a scientific problem; take the necessary steps in solving the problem; and reflect on the success of the result (USDE, 2011:31). In terms of higher ordered thinking skills, the researcher viewed metacognition as a cognitive management system in which learners' plan goals, monitor progress, and evaluate the success of

the outcome in order to have a deeper understanding of content studied and problem solved.

1.2.2 Western science

According to Lindberg (2007:2), Western science is the contemporary teachings of physics, chemistry, biology, geology, anthropology, psychology, cosmology, botany, zoology, etc. Western Science is an organised system of knowledge used to describe the physical world (Lindberg, 2007:1). Science is considered to be the pursuit of the nature of facts and how scientists access them as well as how laws and theories construct our knowledge which is derived from facts (Chalmers, 2013:3). The origins of science are routed back to more than three millennia (Lindberg, 2007:1). In this research, we will consider Western science to have its birthplace in Europe (Cobern, 1996:287; Cohen, 1994:380). The major distinction from science practised in other cultures is that Western science focuses on expressing hypotheses and undergoes rigorous scientific testing under controlled conditions (Kafatos & Nadeau, 1990:4).

1.2.3 Physical Science

Physical Science is be broadly defined as the categorisation of progressive knowledge about the physical universe, gained by experience, and verified by experimental research (Jain et al., 2006:38). Van Aarde (2009:4) adds that Physical Science embraces physics, chemistry, biology, applied sciences, agriculture, medicine, and a study that concerns the world as experienced by the human body.

1.2.4 Culture

Culture refers to a unique way of life and an information system which is shared by a group and transmitted across generations (Matsumoto & Juang, 2013:15). The goal is to survive and pursue happiness and well-being (Matsumoto & Juang, 2013:15). Culture drives emotional connections to a community by sharing similar values (Almond & Verba, 1963:13). The apparent contradiction of culture stems from the belief that it makes all humans basically the same, but human groups differ in culture

because humans tend to form cultural groups based on their needs and wants (Naylor, 1997:3).

1.2.5 Indigenous

The general definition of indigenous refers to something that occurs naturally in a certain place, or if it is referred to people, it is the descendants of the original people of the land (Gupta et al., 2007:168). Indigenous people are those who have inhabited a region before recorded history and have a strong ecological engagement with that land (Harrison, 2007:61).

1.3 Rationale of the research

Metacognition in different domains is needed (Zohar & Dori, 2012:2), therefore a research directed specifically to Physical Science is very relevant. Many experts on metacognition confirm that learners with a higher metacognitive awareness performed better in science (Akin, 2016:392; Jayapraba, 2013:165-166; Hartman, 2001:198; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Sinatra & Taasoobshirazi, 2011:212; Thomas 2015:632). However, there is no existing evidence to suggest the link between metacognitive processes of indigenous learners in South Africa and their Physical Science attainment. Previous studies show there is a positive relationship between metacognition and academic success (Akin, 2016:392; Jayapraba, 2013:165-166; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Thomas, 2012:132), but the results of these research projects fail to account for poor results obtained by South African indigenous learners of Physical Science and relate it to levels of learners' metacognition.

The cultural effects on metacognition in South African Physical Science classrooms have received little attention. Hacker and Bol (2004:278-279) state that social-cognitive activities occur within a cultural context and there is evidence to suggest that differences in culture can cause differences in social-cognitive activities. Metacognition is highly linked to the type and amount of a person's knowledge; therefore, it is reasonable to assume that different societies place different values on education at home and school, resulting in dissimilar metacognition (Hacker & Bol, 2004:278-279).

Whilst other studies have looked at the impact of metacognition on academic performance, this study's originality stems from investigating the metacognitive ability of indigenous learners in South Africa and their performance in Physical Science. It is true that non-Western learners have cultural conflicts in processing Western values embedded in modern science (Aikenhead & Jegede, 1999:269; Baker & Taylor, 2007:702; Cobern, 1996:287). However, the extent to which metacognitive process of South African indigenous Physical Science learners is affected by studying a Western science curriculum has not yet been considered. Consequently, we had little basis from which to develop an effective improvement plan to successfully improve Physical Science learners' metacognitive awareness and possibly improve their science attainment.

This research was considered to be supportive in improving the achievements of indigenous Physical Science learners in South Africa and is important, innovative and worth doing because of the following:

- There is a close correlation between metacognition academic success (Akin, 2016:392; Jayapraba, 2013:165-166; Hartman, 2001:198; Nongtodu and Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Sinatra & Taasoobshirazi, 2011:212; Thomas 2015:632) which may apply to the indigenous learners studying Physical Science;
- Improvement of metacognitive awareness improves attainment of low-ability indigenous learners and indigenous learners who have insufficient knowledge and metacognition (Bruning, 2004:84; Schraw, 2001:7; Schraw, 1998:117);
- Metacognitive skills of indigenous learners may be learnt and improved within subject content (Griffiths, 2008:104; Israel et al., 2006:56; Li & Zhoa, 2014:35; Vas'quez et al., 2013:86);
- Cognition, which is a major part of indigenous learners' metacognitive process can be taught or attained by peers, teachers, or one's culture (Schraw & Moshman, 1995:359).

According to Dunlap and Lowenthal (2013:171-173), metacognitive awareness is crucial for self-directed and effective lifelong learning. When indigenous Physical

Science learners improve their metacognitive skills, they become more confident and become better self-directed learners geared towards pursuing a career in science.

1.4 Conceptual-theoretical framework

1.4.1 Introduction

This research constantly considered the main theories listed below which was crucial in answering the research questions. These theories were synthesised in the final chapter to bond the theoretical framework to the analysed data and suggested solution. This solidified the rationale for the arguments posed in the final chapter. Despite the list of main theories being vast, the researcher felt that it was necessary to consider major aspects of these theories in order to draw sound conclusions with theoretical backing (cross-referencing).

- Flavell's (1976:232) Model of Cognitive Monitoring and Regulation will be used as a theoretical framework for metacognitive aspects of Physical Science learners higher level thought processes (see section 2.4.3.);
- Vygotsky (1978:86) constructivist theory and zone of proximal development (ZPD) as a framework to assess enquiry-based approach to teaching Physical Science (see section 2.9.2.);
- Yrjo Engeström's Cultural-Historical Activity Theory (see section 3.2.);
- Thomas (2002:241) socio-cultural embedment of metacognition (see section 3.5.);
- The learning pit (see section 2.10.4.);
- Hattie's (2012:2) visible learning model to raise attainment (see section 2.11.);
- Hollingworth and Mcloughlin's eight-phase model to improve problem solving in Physical Science (see section 2.10.1.);
- The American Psychological Association's 14 psychological principles that holistically deal with the real-world context of learning (see section 2.5.1.);

- Behaviour, Attitudes, Cognition, and Environment Interacting Systems model (BACEIS) which includes socio-cultural influence on metacognition (see section 3.6.).

Flavell (1976:232) provided the groundwork for the pioneering of metacognitive principles and is considered to be the founder of metacognitive theory (Livingston, 1997). The basis of this this research stems from Flavell's contributions to the field of metacognition (see section 2.4.3.).

It is important to note that Engeström's (2005:20) Cultural-Historical Activity Theory is an extension of Vygotsky's work on socio-cultural learning. The impact of rules, community, division of labour, and socio-historical characteristics of thinking were acknowledged by Engeström but were not included by Vygotsky (Yamagata-Lynch, 2010:23). Engeström's is considered to be the modern-day interpreter of Vygotsky's theory. The CHAT theory is used as a lens for this study, whilst Vygotsky's ZPD (see section 2.9.2) is referred to during social construction of knowledge during problem solving. The innovativeness of Vygotsky as referred many times in this research is the simple idea of ZPD (see section 2.9.2). This is a highly valued part of the study. The social construction of knowledge in the ZPD laid the foundation in the fostering of metacognition, but Engeström's (2005:20) CHAT added value due to the socio-cultural nature of the research.

The socio-cultural embedment of metacognition by Thomas (2002:241) focuses on learners' metacognition within the socio-cultural environment and highlights the factors that affect learners' metacognition. Studies by Thomas (2002:240) suggest that the school and classroom environments can drive learners to greater efforts to achieve academic success in form of high grades in examination, instead of valuing critical thinking. This becomes socially acceptable because learners are examination-driven rather than focused on higher ordered thinking skills. Thomas (2002:241) contribution to this study adds to the discussions in section 1.1.2. on meta-activities requiring lots of time and mental efforts which some learners do not want to pursue, thereby focusing on exam driven content to achieve high grades in the Physical Science examinations.

The learning pit model created by Nottingham (2016:109) promotes academic tenacity, growth mindset and is metacognitive by nature (see section 2.10.4.). This model contributes to the motivational elements of metacognition.

Hattie's (2012:2) visible learning model to raise attainment was the largest ever study of teaching strategies in a classroom environment ever done. (see section 2.11.). Hattie's theory guided the research in viewing the metacognitive teaching and learning process through the eyes of visible learning and in promoting outcomes with high effective sizes which optimises learners' academic success.

Hollingworth and Mcloughlin's eight-phase model to improve problem solving in Physical Science is a metacognitive model to promote metacognitive awareness in Physical Science (see section 2.10.1.). This research views metacognition as domain specific and regards the model as an important strategy to explicitly promote metacognition during Physical Science problem solving.

The 14 psychological principles categories of cognition and metacognition, motivation and affective factors, developmental and social factors, and individual differences are connected psychological principles which are intended to involve all stakeholders in the educational system (see section 2.5.1.). These principles emphasise the interconnectedness of the multidimensional components of metacognition which is valued in this research.

Behaviour, Attitudes, Cognition, and Environment Interacting Systems model (BACEIS) includes socio-cultural influence on metacognition (see section 3.6.). BACEIS is two-way interaction between metacognition and affective self-regulation, which is required to best enhance intellectual performance taking the important element of culture into consideration. This includes the multidimensional nature of metacognition and its connection to motivation and culture.

1.4.2 Research lens

This study looked through a lens of socio-cultural influence at the state of metacognition in indigenous learners of Physical Science. The third-generation

Cultural-Historical Activity Theory (CHAT) theoretical framework was used to understand and analyse the relationship between interacting systems influencing indigenous learners' learning (Engeström, 2005:20). CHAT centres on understanding people's history and traditional practises, their objects, mediating artefacts, and societal establishment (Engeström, 2005:307-308). CHAT focuses on the innovative potential of the human mind (Engeström, 2005:308). Therefore, by using CHAT with mixed methods data gathering, the researcher sought to identify possible hindrances in the metacognitive process, and find opportunities for improving metacognition, thereby gaining a better understanding of how learners construct meaning and use strategy during problem solving.

The research throughout considered the following aspects:

- There is a socio-cultural influence on metacognition (Hacker & Bol, 2004:292-293; Helms-Lorenz & Jacobse, 2008:14; Kurtz, 1990:185; Kruglanski et al., 1998:77; Thomas, 2002:242);
- The indigenous science learners of South Africa are historically disadvantaged (Barnard et al., 2009:269; Hewson, 2015:22; Sichone, 2003:470-471);
- Physical Science has cultural embedded values that might be different from cultural values of indigenous learners in South Africa (Aikenhead & Jegede, 1999:269; Hwang, 2011:3; Shizha, 2011:15-16; McKinley & Stewart, 2009:52);
- Motivation of learners plays an important role in the metacognitive process (Efklides et al. 2001:303; Hartman, 2001:199; Larkin, 2009:85; Myers, 2008:37);
- The necessity for promoting metacognition in the Physical Science classroom to improve attainment (Hartman, 2001:198; Holmes, 2007:15; Jayapraba, 2013:165-166; McCraight-Wertz 1999:14; Sinatra & Taasoobshirazi; 2011:213-214).

1.4.3 Summarised overview of literature

1.4.3.1 Metacognition

Epistemology and metacognition enable us to understand the nature of the learning environment (Bassford & Slevin, 2003:144). Bassford and Slevin (2003:143) suggest the epistemological thought process is at play when people constantly update their knowledge and skills by lifelong learning. Major theories do not emphasise the important link of epistemology in the success of metacognitive awareness, however, Lesh and Doerr (2013:293) suggests that metacognition is dependent on content. Furthermore, work done by Magiera (2008:42) implies that if the learner has a good epistemological thought process and is keen in updating his or her knowledge, their metacognitive skills may improve. As in Physical Science, this can be achieved by reading science books and journals and attending Physical Science lessons.

Metacognition, as stated by Livingston (1997), is advanced thinking which involves active control over thinking processes engaged in learning. Flavell (1976:232) refers to the metacognition process as the knowledge that learners have about their cognitive processes while Jime'nez et al. (2009:782) describe metacognition as the product of the process and other information relevant to learning. A popular view is the two subcomponents of metacognition are metacognitive knowledge and metacognitive regulation (Schraw & Dennison, 1994:460; Young & Fry, 2008:1). Metacognitive knowledge is further categorised into declarative knowledge (knowledge about strategies and information); procedural knowledge (knowledge of applying information and strategies) and conditional knowledge (knowledge about choosing the correct strategy) (Schraw & Dennison, 1994:460). Metacognitive regulation facilitates the learning process and is classified as planning, monitoring, and evaluating (Schraw & Dennison, 1994:460).

Jime'nez et al. (2009:782) summarise metacognitive knowledge variables as:

- Declarative knowledge: what is the learner learning?
- Procedural knowledge: how does the learner go about acquiring learning skills?
- Conditional knowledge: using the most effective strategy when needed.

Pintrich et al. (2000:50) describe metacognitive regulation as activities that lead learners to adapt and change their thinking. Sinatra and Taasobshirazi (2011:204) add that metacognitive regulation is the knowledge and the skills required to solve problems that require higher-order thinking. Schraw and Moshman (1995:354) state that planning, monitoring and evaluation are key components in developing the metacognitive regulation. Zohar and Dori (2012:59) summarise the key components as follows:

- The first phase is planning, which involves target setting, considering different strategies, and selecting the best strategies using resources on hand to solve the problem;
- The second phase is monitoring where self-analysis and self-reflection are required for success, and anticipating what should be done next;
- Finally, the evaluation stage refers to self-appraisal done to gauge the overall success of the process, by assessing both the process and the product.

Merging these definitions of metacognition with epistemology, the researcher viewed metacognition as a cognitive management system in which the learners' plan goals, monitor progress, and evaluate the success of the outcome in order to have a deeper understanding of content studied and problems solved. Metacognitive knowledge and metacognitive regulation are central to the study, with metacognition regarded as part of the problem-solving process in which learners use to acquire strategies to solve a scientific problem and reflect on the results (USDE, 2011:31).

Metacognition plays a crucial role in successful academic success (Akin, 2016:392; Coutinho, 2007:39-40; Thomas, 2012:132; Himghaempanah et al., 2014:487; Landine & Stewart, 1998:200; Nongtodu & Bhutia, 2017:54-55; Owo & Ikwut, 2015: 6; Vrugt and Oort, 2008: 123). It is encouraging that many authors, including Griffiths (2008:104), Israel et al. (2006:5), and Li & Zhoa (2014:35) agree that metacognitive skills can be taught, learnt, and improved. A point of consideration during this research was that if teachers promoted metacognitive awareness, the learners' higher order thinking skills would improve. For metacognitive awareness to occur in the Physical Science classroom, the teacher must teach metacognitive planning,

monitoring, and evaluation during the lesson. Focusing on the development of metacognitive skills contribute to the improvement of Physical Science attainment, which in turn leads to more world-class scientists being developed in South Africa. Moreover, every learner benefit from developing strong metacognitive skills irrespective of their ability (Bruning, 2004:84; Schraw, 1998:117).

The research requires close analysis of the concept of metacognition and how it can be improved before synthesising a conclusion, because research on metacognition provides scope for misinterpretation and over-generalisation (Simmons & Kameenui, 1998:302).

1.4.3.2 Western science in developing countries

Europeans succeeded in formulating modern science where other nations such as India, China, and Arabia failed (Needham & Wang, 2004:211). Modern science, also known as Western science (Cobern, 1996:287), is at the heart of the Physical Science curriculum in South Africa (DBE, 2011). Indigenous learners find it difficult to understand and contribute towards Western science because of the embedded dominance of European history and philosophy in Western science (Hwang, 2011:3-4). In most African countries the science curriculum is based on a Western standpoint and alienates African learners (Shizha, 2011:15-16). McKinley and Stewart (2009:52) inform us that science education is going through a transformation in response to Western science, which might promote a new form of colonialism that is embedded in modern science, being forced on developing countries. The researcher considers the rooted Western culture entangled within the Physical Science curriculum and is aware that this has a negative impact on the indigenous learners' success in Physical Science. During the data gathering the researcher attempted to find out to what extent this affected the South African indigenous learners.

Science curricula in developing countries are often replicated from Western countries (Cobern, 1996:287-288). Learners in developing countries, according to Maddock (cited in Aikenhead & Jegede, 1999:269) feels they are unable to relate to a Western science curriculum because it is foreign to their culture. Aikenhead & Jegede (1999:269) further assert that these feelings experienced by non-Western learners

are due to differences between their indigenous culture and the culture of Western science. South African indigenous culture draws freely on the spiritual, emotional, mental, and physical nature of life, but Western science rejects the emotional and spiritual qualities of life and focuses mainly on the mental and physical (Hines, 2007:107). The extent to which the South African Physical Science curriculum promotes indigenous knowledge will be studied. This will guide the researcher into understanding to what degree the cultural values of the indigenous people are included within the Physical Science curriculum. The more inclusive the Physical Science curriculum is towards the indigenous learners' culture, the lower the impact of Western imbedded values of the Physical Science curriculum has on the learners. Furthermore, the researcher is of opinion that a culturally inclusive Physical Science curriculum motivates the Physical Science learners.

Baker and Taylor (2007:702) add that Western science does not jibe with non-Western learners' languages and beliefs. Furthermore, there is a conflict of meaning between indigenous languages and cultural meanings rooted in the language of Western science education (Baker & Taylor, 2007:702). Conflict of meaning between the scientific language and the indigenous learners' language could occur from time to time during the Physical Science lesson. For example, the isiZulu word for earth is "umhlaba", but there is no isiZulu word for Mars and Saturn. The name of the planets in the solar system is derived from Western culture. Moreover, the term planet, is derived from the Greek word *planitis* which means wanderer. There is no traditional isiZulu word for planet.

Hofstein et al. (2008:114) concludes that understanding the history and philosophy of science during teaching and learning processes encourages the metacognition necessary for understanding science. For example, the structure of the atom can be better understood by learning about the history of its development and the scientific philosophy that shapes the theory. This will help science learners to visualise and understand the microscopic world of the atom during the problem-solving process. In this research, learners' attitude towards studying Western science could be at odds with their own culture and history will play an important role in drawing conclusions.

1.4.3.3 Metacognition in the science classroom

In line with problem solving in physical science, cognitive failure occurs when the understanding, reasoning, and perception of the Physical Science learner is not enough to solve the problem successfully. Metacognition which can be seen as the cognitive management process during problem solving is activated by the learner by planning, monitoring, and evaluating the cognitive and epistemological processes during problem solving. The learner's metacognitive awareness controls and monitors cognitive performance (Chambres et al., 2002:xiii). In the observed Physical Science classes, the researcher identified epistemology as cognitive goals required for the achievement, whereas metacognition is part of the process in which goals are attained. Research by Hartman (2001:198) concluded that metacognition assists science learners to improve on and implement effective techniques in obtaining, understanding, executing, and retaining extensive, difficult models and skills. Feasey (2005:30) notes that risk-taking and critical thinking underpins creativity in science. He further states that the process of metacognition and creative thinking can develop creativity in science (Feasey, 2005:32). Creativity is an essential key in producing world class scientists which creates scientific and technological solutions to the political and socio-economic problems in South Africa. South Africa needs excellent scientists that produce excellent results as well as having the ability to go beyond what has been learnt and create new ideas.

According to Zohar and Dori (2012:2), metacognitive skills in different subjects can be different. For example, meta-skills required in science are different to meta-skills required in history. Therefore, extensive research on metacognition in Physical Science is essential. It is hoped that this research makes an invaluable impact in this field.

If the Physical Science curriculum is highly content driven, it hinders the progress of the indigenous learners' metacognitive awareness. In section 1.1.2. it was discussed that meta-activities require a lot of mental efforts and high motivation which some learners do not want to pursue. Furthermore, Physical Science is very cognitively demanding. Limitations may arise when learners fail to put in the time and effort needed to develop higher ordered thinking skills associated with Physical Science.

Certain authors discuss whether metacognition occurs without the learner knowing, while others conclude that learners have conscious control in metacognitive processing (Chambres et al., 2002:xiii). The conflicting theories arise between learners being consciously aware versus the learners being unconsciously aware (automation) during the metacognitive process. The contradiction, in theory, limits the researcher if either argument inordinately influences the researcher. This researcher, therefore, considered both points of view and acknowledges that not all strategy selection is metacognitive by nature.

Even young learners possess metacognitive knowledge (Davis et al., 2010:498; Roberts & Powell, 2005:1019; Robson, 2015:185; Voogt & Knezek, 2008:282). This means that metacognitive awareness can be encouraged at an elementary level. Young learners should be encouraged to plan, implement, and reflect on metacognitive strategies undertaken during class activities. Metacognitive skills improve as the child gets older. Metacognitive teaching should thus be provided to all learners, regardless of ability (Frazee & Rudnitski, 1995:141; Schraw, 2001:7; Sperling et al., 2002:53). Indeed, metacognitive awareness improves attainment of low-ability learners and learners who have insufficient knowledge (Bruning, 2004:84; Schraw, 2001:7; Schraw, 1998:117). Despite this research focusing on Physical Science, it is hoped that the findings will be transferable to all science learners starting from elementary level learners all the way to high school.

Apart from cognitive factors affecting the metacognition process, motivation plays a vital role in carrying out a task (Efklides et al., 2001:303; Hartman, 2001:99; Larkin, 2009:85; Myers, 2008:37). According to Jime'nez et al. (2009:783), cognitive factors relate to the capability of carrying out a task, while motivation factors deal with the implementation of the task (Jime'nez et al., 2009:783). According to Zelick (2007:119), learners' attribution is a major indicator of success or failure in solving a science problem. The researcher analysed learners' attitude towards science and related it to their metacognition. The researcher is of opinion that motivation is the stepping stone in promoting metacognitive awareness. If the learners are not motivated, they will not make the effort to improve their metacognitive skills, therefore the scientific attitude of the learners was assessed to draw conclusions.

1.4.3.4 Culture, metacognition, and Western science

Despite some perceiving good science as unbiased and objective, and should not have a socio-cultural influence (Ratcliffe, 2007:120), many researchers argue against this (Aikenhead & Jegede, 1999:269; Cobern, 1996:287; Ratcliffe 2007:130; Sutherland, 2005:597). Ratcliffe (2007:130) analysed data from learner assessments in science based on their values, their socio-cultural perspectives, and how well they argue their point scientifically. She concluded that in addition to the cognitive process of science, human qualities and socio-cultural aspects are important in the study of Western science.

Ratcliffe's (2007:130) studies state that the latest model of Western science is seen as cognitive, socio-cultural, and epistemic practise. It is important to consider values such as creativity, collaboration and culturally bound activities in which reliable information is created through diverse but rigorous approaches which change depending on evidence embedded in society (McComas & Olsen cited in Ratcliffe, 2007:120).

Studies by Ornek (2011:255) suggest that African children's socio-cultural background hinders their success in learning science. African children are raised with non-scientific beliefs, such that lightning is created by a witch doctor; people don't die of natural causes but die because of witchcraft; a chameleon is evil (Ornek, 2011:256). In many cases, these beliefs negatively impact on African learners' attitudes and achievements in science (Ornek, 2011:256). Various cultures, including Western society throughout the world, are brought surrounded by non-scientific superstitions (Cushner & Brislin, 1996:309). These sorts of non-scientific beliefs could hinder learners' progress in science. For example, lightning is caused by the potential difference between the earth and clouds causing electrons to move in form of lightning. Some indigenous learners have internal conflicts with this theory and their traditional beliefs. A way forward is to include indigenous knowledge within the science curriculum to support metacognition, as discussed in 1.4.3.2.

Problems arise when learners face difficulty caused by the conflict in world view between traditional culture and the Western-culture embedded in science (Shizha,

2011:15-16; McKinley & Stewart, 2009:52; Sutherland, 2005:597). A common worldview across many non-Western cultures tend to be holistic and spiritual (Hines, 2007:107; Sutherland, 2005:597). Research done by Schalk (2009:23) concludes that poor attainment in science was partially due to culturally irrelevant science curricula while science curricula that have integrated learners' cultural identities improved both achievement and attitude towards science. Western learners have a greater advantage studying Western science than non-Western learners, despite growing up with non-scientific superstition. This is due to some of their Western values being rooted in modern science (Aikenhead & Jegede, 1999:269; Baker & Taylor, 2007:702; Cobern, 1996:287). It is important to note that Western culture is not homogenous and does vary between cultures. The point the researcher tries to make is that Western science has more in common with Western cultures than non-Western cultures.

Aikenhead & Jegede (1999:269) termed cognitive clashes between indigenous cultures, the real-world, and the culture of science, as collateral learning. A major factor in collateral learning in science education is the acknowledged feeling that it is an imported culture to non-Western indigenous learners (Aikenhead & Jegede, 1999:269). Collateral learning triggers a need to develop culturally accommodating science programmes and teaching methods to decrease the exclusion felt by non-Western learners (Aikenhead & Jegede, 1999:269; Hassard & Dias, 2013:70; Gough, 2008:42; Jegede, 2011:128)

A science curriculum which acknowledges traditional culture lessens the conflict between the culture of science and the indigenous culture. The argument for a culturally inclusive science curriculum is that it values indigenous knowledge which relies on observations in a naturalistic environment, it includes principles of equality and respect, underpins multiculturalism, and promotes an antiracist education system (Web, 2012:90). Therefore, when studying metacognition in science, it is vital to consider the socio-cultural elements. The way Western values is rooted in modern science benefits Western learners, indigenous knowledge in the South African Physical Science curriculum may advantage indigenous learners. Although the focus of this study is on metacognition, it is noted that socio-cultural factors and motivation

affects the level of metacognitive awareness and will be assessed during the research.

1.5 Research questions

Consequently, this research aimed at addressing the following critical questions:

Primary Research Question: What is the state of metacognition within indigenous learners' Physical Science classrooms in KwaZulu-Natal?

- Secondary Research Question 1: To what extent does the South African Physical Science curriculum promote metacognition?
- Secondary Research Question 2: What is the relationship between grade 11 learners' Physical Science half yearly examination results and their level of metacognitive awareness?
- Secondary Research Question 3: To what extent is metacognition promoted by the teacher in the Physical Science classroom?
- Secondary Research Question 4: What are the views held by indigenous learners and teachers regarding Western science?
- Secondary Research Question 5: What is the relationship between learners' metacognitive awareness and their attitude towards Physical Science?
- Secondary Research Question 6: How does studying Western science impact on the metacognitive processes of indigenous learners in South Africa?
- Secondary Research Question 7: To what extent do Physical Science teachers think metacognitively?
- Secondary Research Question 8: What workable teaching and learning strategies can be exhorted to improve learners' metacognitive skills?

1.6 Aims and objectives of the research

This study investigated the state of metacognition in South African Physical Science classrooms to infer and exhort workable teaching and learning strategies to improve these learners' metacognitive skills, which might improve their Physical Science results. This research analysed the teaching and learning situation from the

perspective of indigenous Physical Science learners in public schools in two KwaZulu-Natal districts. The intention was to generalise results obtained by the research and apply them to other indigenous Physical Science learners in developing countries because they all tend to have similar problems (Howie, 2002:281-283).

Based on the research questions, the research aims were:

1. To determine the extent to which the South African Physical Science curriculum promotes metacognition.
2. To determine the relationship between the grade 11 Physical Science learners' half-year results with their level of metacognition, as measured by the Metacognitive Awareness Inventory.
3. To observe grade 11 Physical Science lessons and assess the extent to which metacognitive activities take place during teaching and learning.
4. To conduct interviews and questionnaires constructed to reveal the views of learners and teachers of Western science.
5. To determine the relationship between the results obtained from the metacognitive awareness and science awareness questionnaires and use it to determine learners' attitudes towards Physical Science.
6. To use the results obtained from the questionnaires, observations, and interviews to deduce the impact of studying a Western science curriculum on the metacognitive processes of learners.
7. To explore the extent of teachers' metacognitive thinking.
8. To exhort workable teaching and learning strategies that may improve learners' metacognitive knowledge and skills.

1.7 Research design and methodology

The research comprised both a literature study and an empirical study that will be discussed in the following sections. However, due to time constraints of the research, the researcher included current theoretical findings as the research progressed. The time constraints refer to the limited time given for the data collection

process in the school by the principals of the school. Chapter 4 presents the complete data analysis.

1.7.1 Literature review

A comprehensive literature review was undertaken before the data collection process, which helped lay the groundwork for the research. The review provided the prerequisite literature on metacognition and highlighted the significance of the new study. The research literature guided the researcher in the following issues (Booth et al., 2016:11):

- Identifying, selecting, and appraising accepted studies connected to the research aims;
- Synthesising evidence to gauge what is known or not known about the study of metacognition;
- Determining the gaps in our knowledge on the key areas of the study;
- Highlighting weaknesses in evidence and argues for further research;
- Recognition of a sound conceptual framework for the research problem;
- Selection of the most effective research design and data collection strategies.

The keywords which informed the search process are metacognition; Western science; Physical Science; culture; non-Western learners; and indigenous.

The researcher used the following online libraries to obtain the most relevant information for the research:

- Institutional Repository of the North-West University
- Unisa Institutional Repository (UnisaIR)
- Questia online library
- ERIC online library
- Google Advanced, Google Scholar, and Google Books

1.7.2 The Experimental design

The learners' metacognition is viewed as a consequence of psychosocial environment which is interrelation of socio-cultural factors and individual thought and behaviour (Thomas, 2012:133). Metacognition vary across cultures (Thomas, 2012:133), therefore an experimental design which considers this is effective in researching metacognition in the Physical Science classroom. Metacognition is a cognitive activity which cannot be directly detected but its existence can be inferred (White cited in Thomas, 2012:135). The learners learning environment is crucial in understanding the learners' cognitive and metacognitive ability. This study reflects this paradigm and feels that the mixed methods approach is most effective.

The pragmatic paradigm enables research to follow a mixed method design which has both qualitative and quantitative methods. Mixed methods research consists of at least one quantitative method and one qualitative method of data collection in the same study (Cizek, 1998:461). Mixed methods research is based on Tashakkori and Teddlie's (2010) typology that includes the parallel and simultaneous gathering of both qualitative and quantitative data (Tashakkori & Teddlie, 2010:19). In this research, there was a parallel gathering of qualitative and quantitative data.

The research was divided into four phases of data gathering, using the triangulation model of mixed methods design (See section 4.3.3).

1.7.3 Population and sample

The research limited the teacher and learner population to grade 11 Physical Science classes from the Phoenix and Tongaat central district office in KwaZulu-Natal. This controlled the variables of maturity, expected scientific knowledge, and level of learners' development.

The researcher felt the research would be valuable to all South African indigenous learners because of the statistics used to show poor performances in science in section 1.1 used data for all indigenous learners of South Africa collectively (Barry, 2014; HSRC, 2011). The sample consisted of 151 grade 11 Physical Science learners from seven different schools. The Physical Science classes were co-

educational (included girls and boys). These schools are located in the middle- to lower-income areas of the Phoenix and Tongaat central district.

The variable of teaching quality was controlled by using qualified Physical Science teachers with a minimum of five years teaching experience and appropriate qualifications (see 4.4.2). This variable was considered when making classroom observations.

1.7.4 Instruments and sources of data

The researcher used different sources and instruments to delineate all qualitative and quantitative measurements (Cottrell & McKenzie, 2011:146). The research was broken down into four phases which are described in detail in Chapter 3. The four phases of data collection used qualitative and quantitative methods to collect and analyse data to determine the level of metacognition in each phase (see Figure 4.1).

1.7.4.1 Phase 1 sources of data

The researcher used qualitative sources of data for analysis, namely, the Physical Science Curriculum and Policy Statement (CAPS) document (DBE, 2011), and learners' notebooks (see section 4.5.3 and 4.5.4). Analysis of the curriculum document showed the extent to which the curriculum-supported metacognition and was used to achieve research aim 1. It also gave some insight into what was to be expected during phase 2, lesson observation.

Physical Science notebooks were selected by teachers. They chose a selection of notebooks from high, medium, and low-achieving learners. The notebooks showed written evidence of the application of metacognition during problem solving and note-taking. The quantitative data included grade 11 learners' half-yearly Physical Science results. The half-yearly results presented physical evidence of the attainments of the Physical Science learners, and this was compared with the notebook review. The data were collected to add value to the data analysis stage described in Chapter 4.

1.7.4.2 Phase 2 Instruments

Phase two of the research comprised of observations of grade 11 Physical Science classes in the seven schools (see section 4.5.5). The researcher observed the Physical Science lessons and completed the lesson observation protocol sheet (see appendix 1). The aim of lesson observation was to analyse the state of metacognition during the teaching and learning process (research aim 3).

1.7.4.3 Phase 3 Instruments

Phase 3 involved quantitative instruments in the Metacognitive Awareness Inventory (MAI) for learners which were adapted from Schraw and Dennison (1994:472-474), the Metacognitive Awareness Inventory for Teachers (MAIT) adapted from the MAIT by Tanner (2012) and Balcikanli (2011:1331), and the Science Attitude Questionnaire (SAQ) adapted from Summers (2012:92-93) (see 4.4.3-5). Quantitative analysis of MAI (see appendix 2), SAQ (see appendix 3) focused on research aim 5, and the MAIT (see appendix 4) focused on research aim 7.

1.7.4.4 Phase 4 Instruments

The interview schedule for the learners (appendix 7) and the interview schedule for teachers (appendix 8) were the instruments used to guide and inform phase four of the research (see section 4.5.6). Learners' responses provided important information about their metacognitive skills and their views on studying a Western-style science curriculum. Additionally, they were asked about their future in science. The teachers implement the curriculum and thus, by responding to the interview questions, provided information regarding learners' attitudes, along with their professional views of the Physical Science curriculum. The teacher interviews were done as structured interviews, while learners were given focus group interviews (see section 4.3.2). Data thereby gathered helped to answer research aim 4.

1.7.5 Data analysis

Mixed methods research involves triangulation of analysed data. Triangulation is a technique for enhancing validity that combines qualitative and quantitative methods. Triangulation aims to avoid the intrinsic predisposition in a study that involves a

single-method, single-observer, or single-theory (Dezin, 1989:313). The researcher used the mixed methods techniques of data analysis in this research to ensure triangulation which would further validate the results and conclusions of the research.

The questionnaires served as a quantitative scientific measurement instrument that yielded scores of reliability and validity (Do'nyei & Taguchi, 2010:93). Construct reliability of the questionnaires about the specific population was determined by calculation of Cronbach's Alpha coefficients (see section 4.4.6). Construct validity of all questionnaires was assured through confirmatory factor analyses. The North-West University (NWU) statistical services were requested to assist the researcher with the descriptive statistical methods (see section 4.4.6).

The qualitative component of the research (see section 4.5) gave a rich, deep description orientated towards analysing concrete research in their natural environment and starting from human expressions and actions in a local context (Flick, 2014:22). After the four stages of data collection, the researcher integrated the qualitative and quantitative data, using the triangulation design (see section 4.3.5) to draw conclusions and answer the critical questions. Notes and transcripts (where applicable) were checked for correctness, and codes, categories, and themes cross-checked by another expert in the field of study in order to establish reliability of the qualitative analysis.

1.8 Ethical considerations

Ethical issues are crucial to the design of a research framework. The participants in the research must be made of aware of their legal and ethical rights. The researcher followed the Kantian moral philosophy, which prohibits simply using the participants to obtain valuable data for the research, and instead encouraged respect for all participants involved (Hasala, 2005). The researcher ensured that the research was conducted in an ethical and legal manner.

Resnic's (2015) general summary of ethical principles helped elevate the research's ethical standards and legal conformity. Resnic (2015) stresses the following key elements in ethical research:

- **Honesty:** The researcher was honest throughout the research and made full disclosure of the research and its methodology to all key participants of the research. The researcher did not falsify or fabricate data. Original survey forms were given to NWU to safeguard.
- **Objectivity:** The researcher played a passive role during the classroom observation phase of the research. He wrote a report on everything that was observed. The researcher transcribed the data gathered during the interviews verbatim and disclosed all personal interest in the research, such as obtaining a PhD for career reasons.
- **Integrity:** The researcher kept all meetings, promises and agreements.
- **Carefulness:** All data gathered, research design, and research activities were carefully recorded and critically examined.
- **Openness:** The researcher shared all data with the relevant participants and was open to criticism.
- **Respect for Intellectual Property:** Acknowledgement was given through citations and notes of appreciation to all contributors of research. The researcher did not plagiarise.
- **Confidentiality:** All participants and schools were coded to protect their rights of confidentiality.
- **Responsible publication:** The research will be published to advance research.
- **Legality:** Relevant informed consent forms and letters were drawn and given to the relevant participants to ensure the participants' legal rights were made public and respected. This is discussed in more detail in section 4.7.
- **Human Subjects Protection:** The researcher researched in a manner that minimised risks and maximises benefits by respecting human dignity, confidentiality, and autonomy.

1.9 Contribution of this study

To date, a considerable body of research has sought to understand the impact of metacognition on the success of learning (Cronin, 2013:85; Lally & de Laat, 2002:162; Quinton, 2010:104). While previous research provides many important insights, this study intends to add to existing theory by focusing on metacognition of indigenous learners in South African Physical Science classes. This research is conceptually intriguing because it correlates the metacognitive processes of indigenous learners in South Africa with their scientific attainments. Indigenous learners have cultural conflicts with the Western embedded culture in Physical Science (see section 1.4.3.4.). This research advances the theory by showing its impact on the metacognitive processes of the South African indigenous learners studying Physical Science.

The findings of this research,

- may be credible and highly beneficial to schools in developing countries that have similar problems to South African Physical Science indigenous learners;
- may assist education policymakers to promote an effective plan to improve attainments in Physical Science nationally;
- could inform science teachers of the benefits of teaching metacognitive skills during their lessons.

1.10 Structure of the study

The thesis consists of six chapters, with the following chapter layout:

Table 1.1 Layout of chapters

Chapter	Heading	Contents
Chapter 1	Orientation	This chapter is meant to stir the reader's interest in the topic by providing a brief background to the state of Physical Science in South African classrooms and the concept of metacognition. Discussed the scope and direction of the research. The interpretation of the research question gives the reader a clear idea of how the research was approached.

Table 1.1 Layout of chapters (continued)

Chapter 2	Literature review: Metacognition and problem solving in Physical Science	This section provides an in-depth evaluation of scholarly articles, research, and books written about the definitions of metacognition, epistemological assumptions, metacognitive theories, and components of metacognition. This was summarised by citing relevant work by various authors, giving a clear idea of why research in this field is important.
Chapter 3	Literature review: Cultural implications of metacognition in Physical Science	Chapter 3 evaluates academic articles, research, books, written theory on the cultural influences of metacognition, CHAT, environment interacting system model, and conflict of non-Western learners studying Western science. This was summarised by citing relevant work by authors stressing the importance of the research.
Chapter 4	Research design and methodology	The research led to the justification of entirety of findings and confirmed the validity of data. The reporting confronted the research problem, investigated metacognition in the South African Physical Science classroom, and built towards a conclusion. Together with the focus in chapter 3, the research methodology should convince the reader of the validity and reliability of the results.
Chapter 5	Data Analysis and results	Chapter 5 presents the data collected by the mixed methods methodology. It is presented and analysed quantitatively and qualitatively in this chapter. Triangulation integrates the data gathered.
Chapter 6	Summary, discussions, recommendations, and conclusions	This chapter exhorts strategies and approach to promote the metacognitive development of South African indigenous learners. The researcher used the results obtained from the research to justify the need to promote metacognition in South African classrooms. A complete summary of the research findings describes valuable information that has been uncovered. Questions arising from the research were used as a basis to promote further research

CHAPTER 2

LITERATURE REVIEW: METACOGNITION THEORIES AND MODELS

2.1 Introduction

This chapter looks at the importance of metacognition in problem solving in Physical Science, highlighting studies on how the mind works during the problem-solving process and what causes learners to perform poorly in Physical Science. Finally, all the studies reviewed will be synthesised, promoting metacognition as a workable solution to the problem of poor Physical Science performances in South African classrooms. The chapter begins with metacognition and problem solving in Physical Science, emphasising the cognitive demands and theories informing the research. The second part of the review focuses on the socio-cultural implications of metacognition in the study of Physical Science in Chapter 3.

Figure 2.1 shows the interconnection of different components of the literature review for Chapter 2. The diagram illustrates how the subcomponents of the Chapter support the main idea of the review, which is metacognition in Physical Science learning. Analysis of the theories is integrated as part of the conclusion of the literature review.



Figure 2.1: Breakdown of the literature review on metacognition theories and models

2.2 A brief insight into metacognition as the key to success

Educational researchers, supported by substantial evidence, have long supported the necessity for metacognitive awareness in successful teaching and learning (Akin, 2016:392; Coutinho, 2007:39-40; Thomas, 2012:132; Himghaempanah et al., 2014:487; Landine & Stewart, 1998:200; Nongtodu & Bhutia, 2017:54-55; Owo & Ikwut, 2015: 6; Vrugt & Oort, 2008: 123). This was emphasised in section 1.3.; 1.4.3.1.; and 1.4.3.3. Despite metacognition being a widely researched field in

education, many educators remain poorly acquainted with strategies for promoting metacognition in their classroom. This section of the literature review focuses on metacognition and problem solving in Physical Science and concentrates on:

- definitions of metacognition;
- metacognitive theories;
- factors which affect metacognition and learning;
- elementary components of metacognition;
- cognitive demands of studying Physical Science;
- epistemological assumptions;
- factors demonstrated during metacognition;
- factors which affect metacognition and learning; and
- how learners' metacognition can be improved.

2.3 Definitions of metacognition

Research pioneered by Flavell (1979:906) in the 1970s quoted metacognition as “knowledge and cognition about the cognitive phenomena”. Many researchers added to the work of Flavell, but left the essence of his definition of metacognition virtually unchanged. Researchers in the field of metacognition have offered the following adaptation of Flavell’s metacognition:

- “knowledge about ourselves, the tasks we face, and the strategies we employ” (Garner, 1987:17);
- “thinking about thinking” (Livingston, 1997; Musholt, 2015:153; Teplin, 2008:160);
- “the capacity to reflect and evaluate the learning experience” (Keeley-Brown, 2007:63);
- “the ability to consciously and deliberately monitor and regulate one’s knowledge, processes, and cognitive and affective states” (Hacker, 2009:11); and
- “the monitoring of one's own thought processes and one's existing state of knowledge” (Dunlosky & Metcalfe, 2009:1).

Flavell (1979:906) suggested that the defining attributes of metacognition are active control of self-monitoring and self-regulation. This is accepted by many other researchers of metacognition (McCormic, 2003:81; Schraw & Dennison, 1994:460; Young & Fry, 2008:1). For the purpose of this research, the researcher views metacognition as a cognitive management process where learners use their existing cognitive and metacognitive skills to plan, monitor, and evaluate their learning process. This process extends the learners' knowledge, improves problem-solving techniques, and could make learners more successful in their fields of study.

In a classroom situation, according to Wilson (2014), metacognition is a powerful tool that guides learners towards academic success, while learners who fail to garner metacognitive skills perform poorly academically. It may lead in turn to classroom management issues if poor achieving learners are not motivated during the lesson. This point became significant during the observation phase of the research and analysis of the grade 11 half-yearly Physical Science examination results by placing attention on classroom management issues (see section 4.5.5).

Furthermore, researchers including Bruning (2004:84), Schraw (2001:7) and Schraw (1998:117), describe metacognition as being multifaceted and independent of a single subject or field which can indemnify cases where learners lack the prerequisite knowledge to solve problems. This research offers hope to teachers and learners in that metacognition could be improved irrespective of the ability or developmental stage of the learner. Studies point to the expectation that all learners benefit from achieving the higher ordered thinking skill of metacognition.

2.4 A look at different metacognitive theories

Metacognition is thought to be composed of two elementary parts: metacognitive knowledge and metacognitive regulation (Flavell, 1979:906, Jime'nez et al., 2009:782; Livingston, 1997; Schraw & Dennison, 1994:460; Schraw & Moshman, 1995:352). Several theories have been developed to classify the work of popular researchers on metacognition, such as that of Vygotsky (1962); Piaget (1972);

Flavell (1979); Schraw & Moshman (1995); and Kuhn (2000). The remainder of this sub-section is dedicated to a critical discussion of the chronology of their models.

Before the pioneering work by Flavell (1979) on knowledge of cognitive phenomena and the coining of the term metacognition, Vygotsky (1962; 1978) and Piaget (1972) performed research which was by nature related to metacognition.

2.4.1 Vygotsky (1962; 1978)

Vygotsky (1962:108) theorised that the capacity for the planning, monitoring, and evaluating of the learning process is developed during the learner's interaction with more able peers in the learner's ZPD. Planning, monitoring, and evaluation are the hallmarks of metacognitive self-regulation (Young & Fry 2008:1). The ZPD is the stage in problem solving when the learner cannot progress further without social interaction with more able peers (Vygotsky, 1978:86). The learner and more able peers are responsible for the metacognitive regulation process until the learner becomes more capable of regulating the cognitive activities independently. ZPD will be discussed in greater detail in section 2.9.2.

The ZPD is be interpreted as being where intrapersonal learning takes place, where the individual solves problems on his/her own. Metacognitive activities take place when the learners moves their bodies in certain way to show success or struggle during monitoring of the problem, refer to textbooks and notebooks to plan strategies, and use "think aloud strategies" at various points during the metacognitive stages. Social construction of knowledge occurs when the individual finds that using his/her cognitive knowledge and academic resources is not enough and requires assistance from the more able learners and the teacher. Initially the learner receives the knowledge through interactions with other learners and the teacher, and then integrates this knowledge, adding his/her individual perception to it (Vygotsky, 1978:86). This is when the learner reaches his/her ZPD (see section 2.8.2). From this standpoint, knowledge and skills is be viewed as the cooperative generation of interpretations among the learners within the multi-cultural classroom through collaborative interaction in a learner-centred environment. Interpersonal learners on

the other hand might be seen working in a group where group members plan, monitor, and evaluate the problem-solving activities.

As discussed in section 1.4.3.3., Chambres et al. (2002:xiii) refer to the learners' conscious and unconscious acquisition of metacognition. Vygotsky's (1962) input into the theory of metacognition seemingly leans towards the unconscious development of metacognitive skills. During the social construction of knowledge, Vygotsky (1962) did not formally think of the meta-skills of the planning, monitoring, and evaluation of the learning process. The process is cognisant during the learning process if planning, monitoring, and evaluation of problem solving are emphasised during the social construction of knowledge progression. ZPD is regarded as metacognitive monitoring part of the higher ordered thinking process where the learners find no other option for success, except to seek assistance from more able learners or the teacher. Metacognitive planning and evaluation takes place before and after the ZPD. Vygotsky (1962) did not focus on the higher ordered thinking before ZPD and after ZPD. The ZPD is regarded as only part of the multi-dimensional process of metacognition.

2.4.2 Piaget (1972)

According to Piaget (1972:1-12), there are periods of cognitive development. Table 2.1 shows the interpretation of Piaget's theory by Shaffer and Kipp (2010:55) as the four cognitive stages.

Table 2.1 Four stages of cognitive development. (Adapted from Shaffer and Kipp, 2010:55)

Stage	Age	Features
Sensorimotor stage	0-2 years	Basic non-cognitive skills such as reflex movements; movements in response to stimuli; inability to conceptually characterise unseen objects.

Table 2.1 Four stages of cognitive development (continued)

Concrete Operations stage	5 -11 years	Has mastered the process of verbal communication; can take other's ideas into consideration; can perform operations on valid notions and cannot think critically.
Formal Operations stage	11-18	Can perform all the cognitive abilities of the various stages.
	Beyond age 18	Has reached the peak of cognitive thinking and can acquire more knowledge in conjunction with the cognitive thinking skills.

Piaget's (1972:1-12) theory envisions the child developing thinking skills and knowledge through involvements, social interaction, and motivation during each stage. According to Table 2.1, the child's level of cognition progresses from the sensorimotor stage to the formal operations stage. Piaget (1972:2) further suggests that the child learns to self -regulate his/her knowledge through each stage, which is a basic skill of metacognition.

However, it is clear from Table 2.1 that from the sensorimotor stage to the pre-operational stage, the child cannot solve cognitive problems. Metacognitive skills start developing when children compete with and challenge each other's ideas during discussions and debates, thereby developing their cognitive growth (Piaget, 1972:1-3). This motivates children to think about their thinking during the tasks, which is a metacognitive activity (Livingston, 1997; Musholt, 2015:153; Teplin, 2008:160). This is done at a simple level between the sensorimotor stage and the pre-operational stage. However, the level of problem solving increases as the child progresses towards the complex stages in the model. The level of metacognitive development increases substantially from the concrete operational stage and beyond.

Like Vygotsky (1962) (see section 2.4.1), Piaget (1972) laid the foundation for metacognition, but did not consider the multi-dimension components of the higher ordered thinking skill. Piaget (1972) added to Vygotsky's social construction of knowledge by referring to growth in learners' cognitive development by their social interaction during debates and discussion of ideas. This is viewed as an expression

of the metacognitive process, because, before and after the discussion or debate, the learners metacognitively plan and evaluate their arguments and course of action. Monitoring occurs during the discussion or debate activity. Yet, these metacognitive activities are not highlighted in the Piagetian theory, despite making reference to learners' thinking about their cognitive actions in discussions and arguments. Moreover, the desire to prove or contest an argument allows the learner to reflect on his/her thinking which is metacognitive by nature (Flavell, 1963:279). It is a point of interest that Piaget (1972:1-3) does not specify this activity as being formal. This suggests the meta-skills are being taking place tacitly.

2.4.3 Flavell (1963; 1971; 1976; 1979; 1981)

In sections 2.4.1. and 2.4.2. Vygotsky's (1962) and Piaget's (1972) work on social construction and phases of cognitive development respectively had aspects of metacognition, but failed to include all the key components of metacognition within their theory. Despite this, the work done by Vygotsky (1962) and Piaget (1972) laid the groundwork for the pioneering of metacognitive theory. Flavell is considered to have been the founder of metacognitive theory (Livingston, 1997) and based many of his ideas on Piaget's models, which he discussed in his book, *Developmental Psychology of Jean Piaget* (Flavell, 1963). Work done by Piaget allowed Flavell to conclude that consciousness of a learner's thinking process arises from the need to justify to peers what he/she has affirmed (Flavell, 1963:279). This desire drives the learners to think about their cognition, which is metacognitive by nature.

Below is a flow diagram that summarises Flavell's Metacognitive Modelling:

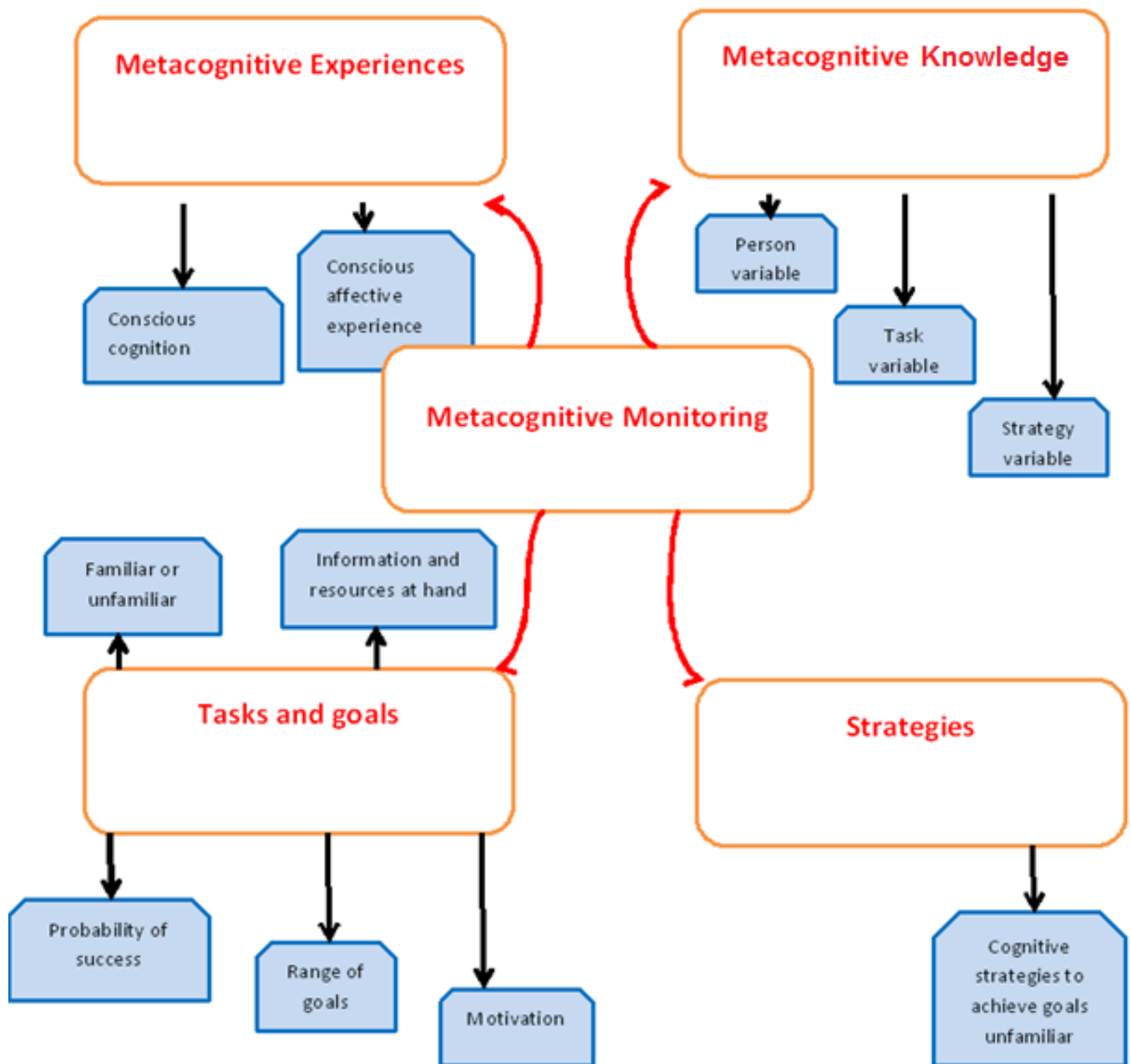


Figure 2.2: Flavell's theory of cognitive modelling (adapted from Flavell, 1981:40).

According to Flavell, metacognition consists of both metacognitive knowledge and metacognitive experience (regulation), seen diagrammatically in Figure 2.2 (Flavell, 1979:906-911). Metacognitive knowledge was described in section 1.4.3.1 as having components called declarative, procedural, and conditional knowledge. Metacognitive knowledge is described as that part of the learner's stored world knowledge that deals with a learner's thinking, goals, activities, and capabilities

(Flavell, 1976:232). Examples of this kind of metacognition are presented when learners describe their reasoning about what is being understood and explicate and distinguish feelings of uncertainty or understanding among peers, where learners consciously regulate their learning (Louca, 2003:13). This aspect of metacognition has its roots in Vygotsky's social construction of knowledge as discussed in section 2.4.1. Metacognitive knowledge consists principally of knowledge concerning which influences interact to determine the progression and outcome of cognitive initiatives (Flavell 1971:273). Flavell identifies the three variables of metacognitive knowledge as the person variable, the task variable, and the strategy variable, which are all subcomponents in Figure 2.2.

In 1979 Flavell added tasks, goals, and strategies to complete his metacognitive model (Flavell, 1979:909). He stated that the task category refers to the goals of the cognitive process, and all the resources and information available to solve the cognitive tasks. During the task and goal phases, the learner gauges the familiarity of the problem; estimates the probability of success; calculates the range of goals that need to be achieved; and how motivated he/she is to solve the problem (Flavell, 1979:909). During the strategy phase, the learner selects the best cognitive strategies to solve the problem successfully (Flavell, 1979:910).

Louca (2003:14) describes Flavell's (1981:40) three variables as set out below (see Figure 2.2):

- The person variable, which incorporates all the learner's beliefs about their nature and their peers as cognitive controls. The presumptive beliefs of the person variable are that some learners memorise information better than others; learners learn more effectively if they listen and read, and acquired knowledge can be forgotten in time.
- The second variable is the knowledge of task variable, where the learner appreciates the nature of information and its constraints. For example, it is easier to summarise and learn key points of a topic than trying to memorise it word for word.
- The strategy variable is concerned with the most effective strategies to use to achieve the goals of the cognitive task. A learner might realise,

for example, that one good way to learn and remember facts is to pay particular attention to the key points and try to repeat the information in his/her own words.

The second dimension of metacognition is metacognitive experiences or regulation, which refers to the activities used to control learning (Flavell, 1971:273). Brown (1987:67) summarises Flavell's (1971:273) metacognitive regulatory processes as follows:

- organising tasks, envisaging results, preparing strategies, and attempting problems using trial and error;
- monitoring, testing, studying, and re-scheduling one's tactics for learning during revision, before attending to a problem or task; and
- checking results: assessing the result of any strategic actions that could be improved or effectively used again.

Further to the metacognitive regulatory processes discussed above, Flavell (1979:908) sub-categorised the metacognitive regulation into conscious cognition and conscious affective experience, as displayed in Figure 2.2. Flavell (1979:908) stated that learners sometimes undergo conscious cognition during which they recall previous experiences, processes, memories, etc., in solving new cognitive problems. The dimension of conscious cognition is related to Vygotsky's social construction of knowledge. Social constructivist theory suggests that learners have some pre-requisite knowledge which they use to construct new ideas or approach new problems (see section 2.9.2.). These skills are transferable, and the teacher should encourage learners to build on this already acquired knowledge and skills in new environments.

Flavell (1979:908) also states that affective responses to tasks taking the form accomplishment or disappointment, hindrance, or gratification, affect the learner's motivation to deal with similar problems in future. This research acknowledges the crucial role which motivation plays in the development of metacognitive skills (see section 1.4.3.3.). Flavell built on the theories of Vygotsky's (1962) and Piaget's (1972) theory on the higher order thinking by adding the metacognitive knowledge,

metacognitive regulation, conscious cognition, conscious affective experience as multidimensional components of the cognitive management process.

2.4.4 Schraw and Moshman (1995)

Schraw and Moshman (1995:351-371) developed the theory of metacognition further. In their model they categorised the traditional theory constructed by Piaget (1972:1-12), Vygotsky (1962:108), Vygotsky (1978:86) and Flavell (1979) by adding tacit and explicit subcategories (Schraw & Moshman 1995:351-371). Figure 2.3 is a flow diagram that summarises the metacognitive model of Schraw and Moshman.

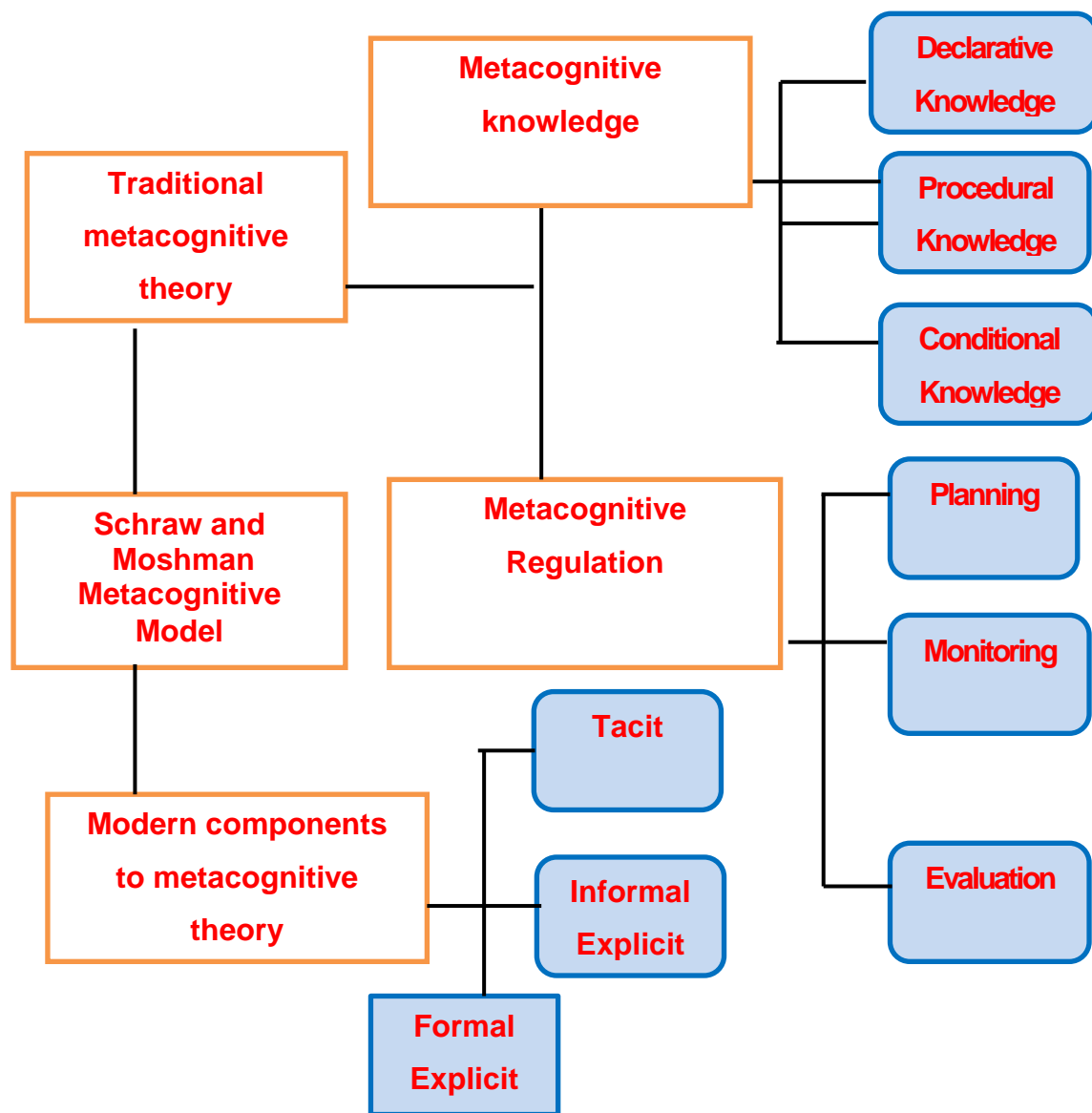


Figure 2.3: Metacognitive model of Schraw and Moshman I (Adapted from Schraw & Moshman, 1995:351-371)

Figure 2.3 illustrates the model promoted by traditional metacognitive theorists Schraw and Moshman (1995:352-353). They acknowledge that, traditionally, the two components of metacognition are metacognitive knowledge and metacognitive regulation as proposed by Flavell (1963; 1981) above. In the model of Schraw and Moshman's (1995:352-354) metacognitive knowledge is sub-categorised into:

- Declarative knowledge: This is the knowledge that learners have about the factors that influence their performance. Declarative knowledge is the cognitive skills associated with obtaining declared knowledge that can be conveyed orally or in writing. For example, a learner with good declarative knowledge will read a great deal; highlight key points, revise regularly, and listen to the teacher's instructions.
- Procedural knowledge: This refers to knowledge about the implementation of procedural skills during a cognitive problem-solving task. This skill is refined with problem-solving practise, and learners with a high level of procedural knowledge are more automatic in the execution of the procedural skills.
- Conditional knowledge: This refers to the learner knowing which cognitive action to apply during the problem-solving process.

Studies done by Schraw and Moshman (1995:354) state that metacognitive knowledge improves learners' success in academic attainment, and these skills start developing as early as the age of six, peaks during adolescence, and continue to develop during adulthood. This study echoes work done by Davis et al. (2010:498), Roberts & Powell (2005:1019), and Robson (2015:185) where it was recognised that young learners have metacognitive awareness (see section 1.4.3.3.). Metacognition, as viewed by Schraw and Moshman (1995:354), is a developmental process and occurs through the lifelong learning process of the individual. Despite the focus of this research being on Physical Science high school learners, the researcher feels it is important to mention that ideally the promotion of metacognitive skills should start at the elementary level and continue to adulthood as viewed by Schraw and Moshman (1995:354). If the findings of the research suggest that teachers did not adequately promote metacognitive awareness, it will still be beneficial to start promoting metacognitive awareness at any point in the learners' stage of

development because metacognition improves academic performance (Schraw & Moshman, 1995:354).

The model of Schraw and Moshman's (1995:354-355) in Figure 2.3, metacognitive regulation, adapted from Flavell (1963-1981) above, is sub-categorised into various phases shown below:

- The planning phase: Comprises the selection of the most effective plan and provision of resources to solve cognitive problems more effectively. Examples of planning include steps that should be taken, time management, expectations before tackling a problem, and what should be focused on.
- The monitoring phase: This refers to the learner's awareness of understanding, conception, and performance of the cognitive task. The ability of learners to test themselves during revision is a good way to develop cognitive monitoring. Cognitive monitoring develops slowly and is improved with consistent practise and routine. Learners trained in self-monitoring can solve complex problems.
- The evaluation phase: This refers to self-appraisal of the end product of the problem-solving process. This is done by reflecting on the goals achieved or not achieved and the reasons behind the successes and limitations of the achieved outcome.

Metacognitive regulation competence increases cognitive problem-solving ability by motivating the better use of cognitive resources such as attention, enhanced use of tactics, and a greater awareness of misconceptions (Schraw & Moshman, 1995:355).

Significant studies show that greater success in learning takes place when regulatory skills are promoted as part of classroom instruction (Schraw & Moshman, 1995:355). When metacognitive skills are imparted within the teaching and learning situation it is expected that the lesson should integrate metacognitive regulation techniques in conjunction with the acquisition of metacognitive knowledge. The researcher will bear this in mind whilst observing the teaching and learning process in the Physical Science classrooms and will assess how theory and practise merge or differ. The

researcher feels that a high level of metacognitive awareness can only be achieved when sufficient training and guidance has been given to the teachers, and the teachers continually promote the metacognitive skills. As discussed above, this is an ongoing process throughout the teaching and learning process.

The theories of Schraw and Moshman's (1995:358) thus far were a refinement of Flavell's (1963; 1982) work. A contemporary approach to their metacognitive model in Figure 2.3 includes the subcategories of tacit and explicit theories which were not emphasised in Flavell's work (1963; 1982). The modern components are set out below (Schraw & Moshman, 1995:358-361):

- **Tacit Theory:** These are metacognitive skills that are constructed or acquired from peers, teachers, or one's culture, and are easily conveyed by actions, instead of being written or spoken. In formal learning environments young learners have tacit beliefs about learning which guide their knowledge acquisition; however, they do not communicate this by speaking and writing, but by their actions during the learning process. Teachers' tacit theories guide the teaching and learning process and affect how they interact with learners and the direction of curricular choices. Tacit metacognitive theories are gradually acquired and affect the individuals' decision-making. Individuals find it difficult to change their tacit theories even if these are incorrect and dysfunctional.
- **Informal Explicit:** Informal theorists believe that individuals have an undeveloped awareness of their metacognitive knowledge and have not formed a theoretical structure to validate their views. Informal theories progress gradually and are societal, with individual effects. Informal theories are explicit to a certain degree and can be conveyed by written and oral means. Awareness of informal theories leads to progression in metacognitive awareness which allows the individual to modify and formalise their theory. For example, children younger than four seemingly do not doubt beliefs, but by the age of four it may be that they recognise that beliefs have the potential to be false. This

shows the child is initially tacit but progresses to informal, explicit theories to test his/her beliefs.

- **Formal Explicit:** the formal explicit theory concerns the development of informal explicit theories to a more theoretically structured system of thought. Formal theories involve highly organised systems and explicit theoretical structures. These include problem-solving prompt cards, and problem-solving steps and flow diagrams, as observed in higher education classes in subjects such as physics, music, and mathematics. Formal theories provide an insightful influence into outcomes and the understanding of performance. The formal explicit theory includes a set of hypotheses that can be used to check and evaluate one's metacognitive knowledge. Formal theorists possess some explicit mindfulness, which involves purposeful efforts to build and transform their current metacognitive theories to more effective ones. This allows students to make informed choices about self-regulatory activities.

The socio-cultural nature of this research (see 1.4.2.) points to the tacit theory of metacognition. During the teaching and learning process, it is recognised that metacognitive skills are acquired by the learner through social interaction with more metacognitively aware learners and the teacher. By observing the success of the more able metacognitive aware individuals, the learner gradually absorbs metacognitive skills. This theory aligns itself with the very effect socio-constructivist theory (see section 2.9.2.). However, this is fundamentally flawed if the metacognitively aware individuals are not trained in all dimensions of metacognitive knowledge and metacognitive regulation. Caution arises due to the uncontrolled nature of the metacognitive activity. Actions outweigh written and spoken tasks. The decision rest with the learner as to which elements of metacognition should be mastered. Despite the first-hand practical nature of the theory, it is questionable whether optimum higher order thinking is achieved within this process. The socio-constructivist nature of the tacit theory is still considered in this research.

Fundamentally, as the informal explicit theory suggests, individuals have untapped metacognitive awareness. During the research, the researcher analysed the state of metacognitive awareness with the assumption that all individuals will have some level of metacognitive awareness. As in the case of the tacit theory, there is a socio-cultural element to this and the metacognitive awareness develops gradually. This theory recognises social interaction during the process of developing metacognitive skills by questioning their understanding. This is the “thinking about thinking” process of metacognition as mentioned in section 2.3. Unlike the flaws of the tacit theory, there are some formal aspects in acquiring metacognitive skills, as well as its communication being written and spoken. The written and spoken part of the theory allows for questioning, discussions, and recall of the metacognitive skills which is essential in developing good metacognitive knowledge. Furthermore, there is a formal component to this which informs correct metacognitive skills, unlike the tacit process. Overall, in this research the informal explicit process is not be viewed as being highly effective in promoting metacognitive awareness in the very academic domain of Physical Science.

Although acknowledging the tacit and the informal explicit theory, it seems that promotion of the formal explicit theory is the most effective in Physical Science. The formal explicit theory is the progression of the informal explicit theory. It is well structured and organised and is promoted in the study of mathematics and science (Schraw & Moshman 1995:361). The structured element of the theory ensures that the correct theory to optimise metacognitive awareness is promoted. This is the major difference from the tacit and informal explicit theory. Similarly, to the informal explicit theory, the formal explicit theory has a written and verbal communication mechanism which is effective in raising metacognitive awareness. However, this researcher feels that the invaluable aspect of the practical action element, as theorised by the tacit theory will add more value to formal explicit theory because it is a part of the effective multidimensional aspect of metacognition.

Instructed by oral and written communication, formal explicit theory will allow the learner to observe and experience effective higher order thinking as an exemplar action. This convinces the learner of the validity and the effectiveness of the

metacognition as a course of action in higher ordered thinking. Formal explicit metacognitive theory is only highly effective if the teachers are highly trained in promoting metacognitive awareness. The teachers need to give explicit instructions in order to promote metacognitive awareness. The research will evaluate metacognition as theorised by the literature and evaluate its assessment based on findings using the qualitative and quantitative data gathered to draw conclusions.

2.4.5 Kuhn (2000)

Below is a flow diagram depicting Kuhn's (2000) contemporary metacognitive model constructed five years after the model of Schraw and Moshman (1995) model (see Figure 2.4).

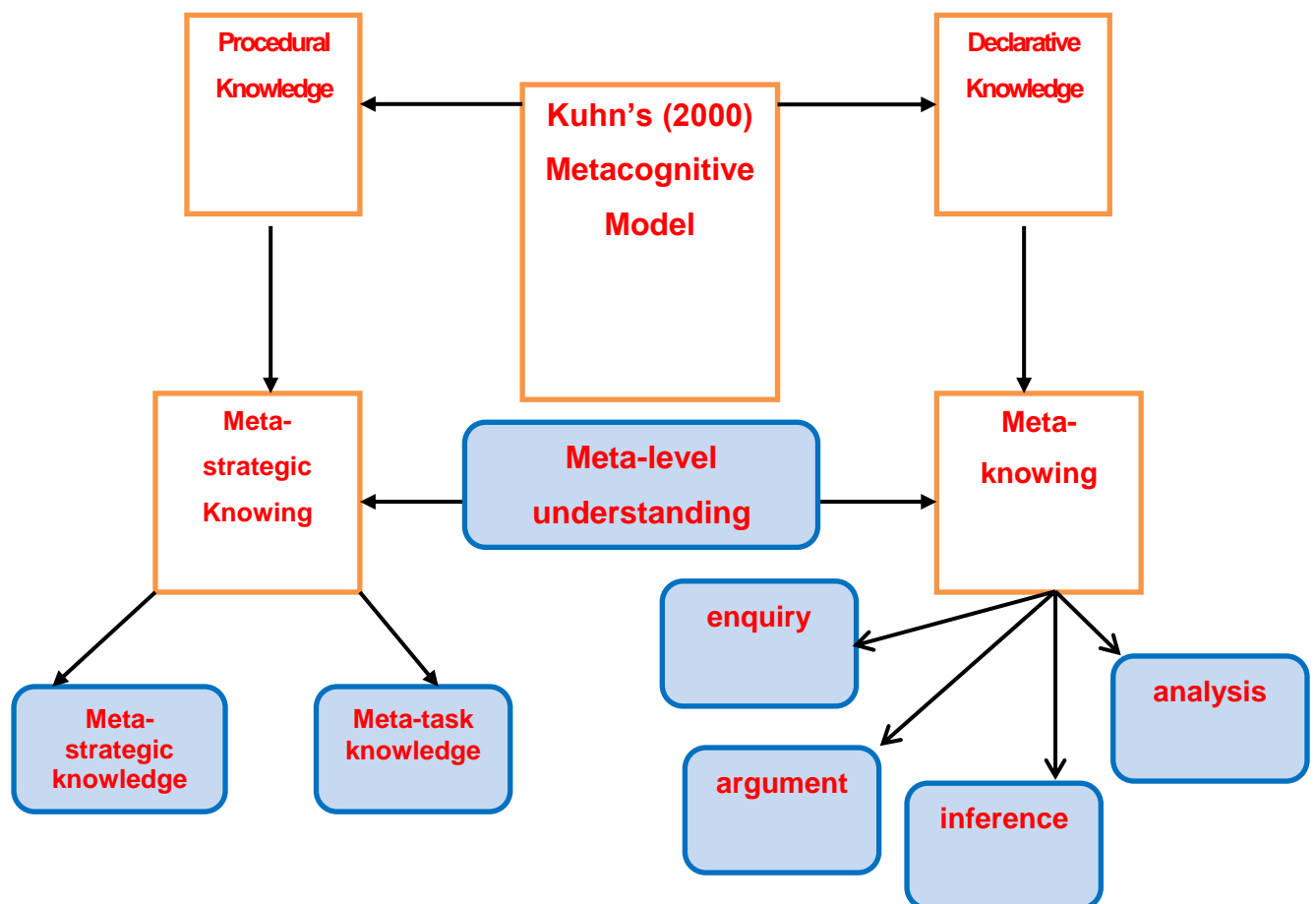


Figure 2.4: Kuhn's Metacognitive Model (adapted from Kuhn et al., 2000:501)

Kuhn's metacognitive model (2000:178) proposed that metacognition does not mysteriously appear, but is developed from a rudimentary form when the child is young and develops into more explicit and efficient forms as cognitive mental development increases with the child's age. This progression is similar to the progression from tacit to the informal and formal theories stated by Schraw and Moshman (1995:354-355) in section 2.4.4. Similar to Schraw and Moshman (1995:354), Kuhn (2000:178) reinforces the idea that metacognition gradually develops with practicing of metacognitive activity.

The meta-level process which Kuhn (2000:179) suggests in her model has major elements of procedural and conditional knowledge also described in Schraw and Moshman (1995: 351-371) above. However, he adds that these processes interact with each other to reach a meta-level understanding (see Figure 4.4). The interaction of the multidimensional components of the meta-knowing and meta-strategic part of Kuhn's (2000) metacognition model (see Figure 4.4) shows the complexity of the higher ordered thinking process. Kuhn et al. (2000:501) view these components as meta-activities working together to create deeper understanding and successful learning. The interaction of the dimensions as viewed by contemporary model of Kuhn et al. (2000:501) (see Figure 4.4.) will be difficult to assess during this research, because of the silent thought processes that occur during metacognitive activities. The researcher will have to assess the learners' perceptions as well as observe the process of social construction of knowledge within the Physical Science learning environment in order to infer conclusions.

Kuhn et al. (2000:501) state that meta-level is a stage in problem solving where the learner knows which strategy should be selected, monitors applications, and modifies the results. This emphasises the interaction process of the procedural and declarative knowledge of Kuhn's model. Kuhn et al. (2000:501) use the dimensions of metacognitive knowledge (selecting strategy) and metacognitive regulation (monitoring) as proposed by Flavell (1963,1982) (see section 4.4.3.), however, Kuhn's model highlights the interaction process within the dimensions. Kuhn (2000:179) found the development of meta-level processes occur when the learner's use of a specific strategy which cannot be substantiated before use, and cognitive

thought processes, move from a performance level to a meta-level, which rationalises the strategy used. This research recognises this idea of unsubstantiated meta-strategy before use, but also promotes the strategy of explicit metacognitive instructions by the teacher. The researcher encourages the idea of confusion during the learning process and risk taking (see section 2.10.4.). After the strategy has been used, Kuhn (2000:179) found that the learner vindicates the outcome by evaluating the strategy used (metacognitive evaluation). Kuhn omits out the important detail of failure. During successful learning at a meta-level confusion and failure is part of the progression towards success (Nottingham, 2016:109). There should be no guarantees that success is achieved just by the first attempt. This is a crucial point which Kuhn (2000:179) misses in the rationale of his model.

Furthermore, Kuhn's model suggests that, if declarative knowledge and procedural knowledge are fundamentally different, their meta-level processes also differ (Kuhn, 2000:179). Therefore, Figure 2.4 shows declarative knowledge and procedural knowledge on the opposite ends of Kuhn's (2000) model. Kuhn's (2000:179-180) model builds more on the declarative knowledge and procedural knowledge sub-category of metacognition by highlighting the fact that the components of the meta-level fundamentally different, despite their interaction during the metacognitive activities, as compared with Flavell (1963:279); Flavell (1971:273); Flavell (1979:906-911); Flavell (1981:40); and Schraw & Moshman (1995:354-355) above.

Kuhn (2000:179) proposed that meta-strategic knowing refers to the meta-knowing of procedural knowledge. A pictorial representation of this is shown in Figure 2.4. further sub-categorised meta-strategic knowledge into meta-task knowledge, which deals with the goals set on the cognitive task, and meta-strategic knowledge, which deals with the strategies used to achieve the goals of the cognitive task. Meta-strategic understanding dictates which strategy a learner selects to solve a problem (Kuhn et al., 2000:501). Despite Kuhn's model acknowledging metacognitive regulation, she does not emphasise this enough within the structure of her model in terms of planning, monitoring and evaluation which is fundamental in this research.

Kuhn (2000:179) describes meta-knowing of declarative knowledge. Meta-knowing is further categorised into:

- Enquiry: What is required to be found?
- Analysis: Will analysing be advisable?
- Inference: Is it advisable to have untested views?
- Argument: Is there any point in challenging the theory or results? (Kuhn et al., 2000:501)

From Figure 2.4 we see there is an interrelationship between meta-strategic knowing and meta-knowing that is informed by meta-level understanding. Kuhn et al. (2000:501) state that meta-level understanding informs and is informed by strategic performance. There is an interrelation between meta-level and performance level (Kuhn et al., 2000:501). Further, in the traditional theory discussed above, Kuhn (2000:179) focuses in more detail on the meta-thinking involved in the metacognitive process. The shortcomings of Kuhn's model are its lack of focus on the socio-cultural element of meta-thinking (Flavell 1963, 1882; Schraw & Moshman, 1995), motivation (Flavell, 1979:908), and its encouragement of risk taking during metacognitive activities (Nottingham, 2016:109), which the researcher believes are fundamental in successfully promoting metacognitive awareness.

2.4.6 Summary

From the theory discussed above, it is seen that the traditional theory on metacognition evolved through time from work done by Vygotsky (1962:108); Flavell (1963:279); Flavell (1971:273); Piaget (1972:1-12); Vygotsky (1978:86); Flavell (1979:906-911) and Flavell (1981:40). Schraw & Moshman (1995) refined the traditional theory of metacognition and built on the works of earlier authors. This researcher used the traditional metacognitive theory as refined by the Schraw & Moshman (1995) model of metacognitive knowledge and regulation, due to its well-grounded theory which aligns itself to the research. Less emphasis has been placed on contemporary theory during the research, because the main ideas of metacognition, such as metacognitive knowledge and regulation, overlapped traditional and contemporary theories. However, the interactive process within the dimensions of meta-thinking as stated by Kuhn et al. (2000:500) was considered

during the research. During the study, the researcher analysed the metacognitive awareness of participants by referring to the formal explicit theory as mentioned by Schraw and Moshman (1995). The MAI (Appendix 2), SAQ (Appendix 3), MAIT (Appendix 4), lesson observation protocol (Appendix 1) and the interview schedule (Appendix 7) have been structured into the theoretical system of thought flowing from the traditional theory discussed. The data collection strategies of this research aimed at assessing the metacognitive knowledge, metacognitive regulation, motivation, the socio-cultural influence in thinking, the interaction of the multidimensional components within the metacognitive activities, and formal explicit activities during meta-thinking.

2.5 Factors which affect metacognition and learning

At this point this study has discussed in detail the multidimensional components of metacognition and its crucial role in successful learning. The next part of this chapter concentrates on the factors which affect metacognition. In the context of the research, the researcher will consider variables which affect metacognition and assess how it fits into this research.

2.5.1 The 14 psychological principles

The American Psychology Association states there are 14 psychological principles that holistically deal with the real-world context of learning (McCombs & Miller, 2009:29; Richlin, 2006:113-114). These principles are interconnected and are categorised as cognitive and metacognitive, motivational, and affective, developmental, social, and individual differences (McCombs & Miller, 2009:29; Richlin, 2006:115-117). The researcher found these 14 psychological principles align themselves within the fundamentals of the research, because the researcher agrees that the categories of cognition and metacognition, motivation and affective factors, developmental and social factors, and individual differences are connected psychological principles which are intended to involve the major stakeholders in the educational system (McCombs & Miller, 2009:29; Richlin, 2006:115). These principles emphasise the interconnectedness of the multidimensional components of metacognition.

Cognitive and metacognitive factors (McCombs & Miller, 2009:29-30; Richlin, 2006:115) include the issues set out below:

- The first is nature of the learning process, in which learners derive meaning from scientific theory, their own experiences, and own beliefs by being active, goal-directed, self-regulating, and independent learners.
- Goals of the learning process: Learners need to be trained to create meaningful learning goals that are consistent with personal aspirations.
- Construction of knowledge: Learners must strive to link new knowledge to existing information in a constructive way.
- Strategic thinking: A successful learner can promote and use a range of thinking skills to achieve higher-order learning goals.
- Thinking about thinking: Complex thinking strategies for monitoring problem solving promote creative and critical thinking.
- Context of thinking: Successful learning is influenced by culture, technology, and instructional pedagogy.

Cognitive and metacognitive factors are regulatory by nature in which setting goals encourages metacognitive planning and self-regulating encourages metacognitive monitoring and evaluation (see sections 2.4.3. and 2.4.4.). In alignment with this research, the training to set meaningful learning goals is metacognitive planning. The formal explicit theory of Schraw and Moshman's (1995) are implied when explicit instructions are given during the meta-activity of goal setting. Linking new knowledge to existing understanding is the social construction of knowledge which was discussed in sections 2.4.1. and 2.9.2. It is accepted that the learners have pre-requisite knowledge which is used to understand new knowledge. Strategic thinking is metacognitive conditional knowledge by nature, where effective strategies are selected during problem solving (see 4.2.3. and 4.2.4.). Thinking about thinking is an expression of metacognition. This encompasses the meta-activities used to manage cognitive tasks (see section 2.3).

This research orientates itself to the point of context of learning within the cultural and pedagogical instruction. The research is viewed through a socio-cultural lens

(see section 1.4.2) and promotes the formal explicit theory within the learning environment (see section 2.4.4.). The cognitive and metacognitive components have echoed most of what has been discussed in the previous sections. However the research does not support the view that technology has a major influence in achieving a high level of metacognitive awareness. None of the theories discussed thus far supports the point of technology being a key in enhancing metacognition in learners. There is no mention of technology being crucial in raising attainment levels in the section on ground breaking research on visible learning (see section 2.11.1.).

Motivational and affective factors (McCombs & Miller, 2009:30; Richlin, 2006:116) include:

- Motivational and emotional influences on learning: The learner's emotional state, beliefs, interests, and goals affect how much is learnt.
- Intrinsic motivation to learn: Inquisitiveness, flexibility, and perceptive thinking are major factors of the learner's intrinsic motivation to study.
- Effects of motivation on effort: There is a direct correlation between motivation to learn and willingness to put effort into study.

Work done by Flavell (1979:908) reflects the points of affective experience of the learners in relation to their motivation to deal with similar problems in future (see section 2.4.3.). Furthermore, motivation has a huge influence on metacognition (see 1.4.3.3.). Section 1.4.3.3., discusses motivation as the implementation of the meta-task and as being a major indicator of success or failure in science problem solving. This is all due to the motivated learner's intrinsic motivation to integrate metacognition during his/her learning process. During the task and goal phases, the learner gauges how motivated he/she is to solve the problem (Flavell, 1979:909). When the learner is motivated towards learning meta-skills, they will invest time in the meta-activity.

Developmental and social factors (McCombs & Miller, 2009:31; Richlin, 2006:117) listed below.

- Developmental influences on learning: Learners learn best when their activities are at an appropriate developmental level and are enjoyable to do.
- Social influences on learning: Learning is enhanced if learners are given the opportunity to be collaborative.

Developmental influences are the Piagetian effects on learning, whereby the instruction and the tasks for the activity are at the appropriate developmental level of the learner as theorised by Piaget (1972) (see section 2.4.2.). Learners are demotivated if they are doing a task that is above their cognitive level. This has a negative impact on their metacognitive development and their success in learning (see section 1.4.3.3. and 2.4.3.). Shaffer and Kipp (2010:55) interpret Piaget's theory as being the four cognitive stages but this does not consider the common situation of many learners at similar ages but varied cognitive ability in a class. The point made on the social influences plays a crucial role in this common scenario within the learning environment. Despite the curriculum being designed for the age appropriateness of the learners, differentiation of the lesson must take place. Learners must be guided by the more able learners and the teacher within their ZPD (see section 2.9.2.). Differentiation occurs socially when the level of guidance given to individual learners varies according to their ability level and the amount of support they require to come out of their ZPD. The developmental and social components of learning with respect to this research will be guided by the Vygotsky's constructivist theory (see section 2.9.2.) and the Piagetian phases in cognitive development (see section 2.4.2.).

Individual differences (McCombs & Miller, 2009:32; Richlin, 2006:118) include:

- Individual differences in learning: Learners are born with abilities that can be modified to improve their learning.
- Learning and diversity: Language, ethnicity, race, beliefs, and socio-economic status all influence learning.
- Standards and assessments: Assessments provide important information to both teachers and learners during the learning process.

This research does consider that learners are at different academic levels, as discussed in the previous part of this section. It should be further noted that, although this researcher viewed differentiation from a purely socio-cultural perspective, the researcher does consider the varied differentiation techniques used by teachers to handle the varying cognitive abilities of learners within the classroom. It would not be productive to the focus of the research, if the language, ethnicity, race, beliefs, and socio-economic status of the learners varied a great within the Physical Science classrooms studied. Most of the learners' studied were from a Zulu background, with isiZulu as their first language, coming from communities which were of similar socio-economic status. Section 1.1.1. and 1.1.2. confirm that the learning and diversity components impact on the learning success of the learners. The TIMSS and matric results provided invaluable information for this research (see sections 1.1. and 1.1.1.).

2.5.2 Variables which affect metacognitive knowledge and regulation

In conjunction with the factors discussed in 2.5.1., it is important to add the variables which affect metacognitive knowledge and metacognitive regulation. A learner's ability to remember facts and objects has a major influence on his/her declarative skills and problem solving within the context of the task at hand (Stein, 1989:165). Declarative knowledge resides in long-term memory (Ohlsson, 2014:678). The three processes in learning declarative knowledge (Ohlsson, 2014:678) are:

- Knowledge must be acquired so it can be stored in long-term memory.
- Retain the new information for lengthy periods, however knowledge may decay over time.
- Retrieve stored knowledge from long-term memory.

Many studies have revealed that significant experience is essential for the learner to develop expert declarative skills. Repeated efforts to recall and use the information being studied build declarative knowledge (Klein, 1998:16; Ohlsson, 2014:680). Furthermore, declarative skills are enhanced by spending more time learning and consolidating theory that has been taught (Seong, 2005:123).

Procedural knowledge, like declarative knowledge, is a function of motivation, training, education, and experience (Klein, 1998:16). Procedural skills are negatively affected by a lack of knowledge about the relationship between strategy use and the complexities of the problem, as are classroom environments that do not reward effort in the application of strategies (Hartman, 2001:34). Studies show that learners with a strong conceptual understanding of theory develop procedural knowledge and skills more quickly (Walberg, 2011:52). Declarative knowledge is acquired by observations and discourse, whilst procedural memory is enhanced by repeated efforts to apply knowledge during problem solving (Klein, 1998:16). Conditional metacognitive memory is a sub-component of metacognitive knowledge and is affected by the learner's ability to justify a declarative or procedural action (Paris & Oka cited in Schneider, 2010:56).

Essentially, constant repetition of the metacognitive activities can enhance metacognitive awareness. As mentioned in 2.4.4. and 2.4.5. the development of metacognitive skills is gradual. It is accepted that when a learner continually works on metacognitive task during cognitive activities, the level of metacognition improves. As suggested in 1.4.3.3. the researcher hopes that formal explicit metacognitive teaching starts at elementary level and progress throughout the learners' educational environment. This will provide many opportunities for the learners to become familiar with metacognitive activities and improve their metacognitive development.

Practicing self-regulatory skills are essential to acquire mastery (Ericsson et al., 1993:368). Effective teaching of metacognitive regulation as well as regular opportunities to use the metacognitive skills by learners improves their metacognitive regulation ability. Work completed by Winne and Stockley (1998:113) shows the factors which improves metacognitive regulation as

- learners' insights to a problem determine the level of commitment and self-regulated learning;
- learners' skill in selecting goals impacts on how they regulate learning;
- variables that affect how the learner performs procedures and approaches to problem solving guide self-regulated learning because this affects the outcome;

- variables that support accreting, fine-tuning, and reforming strategies and knowledge that drive self-regulated learning all affect immediate performance; and
- if variables that support accreting, tuning, and restructuring strategies are in long-term memory, they reshape aptitude.

Learners' insight into the problem is their declarative knowledge, which determines the depth of understanding which affects their metacognitive regulation. This shows the interaction of the metacognitive dimensions as discussed in section 4.2.5. By summarising the variables to fit the outline of the research, the researcher has assessed the level of metacognitive regulation on the learners' ability to select achievable goals, plan, monitor, and evaluate during the problem-solving process, reflect on strategies used, and refine to improve performance.

2.5.3 Summary

In conclusion, this research aligns itself with the 14 psychological principles despite not considering the impact technology has on learning. The impact of technology is not practical within the South African context, due to its financial implications. The research regards the variables discussed in 2.5.2 as being true, however it would be essential to highlight that formal explicit teaching and repetition of metacognitive activities should occur as often as possible to improve metacognitive awareness is invaluable.

2.6 Components of metacognition in problem solving in Physical Science

Thus far this research has focussed on the theory of metacognition and the variables which affects it. In section 1.3. it was stated that one of the motivations for this research is that metacognition in different areas is needed (Zohar & Dori, 2012:2). This part of the literature review looks at the metacognitive components aligned to Physical Science.

The deliberate conscious control of the learners' own cognitive action is regarded as being metacognitive (Brown, 1980:453). In this part of the chapter the learners'

careful consideration of the meta-tasks involved in becoming successful in Physical Science is considered. Most explanations of metacognition by theorists suggest a rudimentary difference between metacognitive knowledge and metacognitive regulation (Schraw & Moshman, 1995:352). However, it was recognised that the components of metacognition interact with each other (see section 2.4.5.). The metacognitive knowledge, metacognitive regulation, and formal explicit theory components of metacognition discussed below are based on the Schraw and Moshman (1995:351-371) model discussed in section 2.4.4.

Figure 2.5 below shows the components of metacognition in Physical Science problem solving. It illustrates that the two subcomponents of metacognition are metacognitive knowledge and metacognitive regulation (Schraw & Moshman, 1995:354; Young & Fry, 2008:1). The subcategories of metacognitive knowledge and metacognitive regulation are further broken down by focusing on higher-ordered thinking in deconstructing a Physical Science problem. The subcomponents of metacognitive knowledge and metacognitive regulation in Figure 2.5 are briefly explained with each term, focusing on Physical Science problem solving as viewed by this study. The Schraw and Moshman (1995:351-371) model was adapted to explain the context in Physical Science problem solving. The Physical Science principle used in the example to explain each sub-category of metacognitive knowledge and regulation is the real-life application of calculating the muzzle velocity of a bullet using the Law of Conservation of Momentum. The momentum problem involves finding the muzzle velocity of a bullet fired from a rifle.

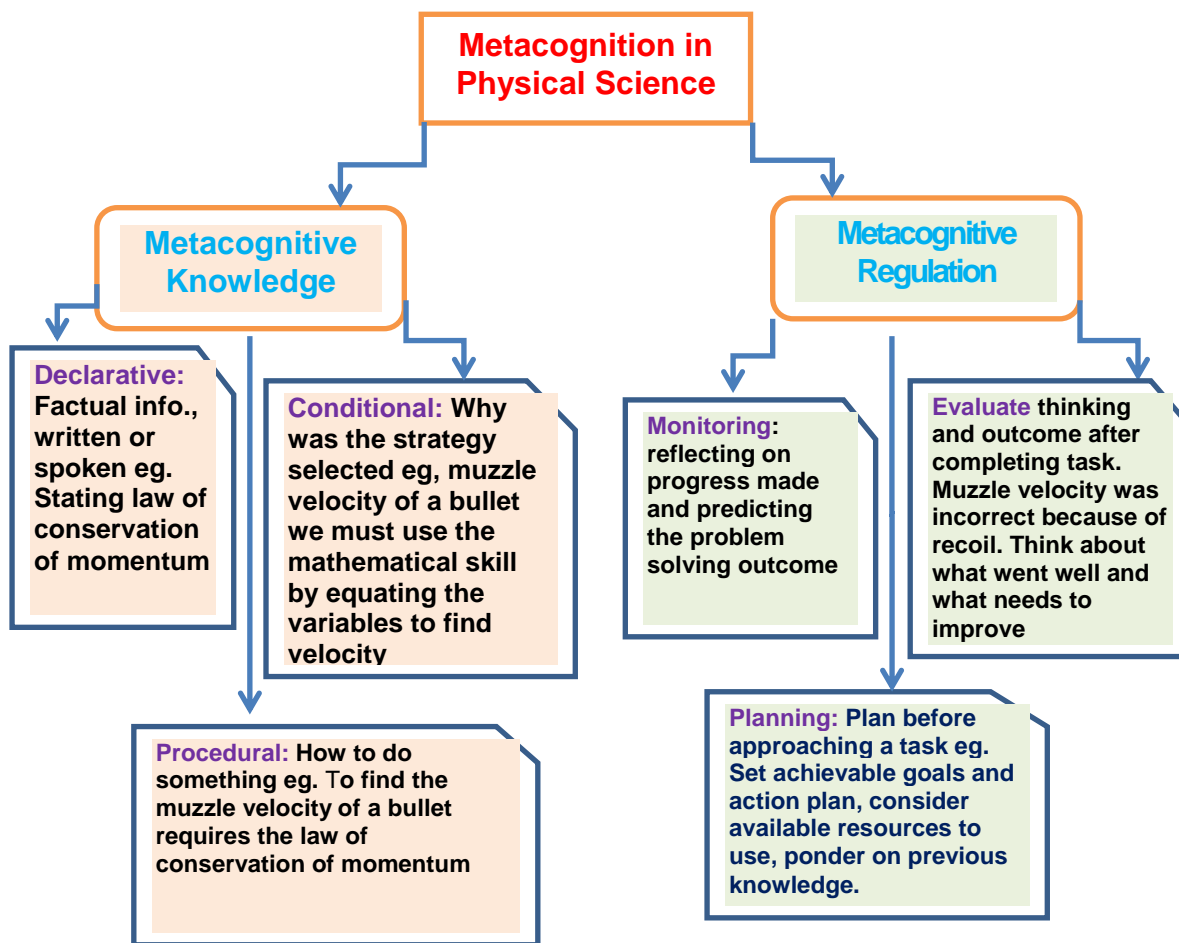


Figure 2.5: Components of metacognition in problem solving in Physical Science (Adapted from Schraw & Moshman 1995:351-371)

Metacognition is a widely researched field of education (Livingston, 1997). With this in mind, metacognition is an integral element of the problem-solving process in which learners' use acquired knowledge and strategies to solve a scientific problem. By referring to the Figure 2.5. the difference in metacognitive knowledge and metacognitive regulation is discussed below.

As discussed in section 1.1.2., the study views the classroom-based investigation of metacognition in the study of Physical Science as problematic. The emphasis of success in Physical Science is on the score attained in the examination. Fostering metacognition is challenging because meta-activities require a great deal of mental efforts and high motivation levels of learners (Alias & Sulaiman, 2017:35), together

with the scarce resources of time and effort of the teacher to promote metacognition effectively (Georghiades, 2004:379).

“Assessment drives learning” is notably accepted in education (Mintzes et al., 2005:XX). Assessment is a powerful tool for motivating and rewarding learners to construct meaning in the real world context. Successful science learners in school acquire a great amount of passive knowledge, but lack other practical and metacognitive skills (Layton in Fensham et al.1994:4). The learners gauge their success in their examination results, but are not be able to apply their passive knowledge in a real-life situation. Science content in relation to metacognitive action and real-life application are merged with the content of science. Rewarding the learners for their metacognitive effects may be a factor in effectively fostering metacognition through assessments. Linking metacognition through assessments is discussed further in the section on predicted grades effect size in section 2.11.2. The analysis in section 5.2.4. uses the Physical Science examination as an assessment tool. It should be noted that the need to have assessment in concert with learners valuing metacognition will always require far greater effort and time commitment from the learner. Together with the classroom observations the researcher determined the extent in which metacognitive skills were assessed and rewarded.

2.6.1 Metacognitive knowledge during problem solving

Prior to solving the problem, the learner had acquired declarative understanding of the problem through the teaching and learning process, from the textbook, and other sources of scientific information. In section 2.5.2. it was identified that the learner’s ability to memorise information will improve the level of declarative knowledge. In relation to the problem, the facts associated with the concept of momentum are stored in long-term memory (see section 2.5.2.). The conceptual understanding and the amount of information the learner has differs in each individual. In order to have a high declarative knowledge in the section on momentum, the learner needs to read the textbook and notebook regularly; to highlights key points, revise regularly, and listen to the teacher’s instructions (see 2.4.2.). The learners’ understanding of momentum is stored in the learners’ long-term memory (Ohlsson, 2014:678).

The learners' understanding of momentum is used whilst trying to solve problems on momentum. In the example in Figure 2.5. the learner uses the equation of the Law of Conservation of Momentum to find the muzzle velocity of a bullet. Solving numerous problems using the equation allows the learner to become familiar with the most effective strategies to solve the problem (see section 2.4.4.). The learner is exposed to many problems on momentum which helps develop various skills in problem solving. This leads to analytical and creative thinking. In other words, practising the procedural skills to solve problems enhances the learner's conditional knowledge.

The learner can use his/her conditional knowledge to implement various cognitive strategies to select the most effective approach to solve the problem (Young & Fry, 2008:1). Declarative and procedural knowledge guides the learner's conditional knowledge through the interactive components of metacognitive knowledge (Kuhn et al., 2000:501). A learner who has a good level of metacognitive awareness will choose the best strategies to solve the problem by using his/her metacognitive knowledge (Young & Fry, 2008:2). Continual effort to recall and use the knowledge on momentum builds the learners' declarative knowledge on the topic (Klein, 1998:16; Ohlsson, 2014:680). Conditional knowledge is affected by the learners' ability to justify a declarative knowledge or procedural strategies used in the problem-solving process (Paris & Oka cited in Schneider, 2010:56). More problem-solving practise on momentum allows the learners to build their metacognitive knowledge and become a more successful problem solver.

2.6.2 Metacognitive regulation during problem solving

Prior to solving the problem, the learner needs to set goals which is expected to be achieved during the planning part of the problem-solving process (see Figure 2.5). During the planning process, the learner thinks about the theory on momentum and uses his/her declarative knowledge to translate key information and pictures into a clear idea and understands what is being asked about the question. The learner then uses procedural knowledge to think about the various strategies which use equations and theory on momentum to solve the problem. Conditional knowledge is at work when the learner implements the action plan. Once again, the instructiveness

between the dimensions of metacognition is highlighted. Metacognition encourages learners to succeed in problem solving in science (Akin, 2016:392; Jayapraba, 2013:165-166; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015:6; Thomas, 2012:132).

The learner has to monitor the problem-solving process and amend the action plan or use the resources available if there is difficulty. When are in the ZPD, they need to socially construct knowledge as an implication of the monitoring process (see 2.4.1. and 2.9.2.). At the end of the process, the learner needs to evaluate the problem-solving process and the outcome. This will allow the learner to reflect on what went well and the challenges. There are no guarantees of success, so there is an element of risk during the Physical Science problem-solving process. Good metacognitive skills promote learner confidence and inspire successful thinking (USDE, 2011:33). The learner works within his/her abilities and is confident about taking risks to achieve the goals (USDE, 2011:33).

The learners' metacognitive knowledge interacts and develops with the learners' metacognitive regulation skills (Kuhn et al., 2000:501). For Physical Science learners to achieve a high level of metacognitive knowledge, they will also have to attain a high level of declarative knowledge, procedural knowledge, and conditional knowledge (Flavell, 1976:232, Li et al., 2006:292). Making learners aware is essential in promoting metacognitive awareness, and to have an all-round skill set with regard to metacognition in science, the Physical Science learner continuously has to continuously make regulatory decisions by planning, monitoring, and evaluating his/her progress (Schraw, 2001:14).

The components of metacognitive regulation expect the learner to set high, yet achievable goals in the topic of momentum, monitor progress during the problem-solving activities, and evaluate the overall outcome achieved. According to Schraw (2001:7), the Physical Science learner plans before undertaking tasks and evaluates the outcomes and strategies used. Metacognitive monitoring is occurring when the learner checks progress during the problem-solving process and plans next steps to achieve academic success. Reflection is the metacognitive evaluation of effort during

and after problem solving, how the effort might be improved, and how transferable the employed strategies were (Ertmer & Newby, 1996:1). The Physical Science learner reflects during the monitoring phase and the evaluation phase. Considering Figure 2.5. a regulatory strategy is the planning strategy to solve the momentum problem, taking action, and engaging in further critical reflection. By referring to the evaluation phase in Figure 2.5 above, the Physical Science learner reviews the task they have accomplished and reflects on the effectiveness of strategies.

Metacognitive knowledge, motivational, and environmental approaches are transformed into metacognitive regulation of the learning process through ongoing critical reflection (Ertmer & Newby, 1996:1). The learner qualitatively evaluates the experience of solving the problem. Metacognitive awareness promotes self-analysis, self-improvement, and lifelong learning, where learners learn and adapt and surpass what they know (Dunlap & Lowenthal, 2013:171-173). Repeating the metacognitive knowledge and metacognitive regulation strategies for all the topics studied in Physical Science ensures that the learner increases in metacognitive awareness in Physical Science and learns effective problem-solving skills whilst unlearning ineffective skills.

Teachers and learners must be aware that even after many attempts' learners may not be successful in the entire metacognitive problem-solving process. Assistance in their ZPD helps them find the solution to the problem. Finding the solution to the problem does not guarantee that the learner can solve the problem independently, which the goal in problem is solving. This is part of the learning process and the teachers must promote academic tenacity (see section 2.10.4.). The next section builds on the metacognitive component in Physical Science by focusing on the cognitive demands in studying Physical Science.

2.7 The cognitive demands of studying Physical Science

Declarative knowledge in Physical Science includes scientific terms, definitions, facts, and statements (Li et al., 2006:292). It is remembered in words, pictures, and sensory representations (Li et al., 2006:292). Procedural knowledge is knowing how

to solve a problem, and takes the form of sequences of steps and production rules in science (Li et al., 2006:292). Procedural knowledge is at play when the learner balances equations or uses a series of steps to solve a problem. As discussed in section 2.6. selecting the best strategy requires conditional knowledge. This research will now look at how from cognitively less demanding activities such as remembering facts, Physical Science can escalate to much more complex cognitive tasks. Bloom (as cited in Braidic, 2009:305) structured the thinking process in order of complexity. This was called Bloom's taxonomy, as illustrated below in Figure 2.6.

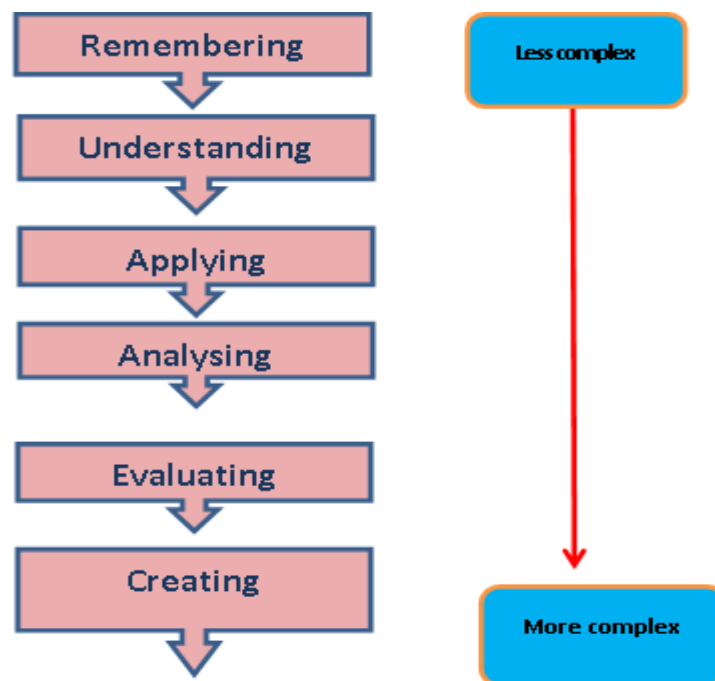


Figure 2.6: Braidic's (2009:305) interpretation of Bloom's revised taxonomy

In Bloom's revised taxonomy the cognitive demands increase in complexity, from remembering down to creating (Braidic, 2009:305). For example, a Physical Science learner can be asked to state Newton's third law. Stating Newton's third law should take place at the easiest level of Bloom's revised taxonomy because it requires the recall of knowledge and simple remembering (Braidic, 2009:305).

The answer to the question should be as follows: If a body A exerts a force on body B, body B will exert a force on body A with the same magnitude, type of force, in the same line of action, and at the same time, but in the opposite direction (Hudson, 2008:31).

Despite the definition of Newton's third law being the easiest stage of Bloom's revised taxonomy scale, it is still fairly difficult to recall and conceptualise. Conceptual knowledge and understanding is vital in the success of science (Sinatra & Taasoobshirazi, 2011:204). Many scientific terms are difficult to remember (Katz & Olson, 2006:63; Lin et al., 2013:463; Pitluck, 2010:57). This is mainly because recalling scientific facts demands a high conceptual understanding of the term (Lin et al., 2013:463). So, to remember the scientific facts of a definition, the Physical Science learner has to understand the scientific term conceptually, and that places the thinking process higher up on Bloom's revised taxonomy (Lin et al.2013:463). The starting point in learning Physical Science lies at a more challenging level than just remembering (Lin et al., 2013:463).

Procedural knowledge is being able to apply strategies using declarative knowledge to solve a problem (Li et al., 2006:292). For example, the learner could be asked to apply Newton's third law to explain why a rocket accelerates as it is launched. If the learner finds it difficult to build upon the declarative knowledge in Physical Science, he/she would struggle with applying the procedural knowledge to solve the problem. Procedural knowledge is crucial for learners' participation in various Physical Science activities (Krajcik & Czerniak, 2012:32). Procedural knowledge is "Apply", an even more difficult phase of Bloom's revised taxonomy scale compared with declarative knowledge.

Conditional knowledge is the skill needed by a learner to ascertain when, where, and how to use declarative and procedural knowledge to solve a problem (Li et al., 2006:292). For example, the Physical Science learner may be asked to use Newton's laws to explain why a person falls backwards in a train when it accelerates. Although the learner may know how to apply all of Newton's laws, he/she still has to choose the laws that are most applicable in this situation. Choosing the most valid skill or strategy use in solving problems is crucial to success in Physical Science (Sinatra & Taasoobshirazi, 2011:204). This fits in the areas named "Analyse" and "Application" on Bloom's taxonomy, which mean they are of high cognitive complexity.

In Physical Science, learners are required to create hypotheses based on observations in nature, to validate experimental data, draw conclusions, and evaluate the accuracy of their results (Bell et al., 2011:232). These skills move up to the “Evaluate” and “Create” levels of the Bloom’s scale, which require a deep understanding of theory because they are more complex.

In conclusion, to undertake many tasks in Physical Science, a high level of procedural knowledge is required (Krajcik & Czerniak, 2012:32), and to maintain success in Physical Science, a good level of conditional knowledge is essential (Sinatra & Taasoobshirazi, 2011:204). Both these competencies fit into the middle-to-high regions of cognitive complexities on Bloom’s revised taxonomy scale. However, these skills are not achievable if declarative knowledge is not remembered and conceptually understood. Scientific intelligence differs from ordinary thinking, not only in the theories used, but in what has been established as a satisfactory scientific description (Wolpert, 1994:16): Scientific thinking is abstract by nature (Bell et al., 2011:232; Wolpert, 1994:16), therefore acquiring metacognitive knowledge in Physical Science would be cognitively challenging. This is also due to the rote application of facts being a poor predictor of the success in science (Sinatra & Taasoobshirazi, 2011:204) and the application of scientific theory to solve problems is more reflective of success. Physical Science, on the whole, is cognitively challenging (Jessen-Marshall & Lescinsky, 2011:16; Koba & Mitchell, 2011:XV; Leiding, 2012:8) because it requires more complex mindsets and skillsets compared with most other school subjects (Jessen-Marshall & Lescinsky, 2011:16). Therefore, metacognition for Physical Science should be absorbed in isolation from other subjects, as it requires different levels of metacognitive skills (Zohar & Dori, 2012:2).

The following part of this chapter deals with epistemological assumptions in Physical Science learning and the popular theories that model epistemology within the Physical Science classroom.

2.8 Epistemological assumptions regarding Physical Science learning

“...before the century is out, no curriculum will be regarded as acceptable unless it can be shown to make a contribution to the teaching of thinking” (Nisbet, 1993: 282).

Integrating metacognitive skills into the “thinking curriculum” is an effective way in fostering higher ordered thinking (Gilbert, 2005:21; Renick & Klopfer 1989:3-4; Schraw et al., 2006:119; White & Frederiksen, 1998:5-6). Maximising the meta-skills of Physical Science learners is regarded as vital in raising attainment in Physical Science. Traditional curricula do not focus on meta-skills, but mainly on content. By doing this, traditional curricula promote low-level skills of memorisation, as to mastery of significant content and meta-skills. Contemporary cognitive scientists advocate the constructivist view of learning (see section 2.4.1.), promoting that learners are not recorders of facts but constructors of their own knowledge (Renick & Klopfer 1989:3). Today's cognitive science is based on the constructivist, self-regulated theory which encompasses questions on:

- how to present and sequence knowledge;
- how to monitor tasks and provide feedback;
- how to motivate learners;
- how to integrate laboratory skills with other cognitive skills; and
- how to evaluate learning (Renick & Klopfer 1989:4).

Promoting thinking about the cognition process is central to the “thinking curriculum”.

Research conducted by White and Frederiksen (1998:4-5) using a “thinking curriculum” model of scientific enquiry and the learning process in Physical Science yielded significant improvements in attainment of low and high achieving learners.

In order determine the accuracy of their hypotheses, they then planned, monitored their experiment and results, and evaluated conclusions (White & Frederiksen, 1998:5-6). A “thinking curriculum” in Physical Science is an enquiry-based curriculum which promotes metacognition (Schraw et al., 2006:118 White & Frederiksen, 1998:4-5). A metacognitive curriculum drives subject specific skills infused with cognitive and meta-skills, whilst delivering the content of the subject (Nisbet, 1993:281). Enquiry-based science curriculum promotes metacognition and self-regulation because learners are better able to monitor their learning and

evaluate errors in their thinking of theoretical interpretation of scientific content (Schraw et al., 2006:119). In this research a “thinking curriculum” in Physical Science must encompass scientific enquiry.

Epistemology focuses on the way human beings obtain and comprehend knowledge (Bassford & Slevin, 2003:144) and epistemological assumptions are the deductions, fundamentals, range, and validity of knowledge (Nkwake, 2013:96). In Physical Science, the epistemological assumption is that theory is not valid unless the prediction has been subjected to rigorous scientific testing under controlled conditions (Kafatos & Nadeau, 1990:4). This forms the basis of scientific process and understanding. The South African Physical Science curriculum promotes the integration of scientific knowledge, scientific skills, scientific enquiry, and the understanding of the nature of science (DBE, 2011:6).

Learning supported in South African Physical Science classes is enquiry-based learning and moves away from the previously popular teacher-centred approach (DBE, 2011:6; Mokiwa & Nkopodi, 2014:1075).

Figure 2.7 below illustrates how learners are exposed to evidence-based practises with a broad range of scientific skills, including evidence gathering, formulation of the scientific argument, justifying findings, problem solving, and communicating the findings (Bybee, 2006:9). The Physical Science enquiry approach to learning supports the popular constructivist model of learning (Charlesworth & Lind, 2013:67; Clary & Wandersee, 2013:167). The constructivist model of learning is discussed in section 2.9.2.

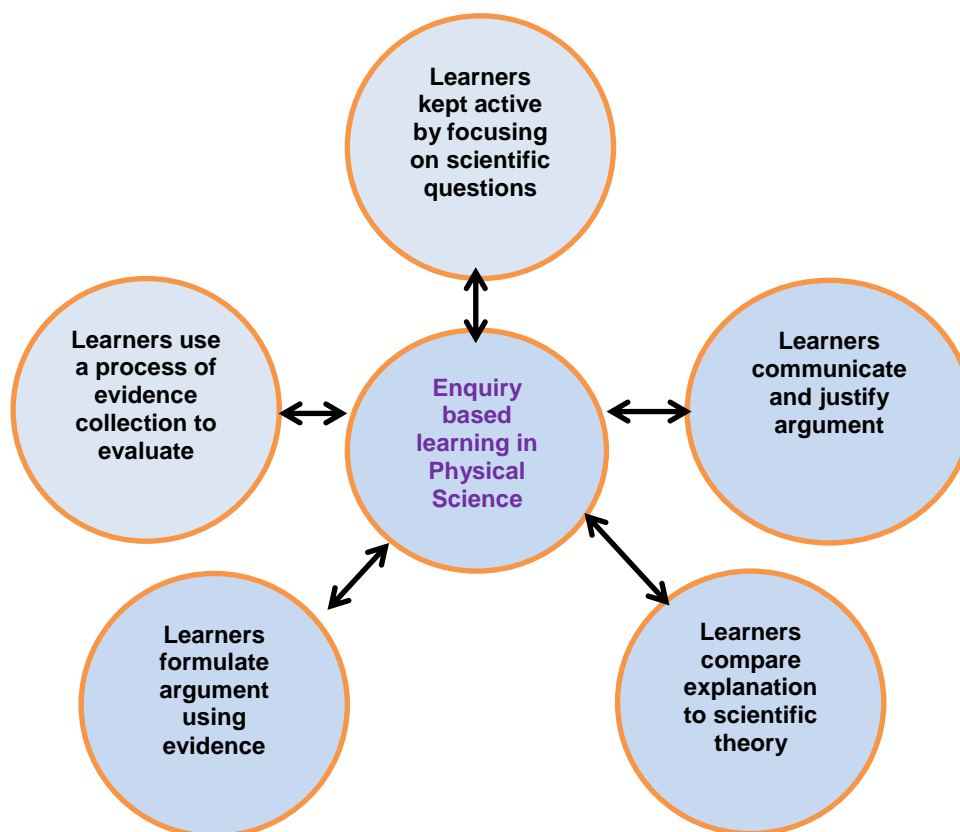


Figure 2.7: Five key features of enquiry-based learning in science (Bybee, 2006:9)

2.9 Metacognition in the Physical Science classroom

Metacognition and scientific enquiry complement each other (Schraw et al., 2006:19). Scientific enquiry in Physical Science is guided by theory, but, due to the rapid pace of growth of the knowledge base in Physical Science, less emphasis on content and more on scientific skills paves the way forward. Theory is used to drive the skills required in Physical Science, but, too much emphasis on theory utilise much needed time to develop the growth of key scientific and problem-solving skills. Solving problems, analysing data, gathering data, applying, and testing theory are the essential skills which should be the focus (Hollingworth & McLoughlin, 2001:51). This research encourages less emphasis on remembering the vast body of theory in Physical Science, and more focus on the more complex cognitive activities discussed in section 2.7. which will develop metacognitive awareness through skills-based learning in problem solving. Therefore, it is essential to analyse the problem-solving process in order to observe and identify the factors demonstrated during metacognitive teaching and learning (Evans & Swan, 2014:1-2).

2.9.1 Metacognition in problem solving

Researchers argue that the ability to self-regulate one's learning is central to expectations about learning, decision making, problem solving, and resource management in education (Boekaerts & Corno, 2005:200). Learning activities that help support self-regulation in the classroom environment are hard to set because the curriculum goals set by the Physical Science teachers do not automatically motivate learners to gain new metacognitive skill (Boekaerts, 2006:352). During the Physical Science activities, the teachers must integrate self-regulation skills in conjunction with the learning process, whilst providing plenty of opportunities for the learners to build on their own metacognitive knowledge through problem solving. Formal explicit instructions are essential in achieving this during the lesson (as discussed in section 2.4.4.)

A significant volume of research shows that learners feel ownership of their goals when they enjoy the problem-solving task or when the goals fit with their values or higher-ordered goals (Boekaerts, 2006:352). Theorists suggest that prior experience and understanding of how the context ties in with the learning process allow the learning process to occur naturally (Boekaerts, 2006:352). In Physical Science, learners should be captivated for the duration of experimentation and exploration during the problem-solving process. This becomes a highly effective learning tool when it is driven by situational interest and it progresses towards deeper learning (Boekaerts, 2006:356). Learning the abstract theory of Physical Science without associating it with real life applications could demotivate the learners. Whenever possible the learners must explore using the scientific enquiry skills discussed in section 2.8, and socially construct their understanding (see section 2.9.2.). The learners must be encouraged to set their own goals, monitor their progress, and evaluate the outcomes during this process (see 2.4.4.). Repetition of this process will ensure that metacognitive awareness is developed.

Schoenfeld's (1992:356-357) work on metacognition in the classroom suggested that learners can be trained to ask themselves metacognitive questions, and this technique can become habitual. This further emphasises the formal explicit theory, where the learners are given unambiguous and clear instructions in order to become

habitual metacognitive aware learners. Learners are capable of reaching expert levels in problem solving by making the metacognitive process a continual part of their learning. The following simple procedural questions are encouraging during the teaching and learning process and during problem solving (Schoenfeld, 1992:356): “What exactly are you doing?”; “Can you describe it precisely?”; “Why are you doing it?”; “How does it fit into the solution?”; “How does it help you?” and “What will you do with the outcome when you attain it?” These metacognitive questions can be displayed in the class for learners to refer to frequently.

2.9.2 Metacognition in the constructivist environment

Hollingworth and Mcloughlin (2001:55-56) formulate three successful instructions for metacognition:

- There should be informed training where appropriate cognitive strategies are made clear to the learner using problem solving to practise those strategies.
- Constructive alignment of metacognitive skills and assessment developed through guided instruction is needed.
- There should be constant support for engaging metacognitive activities.

Informed training echoes major characteristics of the formal explicit theory (see 2.4.4.) Constructive alignment allows the learners to see how the skills and knowledge practised in class align themselves with the key skills essential in achieving well in their assessments. The metacognitive knowledge and metacognitive regulation allow the learner to have a deep conceptual understanding of theory to apply to the assessment and to select the most effective strategies to solve the assessment problems to obtain optimal results. Consistent support by guided instruction allows for mastery of the higher order thinking skills through regular practise of the metacognitive activities.

Guided instruction is supported by the social constructivist theory in problem solving. Fensham (1992:801) stated that the constructivist model of learning was the most significant psychological inspiration of thinking and learning in science. Vygotsky (1978:86) suggested that learners come into the learning environment with social

and cultural ideas, and they learn when they are guided by more able peers or instructors in their ZPD.

“What a child can do in cooperation today, he can do alone tomorrow.” (Vygotsky, 1983:268). The aim of the constructivist approach is for facilitation to occur in the classroom for the learner to gain sufficient knowledge and skills to work independently (Vygotsky, 1978:86). Figure 2.8 below illustrates Vygotsky's theory of the ZPD, focusing on the Physical Science learner (Vygotsky, 1978:86):

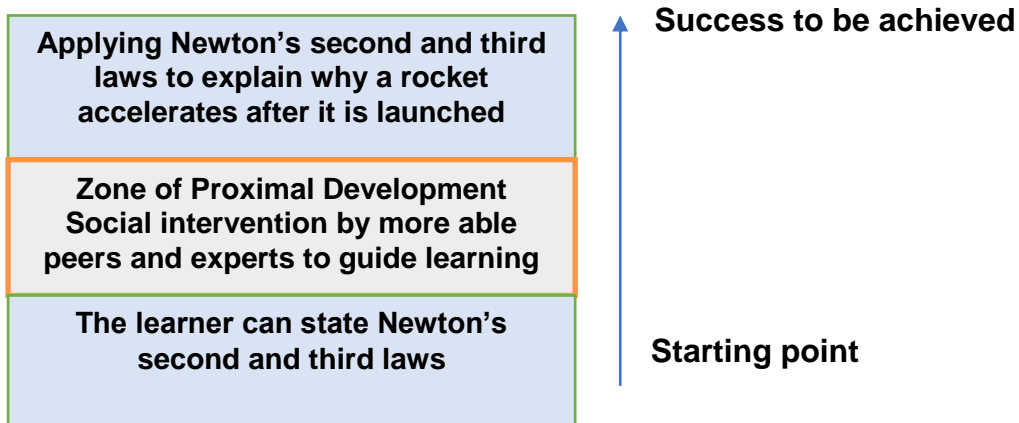


Figure 2.8: ZPD of a Physical Science learner (Vygotsky, 1978:86)

Concerning Figure 2.8, it is assumed that the Physical Science learner has declarative or prerequisite knowledge before attempting the problem in the ZPD (Shell et al., 2010:92). The ZPD is where actual social-constructive learning takes place, and where more able peers or the teacher guide the learner towards a solution of the problem. It is important to note that the learner is guided towards the solution and not given the answer to the problem. For effective learning to take place, the Physical Science learner must be aware that the problem cannot be solved without social intervention in their ZPD (Vygotsky, 1978:86). Cognitive and meta-skills of Physical Science are passed down by participants, learners, and teachers to less able learners to guide them socially towards the point of success during problem solving. Success is achieved when the learner can work independently.

The theory of ZPD can be seen as the driving force of the enquiry-based methods of learning in the Physical Science classroom (Charlesworth & Lind, 2013:67; Clary & Wandersee, 2013:67) The complementary relationship between enquiry-based learning and social constructivism supports metacognitive development in learning ((Schraw et al., 2006:19). Webb (1991:384-387) concluded that collaborative learning, which involves social constructivism, could be an effective approach to promoting metacognitive regulation, because less able learners absorb good work habits from more able learners, while the more able learners practise engaging in metacognitive activities by sharing their learning and motivation strategies.

Social agents such as teachers, parents, and the learner's initiative play a key role in fostering metacognitive skill though the Vygotskian social constructivist approach (Baker, 1994:203). The home environment is crucial in fostering metacognition, where formal and informal interaction between the learner and parents takes place during learning, whilst teachers promote metacognition in the schooling environment (Baker, 1994:232). These two factors must be considered in order to optimise the promotion of metacognitive awareness in the learners' ZPD.

The teacher needs to use effective explicit models (see section 2.10. and section 2.11.) in which social construction of meta-skills is acquired through the learners ZPD. The learners tacitly acquire metacognitive skills socially when working with peers or adults on problem solving in the home environment. Vygotsky's (1978) social influences are central in developing metacognitive skills where the less able learner is assisted by the more able learners in metacognitive regulation, until the less able learner becomes more confident and independent (see section 2.2.1). Furthermore, research has shown that metacognition is best facilitated when learners have some control during the process (Baker, 1994:232), therefore, learner social interaction will be essential. This research supports the Vygotskian approach towards explicitly fostering metacognition. However the non-Vygotskian approach will also be considered (see section 2.10. below)

2.9.3 Good problem-solvers' use of metacognition skills

The researcher mentioned in 1.1.2 and 1.3 that metacognition is a key to raising attainment in Physical Science in South Africa. This part of the study will solidify the theoretical basis for promoting metacognitive awareness to improve problem solving in Physical Science. Good problem solvers use metacognitive skills (Athreya & Mouza, 2016:137; Hoover & Feldhusan, 1994:204; Carr, 2010:180; Hollingworth & McLoughlin, 2005:64).

In this research one can perceive a creative problem solver who can think about their cognitive process, by reasoning through a challenge, recognising areas of weakness in their thinking, selecting suitable strategies, pursuing a course of action, and reflecting on its success (Athreya & Mouza, 2016:137). This was discussed in greater detail in 2.5. During metacognitive thought processes, the learner learns from mistakes made and improves overall cognition (Athreya & Mouza, 2016:137). It is worthwhile to emphasising that the researcher sees mistakes as being an important element in the successful learning. The notion of achieving success without making mistakes is considered inadequate. Reflecting on the mistakes made and modifying strategies to improve success are central features of metacognitive evaluation.

Within the improvement lies the foundation of a good problem solver. It has been claimed that metacognitive problem solving develops good character such as the ability to receive criticism, respect, listen to other points of view, humility, and open-mindedness (Athreya & Mouza, 2016:137). This shows the versatility of metacognition, in the sense that it can develop good problem-solvers and have a positive impact on the learner's character. Good teaching and learning take place when the knowledge and skills taught are holistic and when all-round skills are taught in order for the learner to be a successful member of society.

The implementation of metacognition during the problem-solving process has a greater influence in raising attainment than the traditional approach to problem solving (Hollingworth & McLoughlin, 2005:64-65). Recent research has shown that the traditional method of solving a problem, followed by the practise activity approach to problem solving, had little effect on the learner's attainment compared

with using metacognitive regulation strategies (see section 2.3) (Hollingworth & McLoughlin, 2005:64-65). The range of skills obtained during metacognitive regulation helps the learner to solve problems in a variety of contexts compared with the traditional approach (Hollingworth & McLoughlin, 2005:64-65).

The traditional approach essentially involves the teacher teaching the theory, showing how to deal with a problem, giving the learners opportunities to solve similar problems in the hope that the learners master the problem-solving techniques associated with the section studied. The shortcomings of this method are that it does not promote the social construction of knowledge (see 2.9.2.), does not encourage the planning of goals, monitoring of progress, and evaluation of the outcomes to improve from mistakes. By not promoting metacognitive regulation, the learner does not optimise his/her success according to theory discussed in section 1.1.2 and 1.3. Carr (2010:180) tabulates the abilities of an expert and a novice problem-solver in Table 2.2. The expert problem solver uses planning, monitoring, and evaluation which are key components of metacognitive regulation.

Table 2.2 Expert and novice problem solver (Carr, 2010:180)

Expert Problem solver	Novice problem solver
Spends significant time analysing the problem.	Reads the problem.
Plans and validates results of the chosen method.	Uses trial and error to solve the problem.
Good at predicting outcomes, planning, monitoring and evaluating their work.	Poor at predicting outcomes, planning, monitoring and evaluating their work.
Reflect actual performance effectively.	Do not reflect on performance.
Flexible and adaptable.	Inflexible rote learners.

By referring to Table 2.2, it can be seen that the expert problem solver has good metacognitive awareness, while the novice lacks good metacognitive skills. The key quality of the expert problem solver is taking time to analyse, plan, and rationalises the strategy selected, whereas the novice reads the problem and relies on trial and error to solve this. To sum up, the expert problem solver has good metacognitive regulation while the novice lacks skills in this area. During classroom observations, the researcher looked for evidence of metacognitive regulation, to gauge the effectiveness of problem solving (see sections 4.3.2 and 4.5.5).

2.10 Models to improve metacognition in Physical Science

The theory in this part of the literature review looks at practical models which have metacognitive theory as the basis of their application. These models could be implemented during the teaching and learning process. However, the researcher will select the most important applications of the theory discussed which is considered effective in relation to this research. The researcher will not be restricted to the practical application of one model, but instead he will use theoretical backing in conjunction with the analysed data gathered from this research to justify the recommendations from various models.

Learners do not have to be inherently intelligent to be good at Physical Science; but, being taught scientific enquiry combined with metacognition will improve the learner's capabilities (Hartman, 2001:55; White et al., 2009:200). Realising this not only helps the students to realise how to act as a team, it also leads to an appreciation of the nature of scientific enquiry, and to a consideration of mind and community (White et al., 2009:200-201). This part of the review, will focus on improving metacognitive skills during the teaching and learning of Physical Science.

Figure 2.9 below shows the preliminary analysis of learners' metacognitive problem-solving strategies as adapted from Hollingworth and McLoughlin (2001:55). Parts one and five of Figure 2.9 refer to metacognitive planning; part two refers to the procedural knowledge; part three about the learner's conditional knowledge; and parts six and seven relate to metacognitive evaluation and reflection. Part four associates both declarative and procedural knowledge. During the whole problem-solving process, the learner monitors, evaluates, and reflects on his/her efforts.

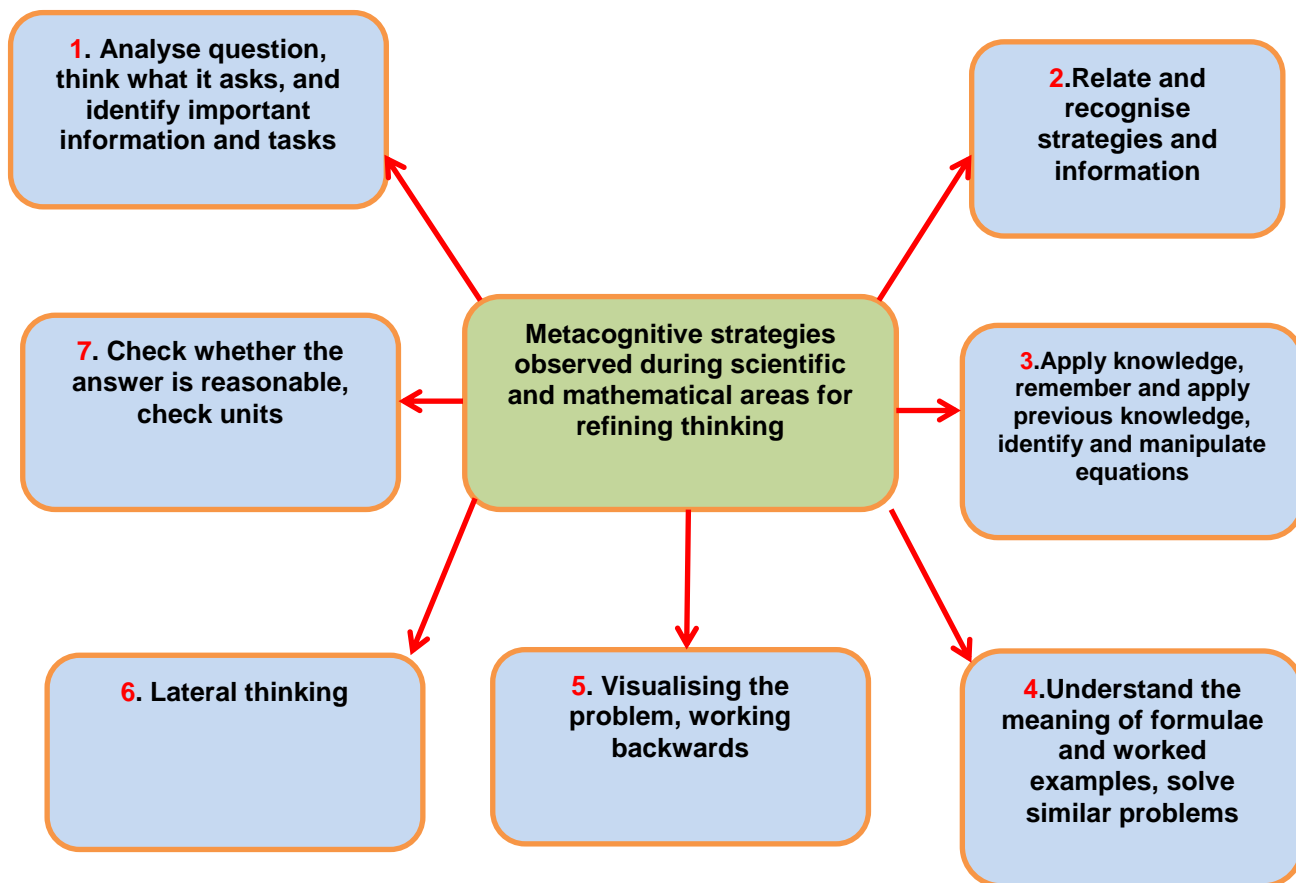


Figure 2.9: Preliminary analysis of students' metacognitive problem-solving strategies (adapted from Hollingworth & McLoughlin 2001:55)

For many researchers, the acquisition of metacognitive skills does not depend on the learner's intellectual ability (Schraw, 1998:116-117). There is a general expectation that metacognitive knowledge and regulation improve as mastery in Physical Science improves (Schraw, 1998:117). Metacognitive knowledge also compensates for the learners' lack of theory in Physical Science as well as for low intellectual ability (Schraw, 1998:117). Despite Physical Science being a challenging and abstract subject, learners with low intellectual ability improves through the acquisition of metacognitive skills (Schraw, 1998:117). Metacognition is beneficial to all learners in Physical Science classrooms, irrespective of their ability.

Kontos and Nicholas (cited in Baker, 1994:209) on the role of independent problem solving concluded that independent problem solving had similar success to the Vygotskian approach in their meta-analysis study. Whilst Physical Science theory

facilitates attainment and the use of metacognition during independent problem solving, it does not guarantee higher levels of metacognition (Schraw, 1998:117). Kontos and Nicholas (cited in Baker, 1994:209) did not consider explicit fostering of meta-skills in their study. It is therefore expected that all participants have some level of metacognition, even if they have not explicitly been taught metacognitive skills. This research will consider both the explicit Vygotskian and non-Vygotskian approach in fostering metacognition. This will embrace the needs of the interpersonal and intrapersonal learners.

The meta-tasks and instructions associated with fostering metacognition must be made explicit to the learners (Hollingworth & McLoughlin, 2001:55). As discussed in section 2.4.4. of the study, the formal explicit model is a theoretically structured system of thought which involves highly organised systems and explicit theoretical instructions. This research highlights the need for an explicit model of metacognition to promote metacognitive skills during Physical Science problem solving. However it considers other ways in which metacognition is fostered effectively.

Merging the Vygotskian theory of social interaction in the ZPD (see section 2.9.2) and the non-Vygotskian approach of learning the metacognitive skills through independently solving problems (see above), is an effective approach to fostering metacognition. Many current metacognitive interventions rely on discuss, model, and practise explicitly as well as a gradual transfer from dependant social constructivist learning to independent learning (Baker, 1994:232). This research uses the idea of metacognitive modelling to promote metacognitive awareness.

The following part of the review focuses on how metacognition can be applied. Metacognition is applied when the teaching and learning situation involves explicit theory (see section 2.3.4) during problem solving. It covers the components of metacognitive strategies observed in scientific and mathematical areas, as shown in Figure 2.9. These areas use the following models:

- The eight phases in metacognitive skills training for Physical Science learners;
- the assessment triangle and the formative assessment model;

- the strategy evaluation matrix and regulatory checklist model;
- the volitional learning model;
- Marzano's six levels of educational objectives model; and
- visible learning model.

2.10.1 Eight phases in metacognitive skills training for Physical Science learners

Research by Hollingworth and McLoughlin (2001:56-57) states that metacognition for Physical Science learners involves eight phases. Figure 2.10 summarises the eight phases of metacognitive training. The phases progress from one to five and revert to phase three until the problem-solving application has been mastered. After mastery, the learner progresses to phases seven and eight, where high levels of metacognitive and problem-solving skills are acquired (Hollingworth & McLoughlin, 2001:56-57).

Despite this model being essentially used in the study of tertiary level Physics, the researcher feels that this approach to Physical Science problem solving is valuable in promoting metacognitive knowledge and metacognitive regulation. Recalling that metacognition could be taught to young learners (see 1.4.3.3.), the researcher does not see why this model, which has the key components of metacognition interacting with each other, should not also be used in Physical Science at high school level. Moreover, the constructivist theory in learning may be adapted using this model to suit the Physical Science classroom. Also, the formal explicit theory could be used in conjunction with this model to further promote metacognition in Physical Science. It would be of major benefit for the Physical Science learners to pursue studies in Physical Science at tertiary level, where the skills acquired using this model is transferable. However, the flaw with this model is that it does not include the affective dimension of metacognition. This will have to be considered, and the model needs to be modified to accommodate affective factors.

In Figure 2.10, phases 1 and 2 require metacognitive planning in conjunction with metacognitive knowledge components (see sections 1.4.3.1. and 2.5). Phases 3 and

4 involve metacognitive conditional knowledge and monitoring skills (see sections 1.4.3.1. and 2.5). Phase 5 gives the learner an opportunity to construct knowledge socially in their ZPD (see section 2.9.2). Phase 6 allows mastery of the problem. Phase 7 and phase 8 practise the skills of reflection and metacognitive evaluation. This model takes into account the multidimensional nature of metacognition with its interacting sub-components.

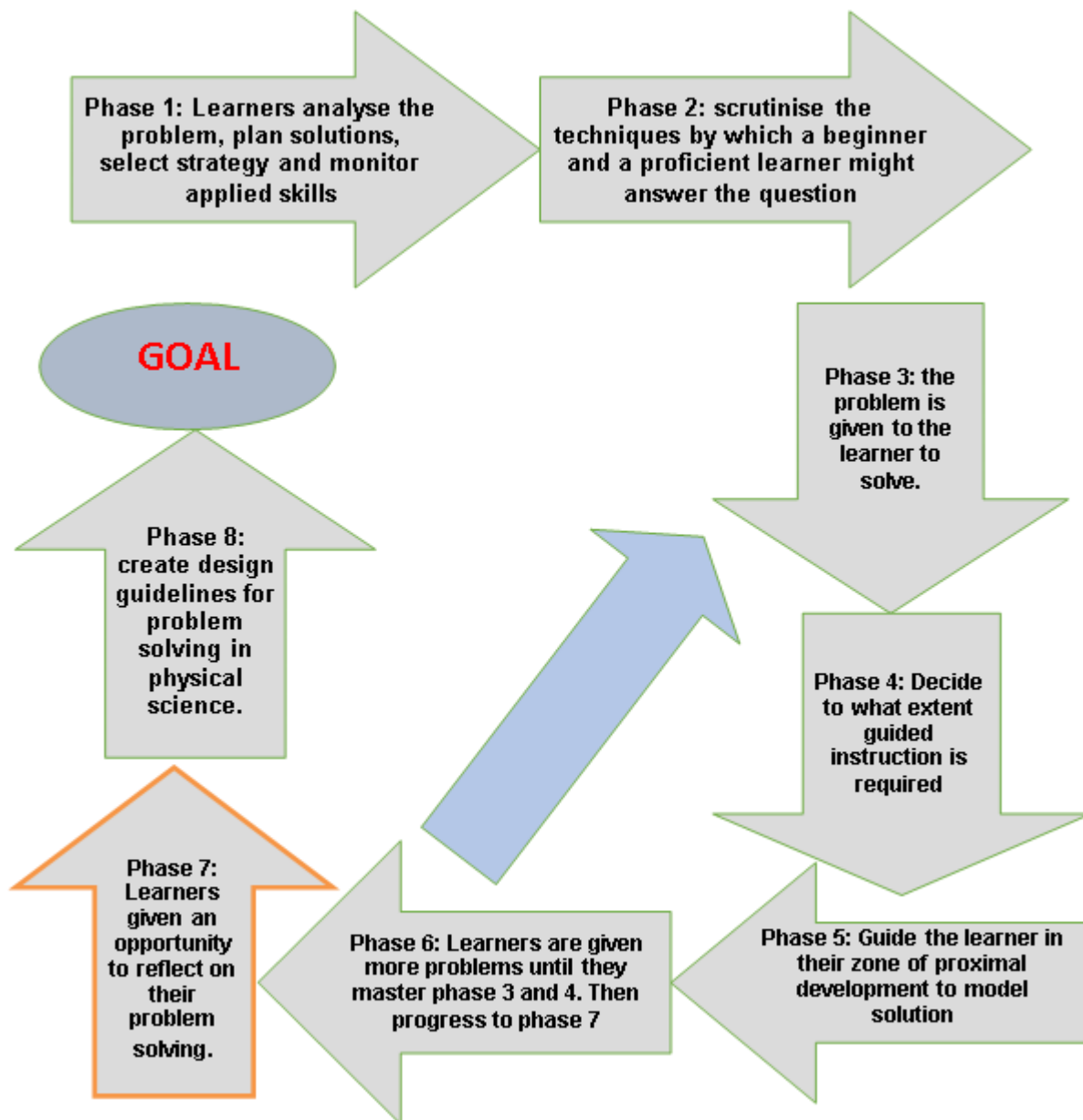


Figure 2.10: Eight phases in metacognitive skills training for Physical Science learners (from Hollingworth & Mcloughlin, 2001:57)

During phase 1 the learner is motivated to plan goals in relation to problem solving. During the planning part of the Physical Science problem, learners decide how

motivated they are and what degree of success they are capable of achieving. They also consider all resources which are available to them. This will assist in monitoring their progress. For example, the learners consider independent and social learning strategy of the brain, book, buddy, and boss approach (McDaid, 2015:16). This is an effective monitoring stratagem to use which promotes self-confidence, lifelong learning skills, and working on each learner's strengths.

The brain refers to the cognitive and declarative knowledge of the learners and their ability to think and reason using their conceptual understanding of the problem. If this fails, the learners need to plan how to use the physical resources available to them. In reference to the South African context they refer to their Physical Science notebook or textbook. Different environments may have other resources, but the schools studied in the research are restricted to notebooks and textbooks. If the learners still fails to solve the problem, they require social intervention from their buddy (the more able learner) and finally the boss (the expert or the teacher).

During phase 2 the learner must be encouraged to compare and modify their method by considering explicit advice from the teachers and perhaps the more able learners. In Physical Science the learners should be encouraged to examine the different ways in which an expert and a novice learner may approach the problem (see Table 2.3.).

During phase 3, the problem is given. In phases 4 and 5 the learner implements the plan, monitors the progress of the activity and uses appropriate intervention methods (brain, book, buddy, and boss), should difficulty arise. It should be noted that the order of the intervention process should be maintained in order to promote academic tenacity. Only after all other options have been exhausted, then and only then should the learner search for guidance from the more able learner and teacher. This takes into consideration the affective dimension of metacognition as stated above. This helps the teaching and learning situation in which the teacher and the more able learner can spend more time in assisting the less able learners (Vygotskian approach), whilst the other learners are encouraged to work independently (non-Vygotskian approach) until they reach their ZPD. This is where the ZPD is used

during differentiation of the lesson. It is expected that the solution to the problem has been reached at phase 5, although the most learners have not reached mastery.

Phase 6 encourages proficiency whereby the process ideally repeats phases 3 to 6 until the learner now becomes an expert in that problem-solving process. The value of repeating the metacognitive activities was discussed in section 2.5.2. Phase 7 requires the metacognitive evaluation process when the learner reflects on what has worked well and what is needed to improve during the problem-solving process. The learners modify their cognitive and meta-thinking strategies to rely on the most effective way to succeed in solving the Physical Science problem. Phase 8 allows the learners to create their set of strategies which they feel will work in the future. This may be used in phases 1 and 2 during the next problem-solving process. Again, this process is repeated for different cognitive activities in Physical Science to allow for the greater metacognitive awareness, affective, and socio-cultural benefits associated with the model. To ensure that that this model is adapted for the Physical Science classroom studied. The theory discussed in sections 2.10.2-2.10.5. should be included in this model.

2.10.2 Assessment triangle and the formative assessment model

It is noted that the teacher plays a crucial role in the metacognitive development of the learner. The first activity of the teacher during the promotion of metacognitive awareness is to promote metacognition using formal explicit theory (see 2.4.4). An effective way in achieving this is by using the eight phases in metacognitive skills training for Physical Science learners in conjunction with the Vygotskian and non-Vygotskian approaches discussed in section 2.10.1. Despite this model covering the key components for metacognitive awareness, it lacks teacher and learner accountability. Even with metacognitive skills being promoted explicitly by the teacher, it does not encourage accountability.

Much of research promotes the importance of formative assessments concerning raising attainment (Atkin et al., 2001:21; Black & William, 1998:3-5; Herman, 2013:2; Popham, 2008:1-2). Some studies reveal that formative assessment strategies have

triggered the highest learner gains (Popham, 2008:1-2). Formative assessment is an ongoing assessment process by learners and teachers to understand where students are in relation the lesson goals (Black & William, 1998:2; Popham, 2008:5). The word assessment comes from the Latin root meaning “to sit beside the learner” (Stefanakis, 2002:9).

Formative assessment strategies promote metacognitive regulation. General formative assessment strategies (Brookhart, 2010:13) are:

- reflection questions (ask learners to “reflect on prior experiences”);
- indicator systems (traffic lights: green is for agreeing, red for disagreeing, and orange is neutral);
- diaries (planning before the activity);
- goal setting (help monitor and organise steps or action).

Formative assessment requires complete evidence to accomplish its goals, whereby teachers must employ effective assessment strategies and tools to yield valid corollaries about raising attainment in the classroom (Herman, 2013:2-3). Simply put, teachers should constantly assess where learners are with respect to their learning goals and pursue immediate interventions to adapt teaching and learning to support the learners’ needs (Herman, 2013:2-3). This researcher will not discuss the general metacognitive assessment strategies in detail, which may be very creative and time consuming for teachers to create, but will restrict the formative assessment strategies of simply observing and communicating with the learners in order to monitor progress. By monitoring the progress of the learners during the teaching and learning situation, the teacher will ensure that the learners understand that they are responsible for following the explicit instructions as set by the teacher. This is how the two-way accountability is viewed by the researcher.

Effective strategies and tools are guided by the assessment triangle model to promote metacognition. Figure 2.11 shows a model of the learning triangle. Formative assessment rests on three pillars: a model of how learners perceive knowledge and develop skills in a subject (cognition); tasks which allow the teacher

to see learners' progress (observation); and an effective assessment method for illustrating inferences from the evidence (interpretation) (Pellegrino et al., 2001:2).

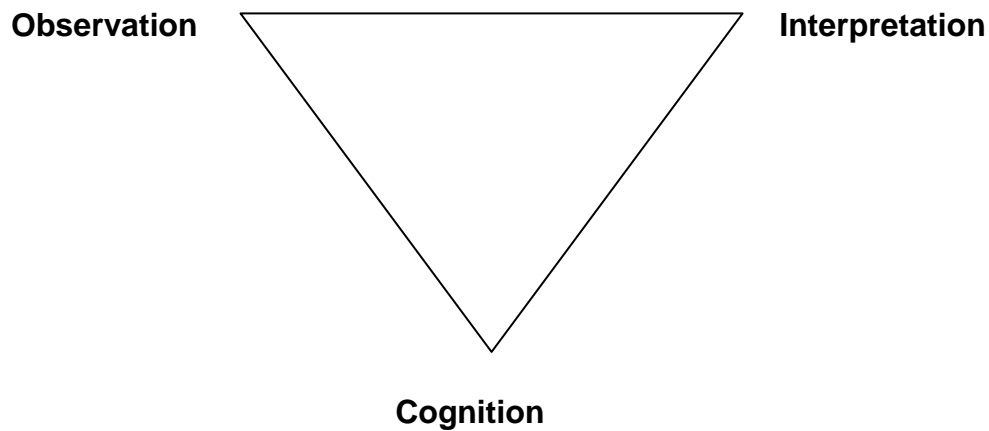


Figure 2.11: Learning Triangle Model (Pellegrino et al., 2001:44)

The cognition vertex (see Figure 2.11) of the triangle refers to formulating knowledge and developing skills in a subject area (e.g. Newton's laws). The teacher needs to have a criterion to measure the skills and knowledge necessary during the formative assessment process (Pellegrino et al., 2001:45-46). During the cognition part of the process, the teacher must set clear learning intentions and success criteria which both the teacher and the learner will evaluate at the end of the lesson. The lesson may vary in time, depending on the length of the activity.

The learning intention refers to what is being learnt and what the learner will know by the end of the lesson. For example, "state and apply Kirchoff's First Law" is a learning intention. By the end of the lesson the learners need to be able to recall Kirchoff's First Law, apply their understanding of the law to solve conceptual and numerical problems.

The learning intention should be explicit so that the learners will know when they have achieved or to what extent they have achieved the lesson's objective. This assists in promoting metacognitive planning by goal setting and is instructed explicitly by the teacher by setting out the success criteria of the lesson (this is explained in greater detail in section 2.11). Learners need to set goals in order to achieve success in the lesson. Success criteria are the steps the learner takes in order to achieve the lesson goals. For this lesson the success criteria are:

- to state Kirchhoff's First Law accurately in your own words;
- to show understanding by describing a real-life application of Kirchhoff's First Law; and
- to select effective strategies to solve numerical problems on Kirchhoff's First Law.

If one analyses the success criteria one would observe that it progresses in difficulty according to Bloom's revised taxonomy as discussed in section 2.7. For the numerical problem part of the problem-solving activity, the learners are encouraged to implement the eight phases in metacognitive skills training for Physical Science learners as discussed in the 2.10.1.

The observation vertex (see Figure 2.11) represents the criteria of the assessment displayed by the learner. The teacher assesses the written or oral responses of the learner's performance by observation or dialogue, monitors progress, and takes necessary action to improve knowledge or skill during the task (Pellegrino et al., 2001:47-48). The tasks created to observe progress should be developed with the purpose of formative assessment in mind. During this task the teacher should be observed walking around the class, monitoring the learners progress, advising learners in their ZPD, encouraging metacognitive monitoring (brain, book, buddy, and boss), supporting collaborative learning, and ensuring the two-way accountability of this learning process. This is essentially the formative assessment part of the learning process. It tells the teacher and the learner at which stage the learner is within the lessons goal.

The interpretation vertex of the triangle (see Figure 2.11) comprises all the strategies and tools used to interpret progress in the observation and cognition parts of the Learning Triangle model (Pellegrino et al., 2001:49). It shows how observations are guided by a set of tasks to create evidence about the knowledge and skills assessed (Pellegrino et al., 2001:49). The interpretation part of the lesson gives the teacher and the learners' ideas on what steps to be taken in order to progress within the lesson. The learners evaluate their progress and reflect on their learning. The learners decide on their improvement strategies. Phase 7 and 8 of the eight phases in metacognitive skills training for Physical Science learners are referred to next. The

learners rate the stage at which they have met the success criteria, and the teacher reflects on which teaching strategies were effective and which strategies needed to be modified.

The learning triangle model validates formative assessment by measuring clear evidence during the teaching and learning processes to achieve goals and raise attainment. During this process, metacognitive regulation is encouraged. This model should be integrated with the eight phases in metacognitive skills training for Physical Science learners.

2.10.3 Strategy evaluation matrix and regulatory checklist model

Stimulating metacognition starts with building awareness among learners where metacognition is already present, noting that it differs from cognition, and that metacognitive skills promote academic success in science (Schraw, 1998:123). The next stage is to impart successful approaches and to assist learners to build explicit knowledge about when and where to use these approaches (Schraw, 1998:123). According to Schraw (1998:123), metacognitive skills can be developed through various instructional practises, but his research favours the use of the formal explicit theory, teacher and expert learner modelling, collaborative activities, and reflection by learners. These practises are shown in more detail in Tables 2.3 and 2.4.

Section 2.9.2 of the review concluded that collaborative learning is effective in promoting metacognitive awareness because the less able learners emulated good work habits from more expert learners (ZPD) by sharing their learning and motivation strategies (Webb, 1991:384-387).

Schraw's (1998:119) empirical research suggests that a strategy evaluation matrix (SEM) is an effective way to improve knowledge of cognition, also known as metacognitive knowledge. The teacher and expert learner modelling in conjunction with the SEM can be used to develop metacognitive knowledge (Schraw, 1998:119). By referring to the success criteria in section 2.10.2., it is clear that the first two success criteria involve the recall of facts and conceptual understanding of

Kirchhoff's First Law which is associated with metacognitive knowledge. Sections 2.10.1. and 2.10.2. focused more on metacognitive regulation than metacognitive knowledge. Table 2.3. shows an adaptation of Schraw's (1998:119) SEM in Physical Science. Column one promotes declarative knowledge; column two promotes procedural knowledge and columns three and four promote conditional knowledge (Schraw, 1998:119). SEMs improve performance significantly, promote metacognitive awareness, and actively construct knowledge on where, when, and how to use problem-solving strategies (Schraw, 1998:120).

Table 2.3 Strategy Evaluation Matrix (Adapted from Schraw, 1998:120)

Strategy?	How to use?	When to use?	Why use?
Skim	Search for keywords, highlighted words, equations and summaries.	Before reading science text or article.	Provides conceptual overview of scientific theory.
Slow down	Pause, read again and think about information.	When information seems important.	Enhances focus on important information.
Active prior knowledge	Pause and think about what you already know and what you need to know.	Before reading an unfamiliar task or word problem.	Makes new information easier to learn.
Mental integration	Relate key points, keywords and equations to draw conclusion.	When deeper understanding of scientific theory is required.	Reduces memory load and promotes a deeper level of understanding.
Diagrams	Use flow diagrams to connect the main ideas with supporting details and pictures.	When there are a lot of interrelated concepts leading to the main idea.	Helps identify and categorise main ideas.

Schraw (1998:120) states that, although SEMs are effective in improving metacognitive knowledge, they do not effectively support metacognitive regulation. By referring to the first two success criteria in 2.10.2:

- to state Kirchhoff's First Law accurately in your own words; and
- to show understanding by describing a real-life application of Kirchhoff's First Law.

Learners have opportunities to apply their declarative knowledge by highlighting keywords, equations and summaries, pausing, reading again, and thinking about information when creating notes or answering questions on Kirchhoff's First Law to show remembering of fact and conceptual understanding. Depending on the cognitive task, the teacher must explicitly create lessons to apply the selected strategies of the SEM. Explicit instructions should be given to the learners in order to promote metacognitive knowledge during the activity.

Schraw (1998:121) suggests a regulatory checklist to improve metacognitive regulation, and this encourages learners to reflect on their learning. Table 2.4 is an adaptation of a checklist suggested by Schraw (1998:121). This checklist is continually referred to during the planning, monitoring, and evaluation phase of metacognition training during problem solving.

Table 2.4 Regulatory Checklist (from Schraw 1998:121)

Planning	Monitoring	Evaluating
What is the nature of the task?	Do I have a clear understanding of what I am doing?	Have I reached my goal?
What is my goal?	Does the task make sense?	What worked?
What kind of information and strategies do I need?	Am I reaching my goals?	What didn't work?
How much time and resources will I need?	Do I need to make a change?	Would I do things differently next time?

In conjunction to the theory discussed in 2.10.1. and 2.10.2. the explicit use of the regulatory checklist is used to promote metacognitive regulation. The regulatory checklist is an important tool during formative assessment. The teacher encourages the learner to refer to the checklist to support the self-regulatory process. This could be done by displaying the checklist and reminding the learner to plan, monitor, and evaluate during the course of the lesson.

2.10.4 Academic tenacity

It is acknowledged by this researcher that the theory discussed in sections 2.10.1., 2.10.2., and 2.10.3., would not be as effective if the learner was not motivated. The

importance of motivation was mentioned in sections 1.4.3.3., 2.4.2., 2.4.3., and 2.5. In order to motivate the learner, the Physical Science teacher must ensure that the learner understands that the learners might not achieve all-round success on their first attempt in solving a problem. There is a very bumpy road towards achieving success and achieving success leads to stressful periods. The more time learners invest in their pursuit of academic success, the greater the chances of success. Furthermore, this research promotes the idea that there must be stages of failure for holistic and metacognitive learning to develop successfully. The willingness to persevere and not give up is referred to as academic tenacity.

Dweck (2006:10-11) promotes the idea of a growth mindset, where learners are encouraged to take risks, believe in themselves, and try harder if they do not succeed the first time. Dweck's studies revealed that learners with a fixed mindset showed a decline in attainment, whilst learners with a growth mindset showed a substantial rise in attainment (Dweck, 2006:10-11). Learners with a fixed mindset accept that their level of intelligence, skills, and creative ability are stagnant, and they cannot improve in a substantial way. This research encourages the change of perception from a fixed mindset to a growth mindset. Research by Dweck et al. (2014:12) into the growth mindset in conjunction with metacognitive regulation (see sections 1.4.3.1; 2.3) ensures that the learners achieve optimum attainment to reach their full potential. Promoting the idea of a growth mindset in South African Physical Science classrooms helps in raising attainment.

The emotions of fixed mindset and growth mindset are similar to the motivational and affective factors stated by the American Psychological Association in section 2.5.1. of the study. These factors deal holistically with the real-world context of learning. The American Psychological Association principles also associate cognitive and metacognitive factors in the real-world context of learning (see section 2.5.1.). The motivational and affective factors of the learners' mindset influence the learner's higher-ordered thinking abilities. Teachers need to promote a growth mindset in parallel to promoting metacognition.

Similarly Dweck, Boekaerts and Corno (2005:199) recommend that when learners have to apply well-refined volitional strategies exhibiting good work habits, they are more likely to show determination to learn and persist, even when they reach stressful situations during learning. Volitional learning strategies refer to conscious efforts driven by tenacity or extrinsic factors to strive for learning goals, despite the impulse to give up in the face of obstacles (Elstad, 2014:3433). Volitional strategies promote metacognitive regulation because they motivate the learner to stay on task in stressful situations (Boekaerts & Corno, 2005:205).

Volitional strategies such as time and resource management, prioritising goals, and marking completed tasks are vital in supporting metacognitive regulation (Boekaerts & Corno 2005:205-206). Conditions of struggle that activate the necessity for volitional control includes the stress of idealistic assessments in class, activity overload, and an inability to categorise academic and non-academic goals (Boekaerts & Corno 2005:205-206). The components promoting volitional skills in learners are for teachers to create a supportive learning environment with care, motivation, and praise (Boekaerts & Corno 2005:205-206). Boekaerts and Corno (2005:199) support the work done by Schraw (1998:123) and Webb (1991:384-387) emphasising the positive effect collaborative learning has on metacognitive learning. Boekaerts and Corno (2005:213-216) promote three types of intervention to modify cognitive behaviour:

- The first is mental simulations: Teachers promote ideas such as hard work helps get good marks in examinations. Mental simulation involves preparation and devising expectations that promote self-awareness about outcomes, thus helping learners to amend dysfunctional views that are damaging to their outcomes.
- Second is manipulating learners' task motivation: Teachers use goal setting, feedback, and positive reinforcement as part of their regular classroom teaching to inspire learners towards productive self-management.
- The third type is to modify the classroom environment: Use programmes such as TARGET, which gears the classroom environment to encourage metacognitive regulation. TARGET stands

for Types of activities, ranks of Authority, means of Recognition, Grouping approaches, Evaluation practises, and use of Time. Interventions such as TARGET inspire learners to set their learning objectives and then work towards mastery, rather than focusing only on tasks prescribed by others in the classroom situation.

Mental stimulation, as viewed in this study, is associated to metacognitive planning. Unlike the metacognitive planning discussed in 2.10.1 and 2.10.2. which focused on metacognition during lesson activities, long-term planning must be done to set goals and mental attitudes towards achieving the long-term goals in Physical Science. This is done at the beginning of the course, towards examination preparation time, and major tests.

TARGET is linked to the metacognitive activities discussed in section 2.10.1, 2.10.2., and 2.10.3. This leads to mastery of problem-solving skills through the interacting components of metacognition. The only part of TARGET that has not been discussed thus far is the component of time. The learners need to appreciate the time constraints within the classroom environment. If success in problem solving is not achieved within the time allocated during the lesson, the learners sometimes have to apply the metacognitive skills outside the classroom environment, for instance at home, to achieve success.

These values of academic tenacity are enhanced by guiding the learner through what Nottingham (2016:109) labels as the “learning challenge”, better known as the “learning pit”. The model of the learning pit includes important metacognitive models discussed in 2.10.1., 2.10.2, 2.10.3., and later in 2.10.5. Further to this, the model of the learning pit promotes academic tenacity. Figure 2.12. below shows an adapted illustration of the learning pit and the discussions below deliberates how it is used to promote metacognitive awareness in conjunction with academic tenacity and a growth mindset.

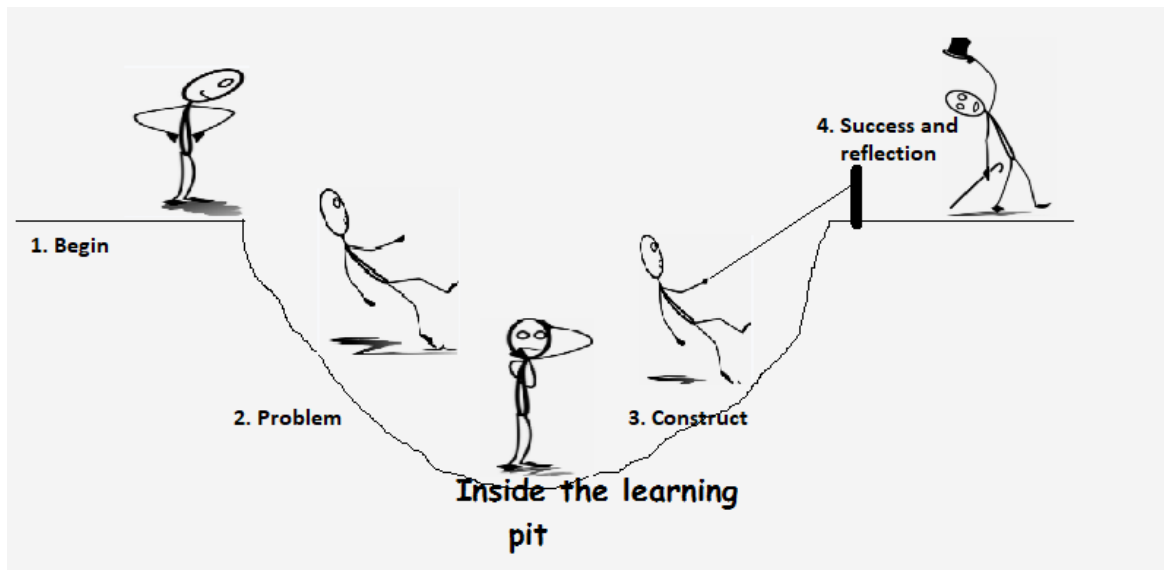


Figure 2.12: Cartoon image of the “learning pit” (from Nottingham, 2016:109)

Like Vygotsky’s (1978:86) principles of social constructivism in the ZPD (see section 2.9.2) the learner “begins” (see Figure 2.12.) with some idea of the theory behind the “problem”. Nottingham (2016:10-11) uses the term “conflict” instead of “problem”, but in Physical Science problem solving the word “problem” will be used. The teacher needs to create this conflict or problem during the teaching and learning situation (Nottingham, 2016:10-11). This is when the learner falls into the learning pit (see Figure 2.12.).

The problem does not only refer to numerical types of problems, but also to conceptual application of theory. All types of Physical Science problems should be practised using this model. The model is only effective if the learner feels the emotions of confusion and struggle. The teacher must make it known that this is a normal part of learning, and if the learner does not fall into the learning pit, effective learning does not take place. Furthermore, not everyone gets out of the learning pit. Achieving success is a constant struggle and the learner with a growth mindset has the best chance of coming out of the learning pit.

The conflict or problem is created by the teacher in setting learning intentions and success criteria, as discussed 2.10.2. and 2.10.5. Conflict arises when the teacher asks a question during a classroom discussion or a worksheet of problems. A learner with a fixed mindset would stay stuck in the pit, but the teacher could promote

sufficient tenacity and perseverance for the learner to climb out of the learning pit. Struggle and confusion should be accepted as part of the process, and the teacher should inform learners that being inside the pit is just temporary.

The pit could be compared with the ZPD. This is where optimal learning and the promotion of growth mindset take place. The third part of the learning pit is the construct phase. This is where learners socially construct ideas in conjunction with their prerequisite knowledge. This is where Vygotsky's (1978:86) idea of social constructivism comes into play, with more able learners making headway in solving the problem for themselves, and then assisting less able peers. Prior to this, the brain, book, buddy, and boss strategy is encouraged (2.10.1). ZPD is reached once the learner has exhausted the resources of the brain and book discussed in section 2.10.1.

Whilst in the pit, formative assessment and monitoring is encouraged and the teacher assess where the learner is in context to the problem-solving process. Unlike, the theories previously discussed, the learning pit encourages the teacher to monitor the emotions of the learner. Within the pit the learner needs to metacognitively plan strategies to get out of the pit, and metacognitively monitor their progress.

Once out of the learning pit, learners achieve success, and the teacher promotes metacognitive evaluation techniques so that the learner reflects on the experience of the learning pit. The teacher must create this situation as often as possible until learners master the skill of escaping from "the learning pit". Repeating will help develop metacognitive awareness (see section 2.5.2.). During problem solving, mastery can be achieved by implementing the eight-phase model to improve problem solving in Physical Science (as discussed in 2.10. and 2.10.2.).

Work completed in promoting growth mindset confirms that it leads to raised attainment (Dweck, 2006:10-11). Using Nottingham's concept of the learning pit in South African Physical Science classrooms leads to a growth mindset. Teaching the notion of growth mindset of teachers and student teachers is important.

2.10.5 Marzano's six levels of educational objectives model

Marzano and Kendall (2006:1-9) rationalised the need to create a taxonomy of educational objectives as a progression from Bloom's revised taxonomy (see section 2.6). Critics of Bloom's revised taxonomy felt the taxonomy over-simplified the cognitive process and ignored the multidimensional and the constructivist nature of thinking (Marzano & Kendall, 2006:8). Marzano's taxonomy of educational objectives is a metacognitive system which specifies goals and monitors the implementation and accuracy of the acquisition of knowledge (Moseley et al., 2001:252). Figure 2.13 illustrates the theoretical model of the taxonomy of objectives.

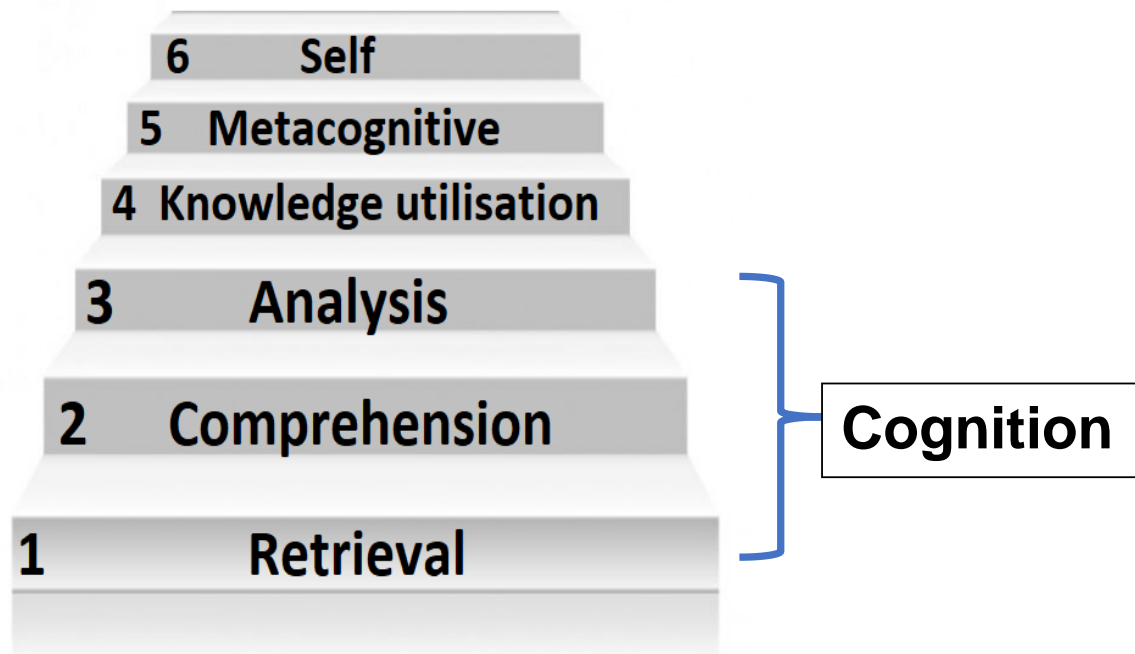


Figure 2.13: Marzano's six levels of educational objectives (from Marzano & Kendall, 2006:66)

This multidimensional constructivist system functions on the prerequisite knowledge of the learner in the form of linguistic (language), non-linguistic (mental images and physical sensations), and affective (emotional) (Moseley et al., 2001:282). Each level requires more intensive thinking than the one below it (Moseley et al., 2001:282).

The retrieval level (see Figure 2.13) refers to prerequisite knowledge which the learner has. This is similar to the knowledge a learner has before entering the ZPD (2.9.2). This knowledge is simply declarative, which means it is recalled, but not

applied (Marzano & Kendall, 2006:65-66). Unlike Bloom's Taxonomy, Marzano's Taxonomy considers the knowledge the learner brings into the classroom which is the basis for social construction of knowledge (see sections 2.6 and 2.9.2.)

The comprehension level (see Figure 2.13) characterises the largest class of intelligent skills in verbal, written, and experiential knowledge (Marzano & Kendall, 2006:72-75). The three types of comprehension are defined as translation, interpretation, and extrapolation. Translation encompasses encrypting information into some different form from what it was initially (Marzano & Kendall, 2006:72-75). In the Physical Science topic on Newton's Second Law the law is changed from words into an equation. Interpretation entails reordering of notions as encrypted by translation. Interpretation occurs when the learners convey their understanding of Physical Science concepts in their own words. Extrapolation refers to the addition of ideas that go beyond literal interpretations of information. For example, the learner uses Physical Science concepts to explain real-life applications. This is compared to the remembering of facts and the understand levels of the Bloom's revised taxonomy (see section 2.6). The comprehension part of the Marzano's taxonomy focuses on the conceptual understanding of concepts.

The analysis part of the model involves analysing, classifying, generalising, and specifying of the information. Knowledge utilisation becomes progressively more difficult as the learner has to make decisions, solve problems, and investigate. The metacognitive level (metacognitive monitoring and planning) and the self-level (metacognitive evaluation) trigger meta-level thinking using the conceptual knowledge of the levels below.

Unlike Bloom's Taxonomy, Marzano's six levels of educational objectives consider the multiple dimensions within higher order thinking and promote metacognition. To write the success criteria, Marzano's taxonomy is re-written as follows:

- to state Kirchhoff's First Law accurately in your own words (interpretation);
- to translate Kirchhoff's First Law into a diagram and equation (translation);
- to describe real-life application of Kirchhoff's first Law (extrapolation).

These three success criteria give the learner very clear instructions of what steps are required to conceptually understand the lesson's theory. These standards have to be met in order to have an in-depth understanding of the theory to provide the grounding to be successful in the more complex problem-solving process which follows. The three success criteria focus mainly on metacognitive knowledge, and the SEM discussed in section 2.10.3. is referred to.

The following success criteria focus on the promotion of metacognitive regulation within the lesson's objective and are focused on the meta-level of Marzano's taxonomy. It must be noted that, despite this being one lesson, it takes more than one period to complete and the success criteria is broken down in parts, depending on the teaching style of the teacher.

Using the eight phases in metacognitive skills training for Physical Science learners you must be able to:

- plan and compare strategies to solve problems using Kirchhoff's First Law;
- select the most effective strategies, monitor progress during problem solving, and seek appropriate help (brain, book, buddy, boss);
- repeat the process until confident; and
- reflect on the strategies which worked, and which did not.

These success criteria provide explicit steps for the learner to refer to in order to achieve success within the lesson. The eight phases in metacognitive skills training for Physical Science learners should be displayed in the class in conjunction with the brain, book, buddy, and boss chart. Other important displays such as the SEM and the regulatory checklist are beneficial. The metacognitive success criteria using Marzano's taxonomy could adapt for the different problem-solving activities in the Physical Science class.

The progression of difficulty is clear as the level moves from one to six. This meta-analysis of instruction uses specific levels to guide higher order of thinking within the teaching and learning situation. The taxonomy of educational objectives model

directs teachers to design educational objectives to promote metacognitive thinking (Moseley et al., 2001:310-311).

2.11 Visible learning as an effective metacognitive model to raise attainment

The broad nature of metacognition has many models and a vast number of theories, which makes it counterproductive to try to consider all the theories in promoting metacognition. The literature review discussed thus far has focused on the theory of metacognition and how to implement it effectively in order to successfully promote metacognitive awareness in Physical Science. Much theory points to metacognition improving academic success, but what are the most effective components which will support the multidimensional nature of metacognition? Work published by Hattie (2012) on visible learning has guided the researcher to narrow down the field. The researcher continues to refer to the theory discussed in the literature review to reiterate the fundamental theory of metacognition accepted by most researchers. The major difference between the visible learning theory which is discussed below, and other metacognitive theories is that the former is ground breaking because of its valid and extensive work which surpasses other educational studies.

It is important to note that all research has its limitations. Despite Hattie's work becoming so popular and coining the term the "Holy Grail in Education", the effect size as a universal measure of impact is questionable (Bergeron, 2017). The meta-analysis process uses formal statistical techniques to collect, select and synthesise data in a quantitative way from previous research (Wachter, 1988:1407). This excludes qualitative data which studies the information-rich learning environment crucial to understanding the socio-cultural elements considered to be very important in this study. This motivated the researcher to consider only the effect size which had the highest impact on attainment, was metacognitive by nature, and affected the learners' motivation. Discussions in section 2.11.2. helped inform the research as what factors was selected using the visible learning approach.

2.11.1 Ground breaking research on visible learning

Hattie's (2012:2) research on visible learning tapped into more than 800 studies on meta-analyses of raising attainment, and involved 52 637 studies focusing largely on mathematics, science, literacy, and social studies, over a period of about 15 years. These studies involved approximately 240 million students, with many being involved in more than one study (Hattie, 2012:2). A further one hundred or more meta-analyses been added since the publication of Hattie's visible learning (Hattie, 2012:2). Ninety-five percent of the 146 000 effect sizes (see section 2.1.10) which affect attainment yielded positive results (Hattie, 2012:3). This research was the largest ever study of teaching strategies in a classroom environment ever done.

2.11.2 Effect sizes

Hattie (2012:3) used effect sizes to compare different measures, such as standardised tests, teacher-made tests, and learners' work, in order to study various influences on the learners' achievements. An outcome of the effect size of less than 0.20 would be measured to be small; 0.3-0.6 would be medium, and more than 0.6 would be considered larger (Hattie, 2012:13). Figure 2.14 below shows the barometer of influences which reveals the analysis of effect size visually (Hattie, 2012:15).

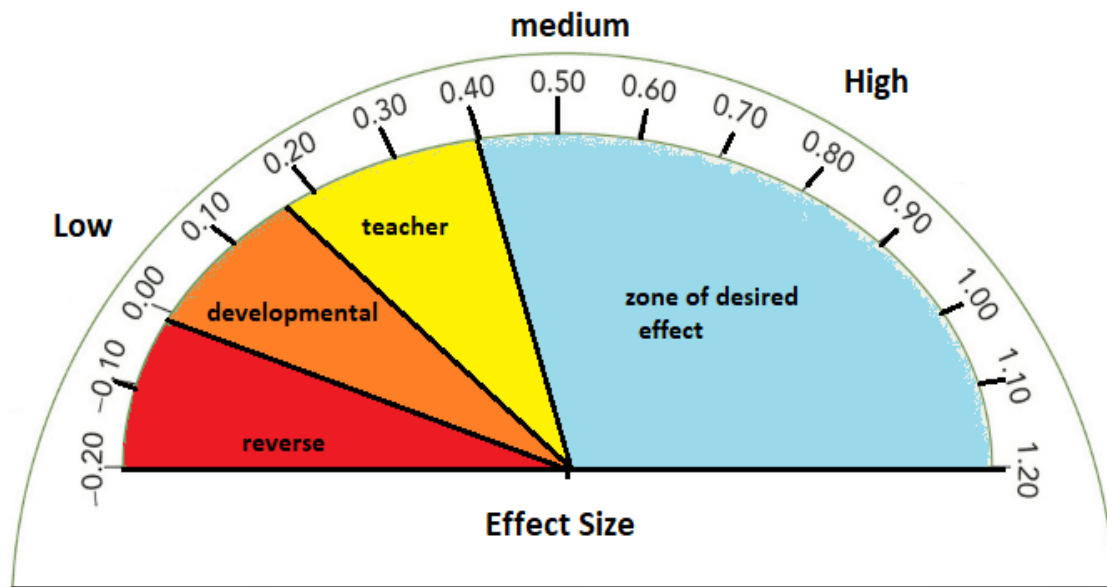


Figure 2.14: Barometer of influences (adapted from Hattie, 2012:15).

The reverse zone (red) in the diagram represents effect sizes with negative values (see Figure 2.14). Interventions such as summer vacations (-0.02); repeating a grade (-0.13); television (-0.18); and changing schools (-0.34) impact on having a reverse effect. The interventions with a negative effective size have a harmful impact on learners' attainment (Hattie, 2012:268).

The developmental part of the barometer shows those outcomes which learners can achieve without schooling (see Figure 2.14). Examples of interventions which lead to the outcomes are out-of-school curricular experience (0.09), changing school timetable (0.09), teacher subject matter knowledge (0.09), and multi-age classes (0.04) (Hattie, 2012:268). These effect sizes are under 0.2 and interventions with these scores are deemed to be insignificant interventions in raising attainment.

The teacher effects region (see Figure 2.14) is the outcomes which the learners achieve by being taught by a teacher for one year. Examples of the effect size outcomes which dominate this region are bilingual programmes (0.37); homework (0.29); time on task (0.38); and simulations (0.33) (Hattie, 2012:268). These interventions are around the low to medium values of the effect size analysis and have some noticeable impact on the learners' attainment.

Hattie (2012) warns of over-simplifying the interventions effect size. An intervention such as homework, with a lower effect size of 0.29, is more practical and cheaper to implement in many South African schools than an intervention of computer-aided

instruction, with an effect size of 0.37, despite having a lower effect size (Hattie, 2012:14).

The zone of desirable effects (see Figure 2.14) refers to interventions that significantly improve attainment. The effect size in this region is 0.4 (medium) and above. Study skills (0.62), problem-solving skills (0.61) and student expectations (1.44) are some of the interventions in this region (Hattie, 2012:266). These effect sizes of the interventions' impact in raising attainment significantly. Figure 2.15 below shows the effect sizes in the desired effects zone (see Figure 2.14).

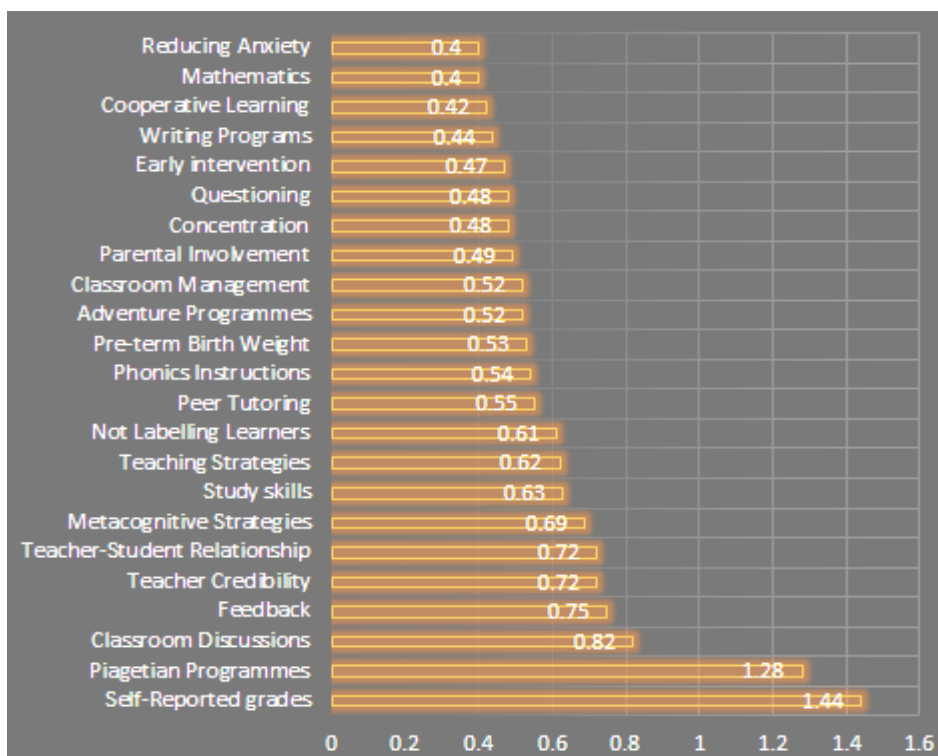


Figure 2.15: Interventions within the zone of desired effects (adapted from Osiris Educational: 2012)

Concentrating on all the interventions may cause the reader to lose focus on the key issue, which is metacognition. Despite metacognitive strategies being treated in isolation, the theories of metacognition are intertwined with many of the interventions studied. Metacognition is multidimensional by nature, and part 2.4 of the study describes the principles which are interconnected to metacognition. Furthermore, the interventions ranked at the top of the effect size graph (see Figure 2.15) have connections to metacognitive theories. The self-reported grades (1.44) require

learners to reflect and evaluate their progress before a test triggers metacognitive evaluation (see section 2.5). The interconnectedness of Piagetian programmes (1.28) and metacognition are described in 2.3.2. Classroom discussions (0.82) have foundations in social learning in a constructivist environment (see section 2.9.2). Feedback (0.75) in the forms of formative assessment was discussed in 2.10.2.

When experts are promoting metacognition to the South African Physical Science teachers, they should emphasise the outcomes which had the greatest impact on attainment, was metacognitive by nature and affected the learners' motivation. This research considered only the outcomes which scored an effect size greater than 0.6, which are those that have the most significant impact on raising attainment. According to Figure 2.15., the interventions with effective sizes greater than 0.6 are:

- self-reported grades;
- Piagetian programmes;
- classroom discussions;
- feedback;
- teacher credibility;
- teacher-student relationship;
- metacognitive skills;
- study skills;
- teaching strategies; and
- not labelling learners.

The top-ranked effect size intervention is the self-reported grades, which are associated with metacognitive evaluation (see section 1.4.3.1 and 2.3). In this outcome, Hattie (2012:59, 93) tries to promote metacognitive evaluation and reflection before the assessment or test. Learners are encouraged to write down the predicted grade before taking the assessment to reflect learners' effectiveness in metacognitive planning and monitoring, and in taking ownership of their learning.

The second-ranked outcome following the self-reported grade is the Piagetian teaching programmes (see Figure 2.15). This educational approach is built on

Piaget's theory of cognitive development, which is founded on fundamental phases in cognitive development (see section 2.4.2). Piaget's (1972:1-12) theory envisions the child developing thinking skills and knowledge through involvements, social interaction, and motivation. However, despite learning basic metacognition at lower stages, the child may only be able to perform more advanced metacognition during the formal operational phase and beyond (see section 2.4.2). Teachers should be trained to implement age-appropriate metacognitive skills which learners understand and can implement. For example, children under the age of 12 may find it difficult to develop abstract thinking; for the child to attempt tasks which involve hypothetical and deductive reasoning would be counterproductive. Section 2.5.1. discusses the socio-cultural differentiation within the teaching and learning process where there are learners of different academic ability.

The third highest scored outcome, which teachers should be encouraged to implement in their lessons, is classroom discussions (see Figure 2.15). This outcome is linked to Vygotsky's (1978) constructivist theory and ZPD, see sections 2.9.2. The idea of class discussions is to move away from the teacher-dominated approach to where the discussions provide opportunities for learners to lead their own learning, express their points of view, and socially construct their ideas. The discussions inspire thinking about prerequisite knowledge, teacher-led group discussions, small group discussions, and teacher and learner communication during the monitoring and formative assessment activities.

Formative feedback is ranked fourth in the effect size scale (see Figure 2.15) and is discussed in detail in sections 2.10.2. and below in section 2.11.4 of the study. Formative feedback encourages metacognitive monitoring and evaluation. The assessment triangle and the formative assessment model (discussed in 2.10.2) are effective ways to provide crucial feedback to learners which promotes metacognitive regulation. The formative feedback could encourage learners to be keep on the task during the eight phases in metacognitive skills training for Physical Science learners (see section 2.10.1.), to refer to the SEM and the regulatory check list (see section 2.10.3), use their cognitive resources of brain, book, buddy, and boss system (see section 2.10.1), and guide them through the learning pit (see section 2.10.4).

Teacher-student relationship, teacher credibility, metacognitive skills, study skills, teaching strategies, and not labelling learners are all important outcomes, but all have a lower-ranked effect size, compared with the top four outcomes. However, they all scored above 0.6 and should be regarded as very effective interventions in raising attainment in learners (see Figure 2.15.).

Interventions with effect size above 0.6 have some rooted link to the multidimensional nature of metacognition. The teaching strategy which promotes metacognitive awareness is considered to be an effective intervention in which this research sees as important in raising attainment. The implementation of metacognition in the Physical Science classroom was discussed in great detail in sections 2.10.1 to 2.10.5.

Teacher credibility is maintained when the teacher is well prepared for the lessons and has expert knowledge and skills in his/her subject area. As with the other intervention, this study sees teacher credibility in line with metacognitive awareness. Physical Science teachers need to be highly metacognitive, have a broad understanding of the nature and structure of Physical Science, be able to converse with the learners on the cognitive and metacognitive activities, and be able to model metacognitive strategies (Thomas, 2012:140).

Study skills and promoting metacognitive awareness effect sizes are rooted in the theory of metacognition. Highlighting these key outcomes while teaching enables teachers to become promoters of metacognition (see section 2.10.5). This is imperative in raising attainment in the Physical Science classroom. Schraw and Moshman (1995) adapted Flavell's (1976:232) Model of Cognitive Monitoring and Regulation (see section 2.4.4) and this is used to guide the metacognitive teaching and learning process. Schraw's (1998:121) SEM can be used during studying to improve metacognitive knowledge (see section 2.10.3) and regulatory checklist can be used to effectively improve metacognitive regulation (see section 2.10.3).

Teaching "cognitive and metacognitive strategy for learning" such as memory tricks; effective cramming; planning; gather information; and problem solving (Rusbult,

2011) could be strategies which could be very effective in studying Physical Science. In conjunction to this, self-directed learning (SDL) would be imperative in teaching effective study skills because its fundamental components are associated with metacognitive regulation. Knowles (1975:18) states that SDL is a method where learners control their own learning, identify their cognitive weaknesses, articulate their learning goals, implement effective strategies, use available resources, and evaluate their learning results. Metacognitive monitoring has to be encouraged during the implementation of strategies during the learning process. Further to metacognitive regulation, SDL encourages the learners to acknowledge their strengths and weaknesses and to utilise effective resources which is available to the learners. The eight phases in metacognitive skills training for Physical Science learners is used in conjunction with SDL as an effective model to study and use meta-tasks to enhance learning.

The teacher-student relationship is vital in forging a positive and productive connection with learners. An effective attitude for teachers to achieve this relationship is to be caring, yet have high expectations of learners (Berns, 2013:216). Hattie's (2012:12,104,122,132) research emphasises teaching strategies aimed at encouraging learners to become their own teachers through metacognitive regulation, self-monitoring, and self-assessment strategies. A good teacher-student relationship is an intervention which has an effect size of 0.72 and encourages a positive teaching and learning environment. It might not be metacognitive by nature, but it addresses the motivational dimension of metacognition.

Furthermore, learners should not be labelled. Being labelled as not good in science or mathematics is a negative approach, while teachers should rather be encouraging and motivating learners through the principles of growth mindset (see section 2.10.4.). The American Psychological Association's psychological principal of individual differences suggests that learners are born with personal abilities that can be modified to improve their learning (see section 2.5.1.). Improvement of metacognitive awareness improves attainment of low-ability and indigenous learners who have insufficient subject knowledge (Bruning, 2004:84; Schraw, 2001:7; Schraw, 1998:117). Teachers should always have high expectations and believe that

all their learners can achieve the aims and objectives of the lesson, whilst promoting metacognitive awareness.

Hattie's (2012:2-3) outcomes that are crucial for raising attainment have roots deep in metacognitive theory. The teaching of metacognitive awareness for teachers and student teachers is fundamental in raising the attainment of learners. Therefore the theory of metacognition should be driven in conjunction with Hattie's outcomes, as discussed in order to raise learners' attainment in South African Physical Science classrooms.

2.11.3 Planning in a classroom guided by visible learning

Effective planning involves

- collaboration among teachers,
- agreement on what is worth teaching,
- challenges,
- progress, and
- evaluation of the impact of planning on the learner outcomes (Hattie, 2012:41).

Visible learning has essential features already discussed in sections 2.10.1 to 2.10.5. These features will be highlighted during discussions on visible learning. Learners bring prerequisite knowledge based on prior achievements in their learning (see section 2.10.2); however, Hattie (2012:42) adds that learners also come with a different level of conceptual understanding. Before the lesson, the teacher needs to know the level of performance of learners to plan a bridge between higher and lower achievers (Hattie, 2012:42).

The two parts of planning the desired level of the lessons are clarity about what is to be learnt (learning intention) and knowing how learning intentions have been achieved (success criteria), as discussed in section 2.10.2 to 2.10.5 (Hattie, 2012:52). The learning intentions (goal; aim) and success criteria are vital for metacognitive regulation (see section 2.10.2. to 2.10.5.) and must be conveyed to learners. The teacher needs to set effective goals and structuring activities to

achieve the goals. Formative assessment (see section 2.10.2) is led by learning intentions (Hattie, 2012:52).

Success criteria are those where teacher and learner both know when goals have been reached. The success criteria are informed by learning intentions and formative assessments and they help the teacher understand when the goals have been reached (Hattie, 2012:56). However, this is not necessarily when the activity has been complete. Two of the most powerful ways to increase the impact on learners' attainment is to know and share learning intentions and success criteria. When learners know the success criteria and learning intentions, it is highly probable that they will work towards achieving the goals, know where they are about the goal, and plan, monitor, and evaluate their learning.

2.11.4 Teaching and learning process through the eyes of visible learning

The teacher has to monitor the progress of the learners through formative assessment throughout the lesson (see section 2.10.2). Hattie (2012:124) coined the term visible learning because the philosophy of visible learning promotes the idea that the teacher should see learning through the eyes of learners. To achieve this, the teacher needs to be metacognitively aware. Hattie (2012:124) promoted the phrase "visible learning" because his philosophy supports the idea that the teacher should see learning through the eyes of learners (see section 2.11). The critical aim of visible learning is for the learner to become their own teacher. This idea is theoretically plausible (Nottingham, 2016:119) because learners remember:

- 10 percent of what they hear;
- 20 percent of what they read;
- 30 percent of audio-visual presentation;
- 40 percent of teacher demonstrations;
- 50 percent of what they discuss;
- 75 percent of what they practise;
- 90 percent of what they teach.

At the start of the lesson, the teacher must act as an evaluator. The teacher should:

- consider how to gauge whether the strategy is working (metacognitive monitoring);
- measure the strategy against a benchmark;
- show theoretical or practical justification of the strategy (metacognitive evaluation);
- know when the strategy is failing (metacognitive monitoring and evaluation); and
- share the ideas with other teachers (Hattie, 2012:98).

The teacher's aim as an evaluator is to ensure that learners accept accountability for their learning by:

- managing and understanding their progress (metacognitive monitoring and evaluation);
- evaluating their progress (metacognitive evaluation and reflection), and
- becoming involved in peer learning (ZPD).

With this in mind, the teacher must state the success criteria and learn intentions (learning outcome). This should trigger the process of metacognition, where the learners:

- plans how to achieve or reach the learning intentions;
- monitors, evaluates, and reflects on the process of learning to lead to the learning intention; and
- evaluates whether they have achieved the learning intentions and reflected on its success.

The success criteria give the learners explicit directions on how to evaluate whether they have reached the goal of the lesson.

During the lesson, the teacher needs to have an endpoint to the goal and teach the learner skills to achieve the goals (Hattie, 2012:126-127). Goal setting, self-monitoring, concentration, and practise are the most effective strategies. The traditional method of providing multiple opportunities for the learner to master the skills are effective (Hattie, 2012:126-127). Formative assessment (see section

2.10.2) provides feedback to learners on their skills and sees learning taking place through the eyes of the learner.

Feedback, the effect size being 0.75 (see Figure 2.14), seems to be one of the most powerful interventions for raising attainment. For feedback to be effective, the teacher must convey the learning intentions and success criteria to learners. The skills acquisition required to achieve the goals must be encouraged (Hattie, 2012:126-151). Feedback must be ongoing and direct the learner towards the goal of the lesson. Effective feedback:

- focuses on the task;
- is elaborated;
- is provided in bite-sized portions;
- is clear and specific;
- is easy to understand;
- is objective;
- emphasises learning intention and success criteria;
- is provided after the learner's attempt (Hattie, 2012:126-152-153); and
- promotes effective error detection skills leading to extensive self-feedback by the learner (Hattie and Timperley, 2007:86).

Effective feedback could be done in conjunction with class discussion, which is an effect intervention as discussed in section 2.11.2.

The lesson concludes when the teacher reviews the impact the lesson had on learners concerning learning intentions and success criteria. This is considered by asking whether learners participated, were engaged, and how well they progressed (Hattie, 2012:163-164). The teacher needs to think about what could be done to assist learners who did not meet the success criteria. Apart from evaluating the effectiveness of the lesson, the teacher needs to evaluate the efficiency of the lesson (Hattie, 2012:163-164). Efficiency is evaluated regarding the time taken, effort and resources used, error rates, and prospects for further improvements (Hattie, 2012:163-164). Effectiveness and efficiency are evaluated through the eyes of the learner.

Visible learning has widespread verifiable research identifying the most effective interventions to raise attainment. Due the socio-cultural nature of this research, the researcher only considered the effect size which had the greatest impact on attainment, was metacognitive by nature and affected the learners' motivation.

2.12 Conclusion

Research has shown that promoting metacognitive skills is key to achieving success in science and higher-order thinking in general (Holtman & Rollnick, 2010:109; Thomas, 2012:132; McGunnis & Stephanich, 2007:307; Zohar & Dori, 2012:189-192). It is thus imperative that teachers support metacognitive development to improve attainment in South African Physical Science classes. It is not within the financial capabilities of the South African Department of Education to solve all the issues surrounding the costs of education. The Department does nevertheless have the capability to promote metacognitive awareness nationally to improve attainment, despite not having the resources to overcome the poverty and social inequality remaining due to the ripple effects of Apartheid (Hamburg, 1997:110).

The models and theories discussed in this chapter are invaluable in improving attainment in physical science. It is a matter for further investigation to determine whether metacognitive strategies are promoted and effectively utilised during problem solving and scientific enquiry (see Chapter 5). Chapter 3 describes the socio-cultural, aspects of metacognition when studying a western science.

CHAPTER 3

LITERATURE REVIEW: CULTURAL IMPLICATIONS OF METACOGNITION AND CULTURAL CONFLICT FOR NON-WESTERN LEARNERS STUDYING SCIENCE

3.1 Introduction

Chapter 2 focused on detailed studies of metacognition and its importance in problem solving in Physical Science. This chapter looks at the cultural factors which affect metacognition and how this impact on the South African indigenous learners studying science. The focus is on the socio-cultural theory and the impact of Western science on non-Western societies and its effect on metacognition. Not much research has been done on cultural influences on metacognition; therefore the researcher attempts to use the socio-cultural theory to support the cultural aims of this study. Figure 3.1 shows the breakdown of this part of the literature review.

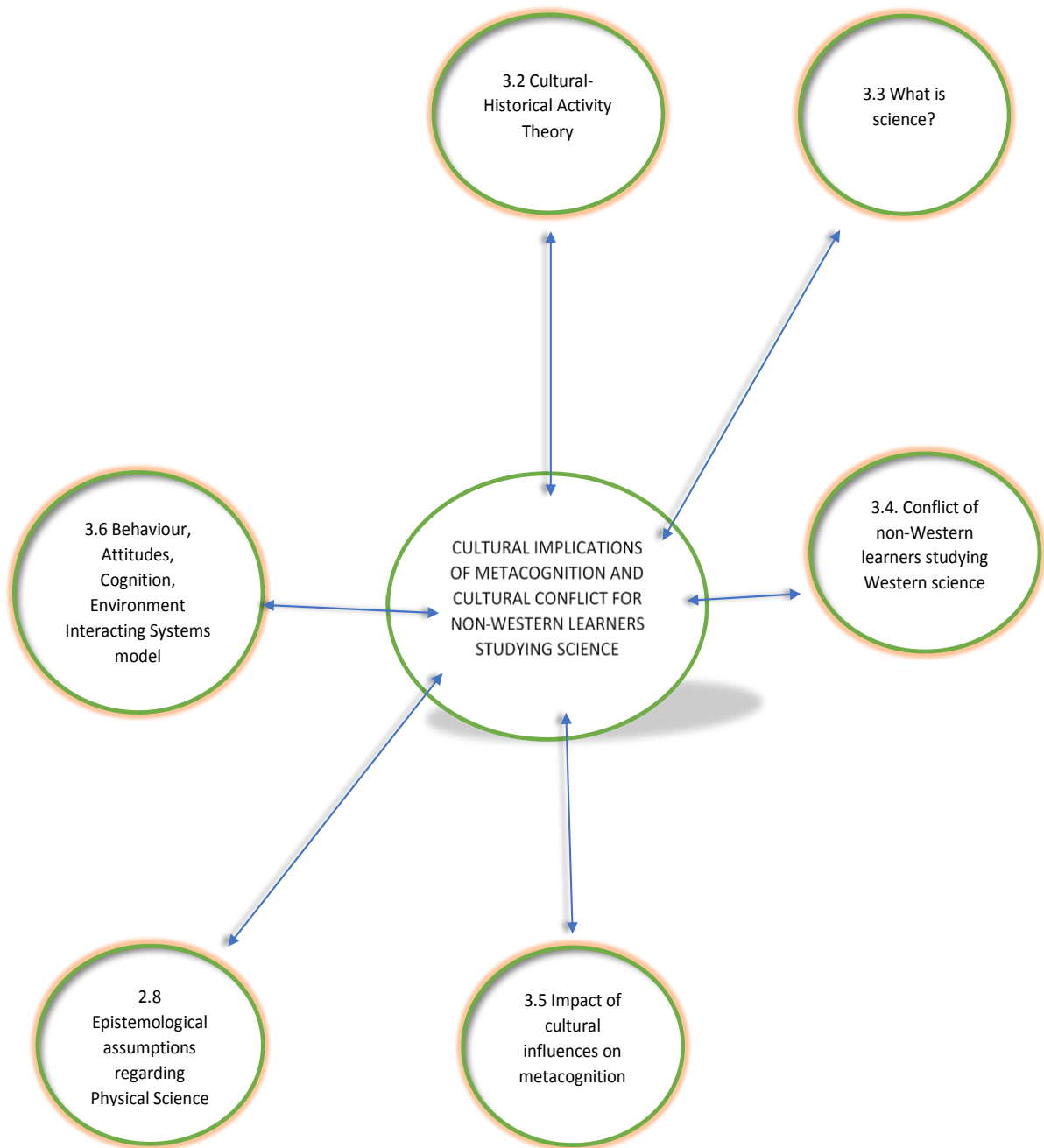


Figure 3.1: Breakdown literature review of cultural influences on metacognition and studying science

3.2 Cultural-Historical Activity Theory

Human behaviour is dependent on culture and varies between historical periods (Rogoff, 2003:80-81; Van Oers, 2008:4). Vygotsky's (1983:145) genetic law of mental development suggests the cultural development of a child takes place initially on a social level, followed by the psychological level. As discussed in section 2.1.2, Vygotsky's (1983:268) ZPD states that what a child can do with social interaction it

can do independently at a later stage. All high-level thinking originates from social interaction between individuals (Vygotsky, 1978:57). The work pioneered by Lev Vygotsky and Alexi Leont'ev on the socio-cultural theory of learning was expanded to CHAT by Yrjo Engeström (Sannino et al., 2009:xiii). This researcher views culture as one of the key components in education and will attempt to add to the limited work done on the cultural influence in the study of metacognition.

Lev Vygotsky's thinking is considered to be first-generation activity theory, and studies by Alexi Leont'ev are considered to be the second-generation activity theory. Vygotsky's work on social constructivism with respect to the ZPD was discussed in section 2.9.2. Engeström's work is known as third-generation activity theory (Yamagata-Lynch, 2010:23) and applies Vygotsky's theory to the modern-day context. Alexi Leont'ev's research stressed the collective nature of the human activity (Yamagata-Lynch, 2010:23). Engeström's activity systems focus on specific traditional practises, goals, written and oral communication, and social structures (Cole and Engeström cited in Engeström, 2005:307-308). CHAT is essential in this study because it focuses on the theory of knowledge and the creative development of the human mind (Ilenkov and Davydov cited in Engeström 2005:307-308). Including the activity system of CHAT in the study of metacognition is a creative way in studying metacognition in a modern-day socio-cultural context. The impact of rules, community, division of labour, and socio-historical characteristics of thinking were acknowledged by Yrjo Engeström but were not included by Lev Vygotsky (Yamagata-Lynch, 2010:23).

This research is viewed from a socio-cultural perspective, which is a determining factor in the effectiveness in promoting metacognition effectively (see section 1.4.2). The wide socio-cultural nature of learning, combined with the CHAT principles below (see Figure 3.2), leads to the basic assumption that learning is constructed through socio-cultural activities (see section 2.2.2. and 2.9.2). The activity is inspired by desire driven by general motivation (Montoro & Hampel, 2011:122). Motivation of learners as discussed in section 1.4.2. plays a significant role in the metacognitive process (Efklides et al. 2001:303; Hartman, 2001:199; Larkin, 2009:85; Myers,

2008:37). The general motivation, in this case, is the drive to utilise metacognitive skills in the Physical Science classroom by socio-cultural means.

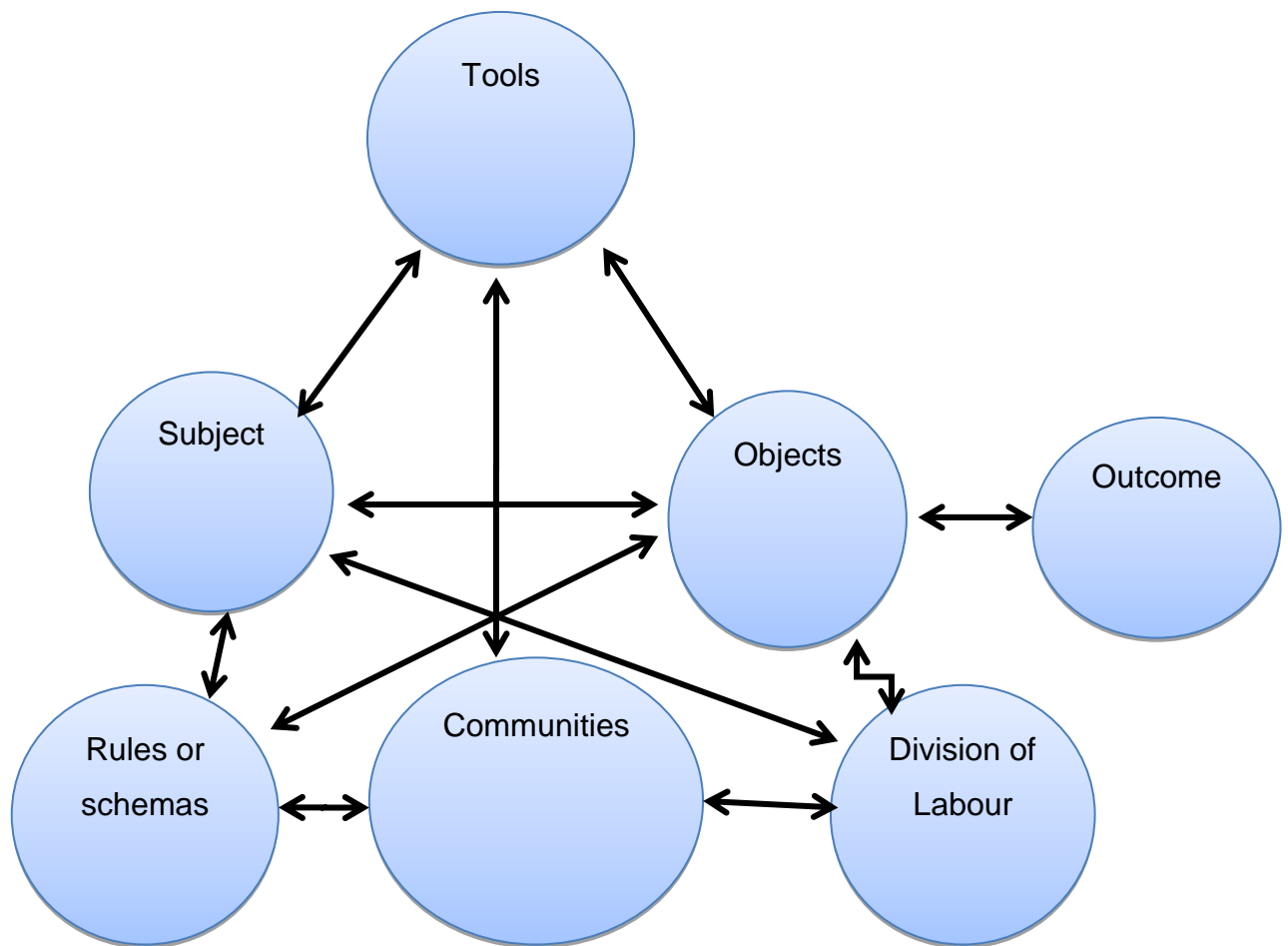


Figure 3.2: Cultural-Historical Activity Theory Diagram (adapted from Engeström, 1987:78)

Referring to Figure 3.2. the term object simply means the motive or the goal of the activity. More so it is the glue which holds the other elements of the activity in place (Yamagata-Lynch, 2010:17). It is interpreted as the motive of the socio-cultural activity. The tool which is also referred to as the artefact is the pre-existing knowledge and the social interaction of the individuals within the activity. Vygotsky promoted the critical connection between an individual's thought processes and that individual's interaction with cultural, historical, and formal settings (Rogoff cited in Yamagata-Lynch, 2010:16). During the promotion of metacognitive awareness, the metacognitive knowledge and regulation is considered to be the cognitive thought

process which will interact with the learners' history and cultural values within the classroom environment.

Figure 3.2. show the interactive elements within the activity theory linking the multi-dimensional nature of the socio-cultural thought process. The individuals find meaning within their socio-cultural environment through mediating collaboration of pre-requisite knowledge and the social interaction. Within the classroom environment the teacher utilises the socio-cognitive tools to promote the goal. Figure 3.2. shows the two-way interaction of the tool and the object. During problem solving Vygotsky refers to this mediating interaction as the ZPD as defined below:

“It 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” (Vygotsky 1978:86).

The ZPD is where the social and independent actions of the cognitive process merge to create effective learning during problem solving. The ZPD is discussed in greater detail in part 2.4.1 and 2.9.2 of the study. The activity theory encompasses a system of structure, inward transformations, discussions, development which is self-regulated, and is driven by goals and motivations in which people choose to play a part (Leontiev, 1974:10). Within the activity theory there is opportunity to cognitively develop, plan goals, and persevere through motivation. These characteristics of the activity theory align itself with this study in the sense of its focus on the socio-cultural nature of higher ordered thinking, cognitive goal setting, and motivation.

The individuals involved in the activity are the subject. The subjects learn new cognitive tools during their socio-cultural activities within their ZPD (Yamagata-Lynch, 2010:16). During explicit metacognitive instructions the learners develop their metacognitive awareness in a socio-cultural classroom environment. New skills could develop during the activities. The division of labour exists within the ZPD, where the less able learner socially interacts with the more able learners and the

teacher (see section 2.9.2.). Figure 3.2. shows the two-way interaction of the division of labour with the object and community. The subjects are goal driven and motivated during the activity and interact with the learner and teachers within the classroom environment.

The objects, communities, and the subjects are governed by the rules or schemas within the socio-cultural environment (see Figure 3.2). These rules or schemas could be explicit instructions or tacit instructions. Tacit and explicit instructions with respect to the promotion of metacognitive awareness were discussed in section 2.4.4. The rules or schemas include the conflicting cultural rules versus the rules of science which will be discussed in part 3.4. of the study. When the study refers to science, it refers to the Western science. The next part of the chapter discusses what science is in context of this study.

3.3 What is science?

In order to understand the cultural implications of science, we need to ask ourselves; what is science? Some of the earliest scholars suggested the world is open to the brilliance of the human mind, while, others felt that the hidden depths of the world are beyond human comprehension (Pesic, 2000:2). Pesic (2000:2-3) views modern science as the experience at the heart of things, unlocking hidden secrets through experimentation. This quotation from Albert Einstein, cited in Saris (2009:9), provides a novel view of what science is:

“In the temple of science are many mansions, and various indeed are they that dwell therein and the motives that have led them thither. Many take to science out of a joyful sense of superior intellectual power; science is their special sport to which they look for vivid experience and the satisfaction of ambition; many others are to be found in the temples who have offered the products of their brains on this altar for purely utilitarian purposes. But there would still be some men, of both present and past times, left inside.”

Einstein suggests that scientists enjoy the challenges of research science and its practical implications because they are motivated to add to its theories. The object of the scientist as seen through the lens of CHAT is to further their intellectual

knowledge, make an impact in the development of science, better humanity, or to dedicate their life's work towards the study of science. Einstein uses "left inside" to refer to the self-motivated scientist Max Planck, who dedicated his whole life to seeking the unifying theory in science known as the "theory of everything" (Saris, 2009:9). However, many scientists study sciences for fun, while others want to produce new products or technology. The meaning of science thus varies, depending on what motivates the scientist to study science.

The point made by Einstein's quotation is that despite respecting the work done by scientist whose effort is for personal gain and enjoyment, greater acknowledgement must be given to the selfless work done by other scientists whose focus is for the betterment of humanity. Teachers and learners should be aware of the inclusive nature of science. Teaching the motives of scientists in conjunction with teaching what science is provides learners with a broader perspective in their study of science. This also offer learners with greater options when considering their future study in the field of science.

One key assumption underpinning the birth of Western science is the law of parsimony. During the renaissance period William of Occam quoted the following:

"Frustra fit per phuraqued fieri potestest per" translates to "It is vain to do with more what can be done with less" (Krebs, 2004:145).

Contemporary scientists and mathematicians interpret this as simplest solution which fits the observation and facts of the problem should always be selected. A second key assumption grounding the birth of Western science is universality (Gasche', 2009:76). Universality refers to universal science which is objective (Gasche', 2009:121). This means that a scientific law or theory is universal and the experiments to prove it will yield similar results anywhere in the universe provided the standard conditions are met.

Science in the modern context is an enquiry process which reveals valid results that surpass cultural contexts and is free from political and cultural values (Harding &

Figueroa, 2003:1). It is suggested that embedded political and cultural values in science hinders progress and harm society (Harding & Figueroa, 2003:1). Harding & Figueroa (2003:1) refers to the misuses of scientific technology and application which causes environmental destruction, isolation of labour, racism, and sexism as “bad science” and suggest that the philosophy of science and the ethics of science should be addressed separately. From this viewpoint one questions whether removing the social and cultural aspects of science is possible. If so, will this prevent cultural conflict within the study of science? This discussion is carried on to section 3.4. of the study.

Scepticism about separating the social, cultural and political views within science is debated. The process in which scientists theorised nature, hypothesised and concluded results were determined by the ontology, epistemologies, and cultural views they brought with them (Quine cited by Harding & Figueroa, 2003:2). Some scholars have shown that culture within science have benefitted its advancement (Harding & Figueroa, 2003:2). It is difficult to alienate the socio-cultural viewpoint with science due to the globalisation impacting on the increase interest in cultural identity (Harding, 2003:49). In modern society globalisation has generated a huge interest in scientific and technological knowledge and practises. For example, in South Africa cars are associated with the country which produces them. BMW and Mercedes are prominent for their German engineering in producing high performance luxury vehicles. Toyota and Mazda are renowned for the Japanese engineering in producing value for money cars which are reliable.

The global movement has promoted the establishment of intellectual right for indigenous knowledge (Harding, 2003:49). The socio-cultural impact on science cannot be ignored. Popular literature, supported by symposiums and academic research have emphasised multicultural and postcolonial science (Harding, 2003:50). The way scientists interact with nature determines their understanding (Harding, 2003:50). It is safe to say scientists from different cultures view the natural environment of scientific method differently. This could yield positive rewards, because different viewpoints add to the clarity of scientific theory and provides an

alternate perspective. Mainstream scientists accept the advancements of science by non-Western cultures such as Egyptians, Arabians, Chinese, and Indian.

Science as we understand it has been shaped by the pursuit of man to understand the natural world through observation, testing, and proving of ideas, and has evolved to become part of the cultural heritage of all nations (DBE, 2011:8). Science has certain methods of enquiry and investigation, such as formulating hypotheses, designing and carrying out experiments to test the hypotheses and repeated research. The procedures and conclusions are carefully inspected and argued before they are acknowledged as valid (DBE, 2011:8). In this research, the term science refers to Western science. It is categorised as components, namely, physics, chemistry, biology, geology, anthropology, psychology, cosmology, botany, zoology, etc. (Lindberg, 2007:2). It is a formal system of factual and theoretical claims expressed mathematically wherever possible and is used to describe the physical world (Lindberg, 2007:1) by stating hypotheses that are then tested scientifically (see section 1.2). The socio-cultural component of science will be considered in the study. The next section focuses on the cultural conflict non-Western learners experience in studying Western science.

3.4. Conflict of non-Western learners studying Western science

The grouping of Western versus non-Western is over-generalised (Rosenthal, 1996:68). People in any society show substantial differences in their beliefs, and it is wise not to stereotype people of any culture (Araujo, 2016:162; Kirwan and Power, 2013:17; Rosenthal, 1996:68). For example, the United States of America is considered Western; however, the Native Americans are more non-Western than Western (Rosenthal, 1996:68). Research has shown the Native Americans' non-Western culture conflicts with their Western science education in the following ways (Rosenthal, 1996:68-69):

- Under four percent of university graduates earn degrees in Physical Science, and around six percent earn degrees in biological sciences;
- Learners are absent from class and examinations because of tribal and family obligations;

- Learners are not assimilating into Western society which is needed to succeed in college life;
- The particular non-verbal behaviour (eye contact, hand gestures, facial expression) of Native American learners;
- Native American beliefs of harmony with nature conflict with Western science practises.

The conflicts experienced by South African indigenous cultures studying Western science compares to the problems faced by the Native American learners. The poor success by the Native American learners in studying Western science at school level and tertiary level is comparable to the South African indigenous learners (see section 1.1.). South African indigenous learners, similar to Native American learners, are very tribal and take family obligations seriously. It does stand to reason that both groups of learners, despite living in different continents, find it difficult to be successful in Western science.

There is extensive literature that explores the way in which the culture of learners affect how they approach the learning of Western science (Aikenhead & Jegede, 1999:269; Cobern, 1996:287; Sutherland, 2005:597). Western science education contains its cultural assumptions about the nature and theories, and laws of science (Baker & Taylor, 2007:702; Cobern, 1996:287-288; Sutherland, 2005:597). Deductively, it is acknowledged that the study of Western science requires learners to have some understanding of the methodologies Western science embraces to understand and explain the universe or their transition from home to the science classroom could be challenging (Sutherland, 2005:597). However, in general non-Western learners do not readily appreciate the Western science worldview (Shizha, 2011:15-16; McKinley and Stewart, 2009:52; Sutherland, 2005:597). A common worldview across many non-Western cultures tend to be holistic and spiritual (Hines, 2007:107; Sutherland, 2005:597).

Aikenhead & Jegede (1999:269) termed cognitive clashes between non-Western cultures, the lived-world, and Western science, as collateral learning. A major factor in collateral learning in Western science education is the acknowledged feeling that it

is an imported culture to non-Western learners (Aikenhead & Jegede, 1999:269). Collateral learning triggers a need to develop culturally accommodating science programmes and teaching methods to decrease the exclusion felt by non-Western learners (Aikenhead & Jegede, 1999:269; Hassard & Dias, 2013:70; Gough, 2008:42; Jegede, 2011:128).

The work accomplished by Jegede (2011:128) on West African societies states that a large proportion of learners perceive science as something magical which conflicts with the embedded views of Western science. Furthermore, Jegede's (2011:128) research suggested that:

- African societies' socio-cultural background has a greater influence on their science education than the science content;
- African learners' reasoning is based on non-Western worldviews which conflict with the nature of science;
- Cultural influences cause learners to be selective when making observations during the science lessons; and
- Rural communities explain natural phenomena in a way which Western science deems irrational.

Research carried out on the implementation of indigenous knowledge in science lessons in Lesotho brought about balance in collateral learning (Liphoto et al., 2008:267). A study of the teaching of lightning phenomena showed that initially, learners had their cultural perception of lightning, which hindered a conceptual understanding (Liphoto et al., 2008:265). Notwithstanding this initial obstacle, some learner's responses were in line with a scientific theory (Liphoto et al., 2008:266). The need to link Western science theory with traditional wisdom motivated learners to rationally conceptualise the scientific theory of lightning (Liphoto et al., 2008:267). This was supplemented by social interaction with experts in traditional knowledge and elders taking part in the lesson (Liphoto et al., 2008:267). Western science education has a better chance of success if non-Western culture were taken into consideration during the teaching and learning process (Hassard & Dias, 2013:70; Gough, 2008:42; Jegede, 2011:128). A culturally inclusive science curriculum is a solution to this issue as it values indigenous knowledge which relies on observations

in a naturalistic environment, it includes principles of equality and respect, underpins multiculturalism, and antiracist education (Web, 2012:90).

During the science lessons there will be a struggle between indigenous culture and the culture of Western science. Aikenhead and Jegede (1999:269) describe those learners' everyday life experiences and their science classroom experience as "cultural border-crossing". Using their declarative, procedural, and conditional knowledge within their science lessons, the indigenous learners have to ignore some of their cultural values. This requires motivation and flexibility of the learner to successfully experience the culture of science within the classroom. However, the problem lies out of the classroom, when the learner switches back into accepting their cultural beliefs. The learner is deprived of experiencing science in the real world due to switching from the culture of Western science and their traditional culture during border-crossing.

Further to culture, the challenges of scientific language and the non-Western language are sometimes a struggle in science (Aikenhead & Jegede, 1999:283; Sutherland, 2005:595). Section 1.4.3.2. gives an example of how scientific terminology cannot be directly translated into isiZulu. Many of the scientific terminology comes from Western culture and the traditional understanding of the words are be easier for Western learners to comprehend, whereas as non-Western learners may find it difficult to interpret. When the learner's language and cultural conflict of Western based values embedded in the science curriculum, it may cause difficulty in advancing their metacognitive knowledge in science.

Aikenhead and Jegede, (1999:283-284) makes reference to support the idea of a holistic view of science where integrating all indigenous knowledge with scientific knowledge as compared to multiple-world outlook which could demotivate the learner. The multiple-world outlook hinders the development of declarative knowledge in science because the learner does not relate science to their lived experience. Research done in culturally diverse schools in California concluded that 90% of learners are limited in science attainment because of the conflict between the micro-culture of their family and the micro-culture of Western science in school

(Aikenhead & Jegede, 1999:269). The holistic view allows the learner to appreciate the idea of their multiple worlds and resolve the conflicts between those worlds (Aikenhead & Jegede, 1999:283-284). This in turn may result in the learners improving in their metacognitive knowledge skills in science by improving the motivation dimension of metacognition (see section 2.5.1.).

3.5 Impact of cultural influences on metacognition

Success in learning is determined not only by genetics but also by the interaction between cognitive, affective, and social factors (Helms-Lorenz & Jacobse, 2008:14; Kruglanski et al., 1998:77; Thomas, 2002:242). Learners could be encouraged to conform to the dominant and hegemonic beliefs held by a society which affect their learning (Thomas, 2002:242). Self-concept, motivation, economic factors, and family influences provide success in learning (Hartman & Glasgow, 2002:95; Helms-Lorenz & Jacobse, 2008:14). Metacognitive abilities and intelligence are also culturally driven. Metacognitive skills can positively influence learners from different cultural backgrounds provided their cultural barriers are taken into consideration during the teaching and evaluation process (Hacker & Bol, 2004:292-293; Helms-Lorenz & Jacobse 2008:15; Kruglanski et al., 1998:77). Culture affects metacognitive skills by influencing patterns of relationship and dejecting certain theories and models (Helms-Lorenz & Jacobse, 2008:14).

Research by Helms-Lorenz and Jacobse in the Netherlands (2008:35-36) on the metacognitive abilities of native Dutch and migrant learners of similar intellectual ability levels concluded that native learners reach their true potential more than migrant learners do and tend to have slightly higher scores. This was due to the migrant learners' lack of experience in the Dutch language, cultural values, and inhibiting acculturation strategies (Helms-Lorenz & Jacobse, 2008:35-36). A specific difference in metacognitive skills was found across cultural groups (Helms-Lorenz & Jacobse, 2008:36). The term metacognitive skills refer to metacognitive regulation and metacognitive knowledge (see section 1.4.3.1 and 2.3.4).

The second finding among the native group was a positive correlation between the high-ability learners' results and their metacognitive skills, but this relationship was not transferable to migrant learners of similar ability. The native learners of the same ability levels as the migrant learners had higher metacognitive abilities. However, where low-ability learners had higher levels of metacognitive skills, the benefit was seen across the cultural groups as improved attainment compared with learners with similar abilities but with low levels of metacognition (Helms-Lorenz & Jacobse, 2008:7). This research further attempt to study the relationship between culture and metacognition.

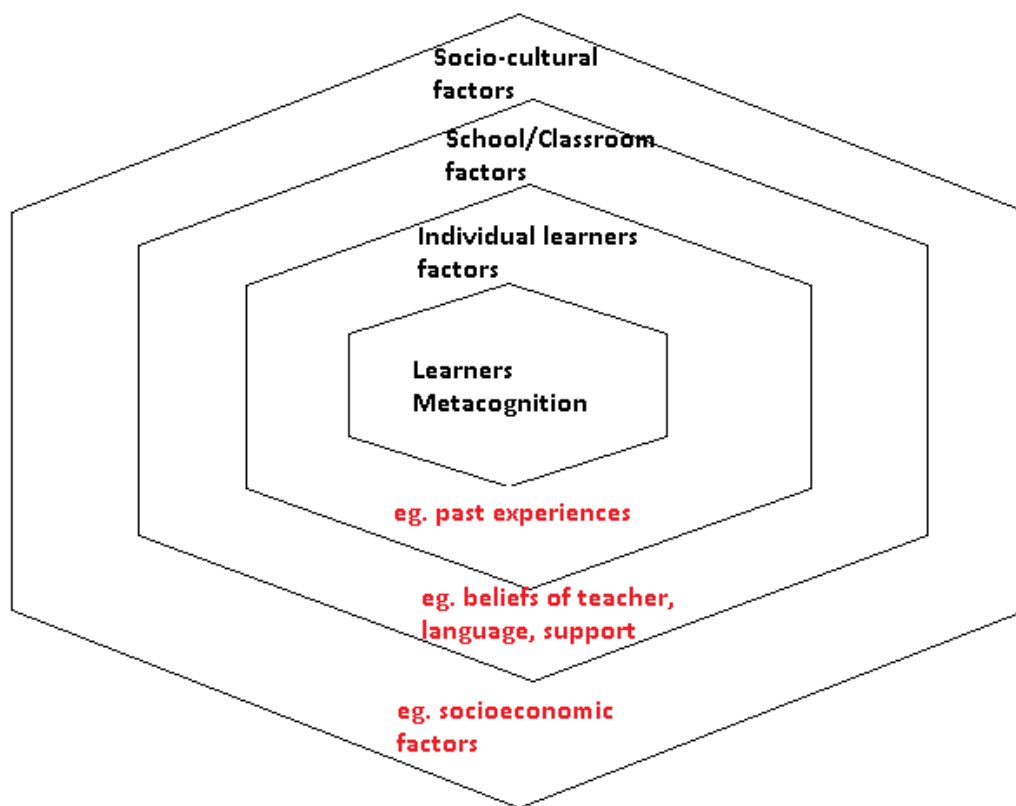


Figure 3.3: Metacognition as socio-culturally embedded (adapted from Thomas, 2002:241)

Figure 3.3 shows learners' metacognition within the socio-cultural environment and highlights the factors that affect learners' metacognition. The learner's individual factors are those that the learner experienced in the past, such as their learning habits and the impact on their assessment results (Thomas, 2002:240). Studies by Thomas (2002:240) suggest that the school and classroom environments can drive

learners to greater efforts to achieve academic success instead of valuing critical thinking. This becomes socially acceptable because learners are then examination-driven rather than focused on critical thinking skills (Thomas, 2002:240). Furthermore, learners' lack of metacognitive skills was found to be a consequence of the socio-cultural learning that learners were exposed to (Thomas, 2002:240).

The negative impact on teaching towards examination hinders the development of higher order thinking. Teachers whom focus more on doing well in the examination instead encouraging key metacognitive skills and critical thinking during their lessons restrict the progress of metacognitive awareness. This study supports holistic education which promotes metacognitive awareness.

Studies completed by Kruglanski and Nelson (1998:150) take social representation into account by using the following examples: German learners possess more advanced techniques in information retrieval than American learners; Western culture holds that memory declines with age whereas the Chinese culture does not have such stereotypes. Some stereotypes distinguish between the cognitive abilities of groups of people: Men are better in mathematics than women; general intelligence is lower among African American than American learners of European extraction (Kruglanski & Nelson, 1998:150). Social representations and cultural views have significant consequences for the metacognition of learners (Kruglanski & Nelson, 1998:150). These socio-cultural stereotypes are engrained in the mindset of society and hinder the promotion of metacognitive awareness. As discussed in section 3.4. the researcher feels that promoting the holistic view where learners accept the notion that the cultural construct of multiple worlds and resolve the conflicts within the compartmentalisation of those cultural worlds to achieve metacognitive awareness.

The cross-cultural research focused on schooling sheds lots of light on cognitive development. Studies have shown that despite the structure of memory being a universal cognition, the controls for cognition is socio-culturally driven (Kurtz, 1990:184). Universal cognition refers to the structural mechanisms of memory as being similar to all individuals, however, it is influenced by socio-cultural factors. Formal education and living in cities impact on the growth of control

processes in cognition in a positive way (Kurtz, 1990:184). Significant amounts of research on mathematical achievement showed that Japanese learners outperformed USA learners (Kurtz, 1990:184). Kurtz (1990:184) concludes that the results obtained were due to socio-cultural factors such as the differences in parenting techniques, school characteristics, and the culturally related principles and views of the two countries. According to Kurtz (1990:184), Japanese mothers

- have a firmer conviction in personal flexibility than American mothers;
- are enthusiastically involved in their children's educational quests;
- demand diligent learning habits from an early age; and
- regularly equate their triumph to the educational success of their child.

Furthermore, Japanese children spend more academic time in school, and the values learnt from Confucian and Buddhist philosophy encourage growth in knowledge (Kurtz, 1990:185). A very crucial variable that was not considered in Kurtz's (1990) research is that most Japanese learners attend after-school cramming classes for mathematics throughout the year. This is a significant variable for learners producing such high mathematics results in Japan and should be considered when comparing the mathematics results between Japan and the USA.

Research studies in USA, Germany, and India identify metacognition as a successful predictor of learners' performance (Kurtz, 1990:192). Among the learners from the USA, the acknowledgement was a vital part of successful performance, but this was not the case among German learners (Kurtz, 1990:192). The difference in the findings was attributed to the variance in the home and school environments (Kurtz, 1990:192). In India, the home environment contributed to learner's performance even when the socio-economic status of learners was limited (Kurtz, 1990:192). This refers to the financial background of the learner. Although the home and school environment impact largely on the success of the learner some communities, this research focuses on the significant impact which metacognition brings to the learners' success.

Table 3.1. below uses TIMSS for 2011 to describe the cultural influence of the top ranked countries and track their progress four years later. This was done to see the

consistency of the top ranked countries. The rationale for using TIMSS data in this study was highlighted in section 1.1.1. As discussed in section 1.1.1. the credibility of TIMSS lies in mathematics and science in their different content areas eliminating the bias of national testing which focuses on a narrower depth which is promoted within the curriculum. Therefore, TIMSS in theory measures the success of a national educational system to drive the mathematics and science curriculum (see section 1.1.1.).

Table 3.1 Top-performing countries in TIMSS 2011 (Adapted from TIMSS, 2011:7)

Top-performing countries in TIMSS 2011	
Fourth Grade	Eighth Grade
Singapore	South Korea
South Korea	Singapore
Hong Kong SAR	Chinese Taipei
Chinese Taipei	Hong Kong SAR
Japan	Japan

Table 3.1 shows that East Asian countries continue to be the top performers in science and mathematics according to TIMSS (2011:11). This further attests to the major role that culture plays in learning. The TIMSS tests in science and mathematics were taken by more than 70 countries around the world (TIMSS, 2011:27). European countries such as Northern Ireland, Belgium (Flemish), Finland, England, and the Russian Federation featured among the top ten performers (TIMSS, 2011:7). The problems shown up in the TIMSS tests included cognitive domains of knowing (35%), applying (40%), and reasoning (25%) (TIMSS, 2011:6). As discussed in section 2.1.1, the questions regarding cognitive domains require the direct application of metacognitive procedural and conditional knowledge skills.

Significant studies highlight the fundamental importance of a supportive home environment in influencing learners' attainment at school. TIMSS (2011:173) has found a solid, positive correlation between TIMSS scores and learners' home environments that promote learning. Research regularly reveals a high positive correlation between attainment and socioeconomic status (TIMSS, 2011:174). TIMSS also found a strong, positive correlation between parents' academic level and their children's educational achievement. Learners with the top TIMSS achievements attend schools that accentuate academic achievement, promoted difficult academic goals, effective teaching, and learners that are self-motivated with parental support (TIMSS, 2011:16). Four years later, the TIMSS results revealed that East Asian countries still dominated the top three spots in science, with Singapore ranked first, Korea ranked second, and Japan ranked third (Gurney-Read, 2015).

3.6 Behaviour, Attitudes, Cognition, Environment Interacting Systems model (BACEIS)

Research on improving cognition ignores the effects of both the affective domain and environmental factors (Hartman & Sternberg 1993:401). The affective domain includes factors such as motivation, attitudes, and values (Hartman & Sternberg's, 1993:401). Hartman and Sternberg's (1993:401) BACEIS model (illustrated in Figure 3.4) promotes improvement in thinking and includes internal and external factors affecting thinking and learning skills (Hartman & Sternberg, 1993:402).

The internal factors are cognitive and affective subcomponents, and the external factors are academic and non-academic subcomponents of learning (Hartman & Sternberg, 1993:402). These factors also include teacher physiognomies, content by subject area, school and classroom atmosphere, and instructional practises (Hartman, 2001:xi). Physiognomies refer to the teachers' facial expressions during the teaching and learning process. The cognitive component of BACEIS includes metacognition, cognition, and learning strategies.

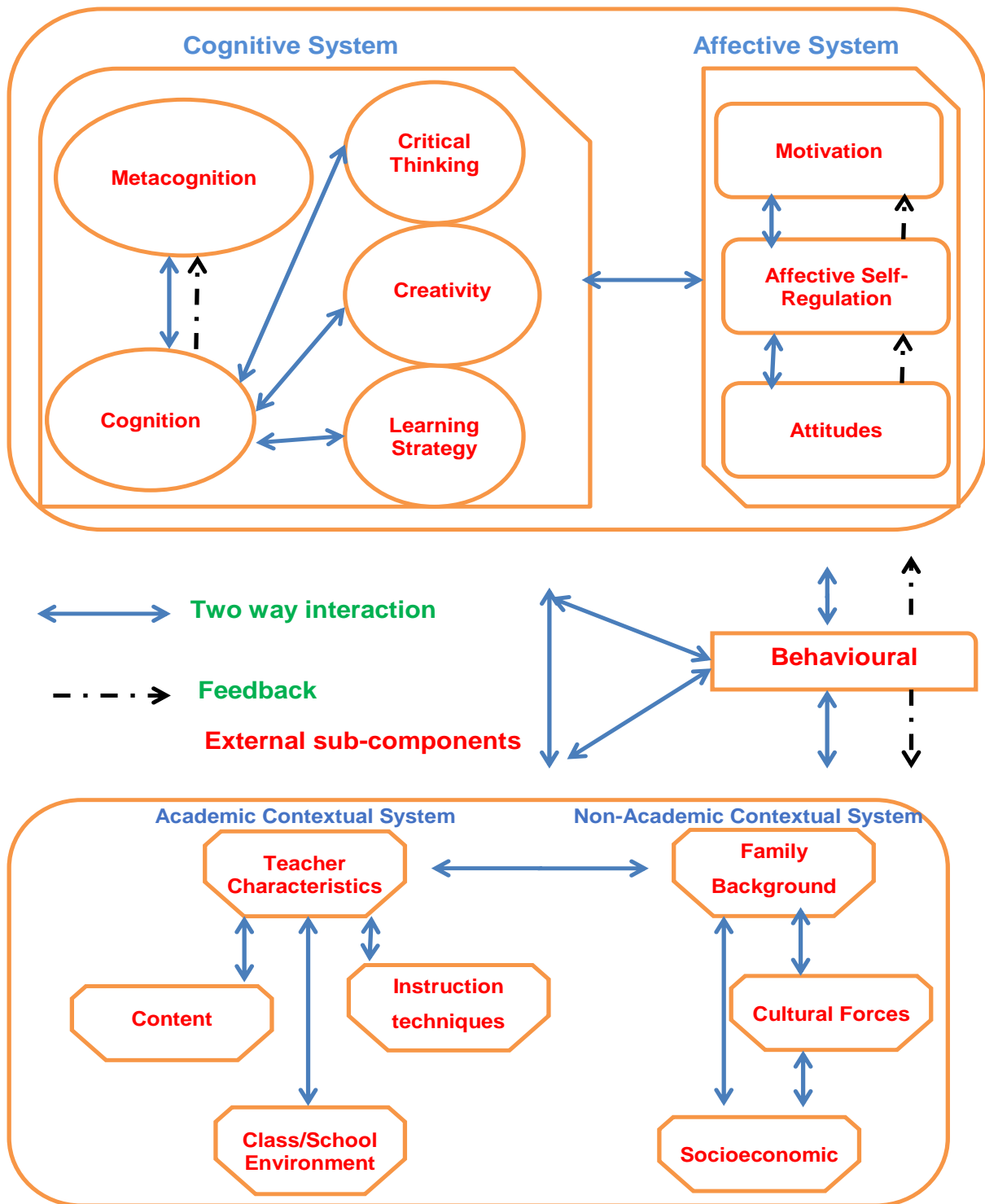


Figure 3.4: BACEIS Model of Improving thinking (adapted from Hartman, 2015:141)

Behaviour, affective system, cognition, and environment complement each other to affect thinking skills inside and outside school (Hartman, 2001:xii). Socio-economic factors, family background, learner's language, and cultural factors are also considered in the BACEIS model as illustrated in Figure 3.3 (Hartman, 2001:xv).

Figure 3.4 shows the two-way interaction between metacognition and affective self-regulation, which is required to best enhance intellectual performance (Hartman, 2015:140). For example: regulating one's motivation to solve science problems increases learners' eagerness to use metacognitive and cognitive strategies in their study (Hartman, 2015:140). This shows the multidimensional nature of metacognition and its connection to motivation.

Figure 3.4 illustrates the two-way interaction between academic and non-academic subcomponents to improved thinking. For example, a learner coming from a supportive family background, who has a culture that promotes a pursuit for knowledge and has the finance to go to a school that has good resources are subcomponents of external factors that complement each other to enhance intellectual knowledge (Hartman, 2015:140). The behaviour system in Figure 3.4 refers to the consequences or rewards of successful interaction between external and internal sub-components.

The BACEIS model requires reflection in the form of feedback between behaviour and the internal and external components. Feedback also occurs between metacognition and the cognition subcomponents, as well as interaction with the affective system as seen in Figure 3.4. The BACEIS model is intended to help improve the cognitive and affective components of the learner. This leads to learners becoming independent and self-directed learners. The external and internal subcomponents continuously interact with each other (Hartman, 2015:139).

3.7 Summary

When viewing science through the lens of CHAT the socio-cultural influence must be taken into consideration. Chapter 3 has highlighted the difficulties non-Western

learners studying science. The non-Western learners experiences cultural conflict between their traditional culture and the cultural values embedded within Western science. The experience of the non-Western learners is labelled as border-crossing and the switching between their traditional culture and the Western science culture could have significant effects in their learning. The research points to the holistic view of science where integrating all cultural ideas with scientific knowledge as compared to compartmentalising the two cultures experienced by the learner. This is the core aspect of this study together with promotion of metacognitive awareness.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

Chapter 1 provided a brief background of the state of Physical Science in the South African classroom and introduced the concept of metacognition. The scope and direction of the research were defined. Chapter 1 and Chapter 2 provided the theoretical framework for the research, focusing on the aims and objectives discussed in section 1.6. They give the reader a clear picture of the research approach.

Chapters 2 and 3, the literature review, provided a contextual viewpoint focusing the key research questions on constructing a metacognitive model to enhance Physical Science attainment in South Africa. The literature review provides an in-depth evaluation of academic articles, research, and books written about the metacognition, Western science, indigenous South African culture, cultural attitude, and metacognition in the South African Physical Science curriculum. This was summarised by citing relevant work by various authors and providing an overview of the current situation of metacognition in Physical Science. The literature review gave a clear idea of why research in this field is important.

Chapter 4 provides an in-depth description of how the research was done. This led to the justification of entirety of findings and confirmed the validity of data. This chapter delineates the research approach according to the following topics: the context of the study, CHAT as a research lens, design of empirical research, mixed methods research approach, quantitative research and qualitative research, ethical aspects, and data analysis procedures. The focus in Chapter 4, the research methodology, should convince the reader of the validity, reliability, and explanation of the results.

4.1.1 Context of the study: the development of science education in South Africa

Throughout the history of the development of science education in South Africa, the South African indigenous learners were the most disadvantaged of all the racial groups because they were politically and economically oppressed (Hewson, 2015:22; Jansen & Taylor, 2003:3; Sichone, 2003:470-471). The negative effect of oppression on the success of indigenous science learners in South Africa becomes apparent when we look at the science results (Barry, 2014; HSRC, 2011:9; Reddy et al., 2015:VI).

European colonies in South Africa began engaging scientific research in South Africa in the early nineteenth century (Sichone, 2003:470-471). The teaching and investigative facilities were set up to cater for the financial and cultural needs of the settlers (Sichone, 2003:470-471). The government hired scientists to modernise colonial society (Sichone, 2003:470-471).

Since 1826, the University of Cape Town has catered for the scientific training and research for English-speaking students; Stellenbosch University catered for the scientific training and research for the Afrikaans-speaking students since 1866; and Fort Hare College catered for the scientific training and research for the indigenous students since 1916 (Hewson, 2015:21; Sichone, 2003:470-471). The introduction of formal modern science to the native people in South Africa started more than half a century later but was short lived due to the rise of the National Party in 1948 and the introduction of the discriminatory policy of Bantu Education (Sichone, 2003:470-471). Verwoerd, the architect of the Bantu Education Act, prevented African intellectuals from fully participating in scientific research and development (Hewson 2015:22; Sichone, 2003:470-471). The apartheid government under Verwoerd maintained colonialist superiority by a parliamentary report in 1953 (Hewson, 2015:22) which stated:

“We must accept the non-European in South Africa, in his level of civilisation, is hundreds of years behind the European, and he can only insist on the same

privileges and rights as those enjoyed by Europeans in South Africa today when he reaches the stage the white man has reached."

Years after apartheid, the low-income levels of most indigenous people decreased even further (Hewson, 2015:35). In predominantly South African indigenous people's townships there is a lack of housing, water, and electricity, which directly impacts on the quality of education (Hewson, 2015:35). Indigenous learners feel the education which they receive is inadequate and has little relevance, and this makes it difficult to overcome the inequalities of the past (Hewson, 2015:35).

The heart of the post-apartheid education reform was the implementation of Curriculum 2005, which modelled the learner-centred approach of the outcome-based education principles (Jansen & Taylor, 2003:3). The outcome-based principles borrowed the best practises of schools in Britain, the USA, Australia, and New Zealand, and adapted them to suit the needs of South Africa (Lungu, 2001:96). Curriculum 2005 (DoE, 2002:22-23) was learner driven and aimed at

- promoting learner confidence in their enquiry about natural phenomena by investigating and problem solving in the science, technology, and environmental contexts;
- increasing scientific knowledge by interpreting and applying scientific, technological, and environmental knowledge; and
- understanding the interrelationships between science and technology, society, and the environment.

Curriculum 2005 was criticised for being inaccessible and difficult, expressed in language in which teachers were not adequately trained. There were large-scale inconsistencies in resources between a small number of advantaged schools and the many disadvantaged schools concerning the application of Curriculum 2005 (Jansen & Taylor, 2003:3). Both the methodology and application of Curriculum 2005 were problematic because it focused too much on skills and the progression of learning, without adequate attention to content and information acquisition (Hofmeyr, 2010).

By 2011, Curriculum 2005 became CAPS (Curriculum and Policy Statement) which concentrates on teaching basic knowledge alongside skills, but still had the learner-centred approach of Curriculum 2005 (Hofmeyr, 2010). The curriculum has been revised to make it easily accessible to teachers, such that every subject has comprehensive, concise CAPS, including details of what teachers must teach and assess (Hofmeyr, 2010).

Science as we understand it has been shaped by the pursuit of man to understand the natural world through observation, testing, and proving of ideas, and has evolved to become part of the cultural heritage of all nations (DBE, 2011:8). Despite scientific research methods being so vast and popular, CAPS (DBE, 2011:8) acknowledges that there are still many unanswered questions. People such as biologists, pharmacists, and archaeologists are seeking out the unanswered questions and writing them down before they are forgotten. Furthermore, CAPS (DBE, 2011:8) includes the appreciation by science of the indigenous knowledge of our forefathers, because modern scientists seek traditional scientific knowledge to use, preserve, and acknowledge.

CAPS (DBE, 2011:11) stress the following aims:

- Learners should be able to undertake scientific investigations, problem solving and use scientific processes and skills in assessing solutions;
- Learners should be able to plan and do simple practical work and solve problems using scientific processes;
- Learners should have respect for the living;
- Learners should have a comprehension of scientific, technological, and environmental knowledge to adapt to new situations;
- Learners should understand the use of science and indigenous knowledge in society and the environment.

CAPS science has a holistic curriculum that aims to develop responsible, lifelong learners in science, who will strive to lead socio-economic development and environmental management in South Africa (DBE, 2011:7).

South Africa is moving forward in developing a Physical Science curriculum which has the capability of producing world-class scientists (discussed in greater detail in 5.3.1). It cannot be ignored that the indigenous people in South Africa had approximately a hundred-year deficit in studying science and science research at university compared with the European immigrants. Their resources were by comparison limited. This inequality in science education was perpetuated by the implementation of Apartheid. Even though learners in this study did not live under the Apartheid era, the researcher feels that they are still affected by the ripple effects which have impacted on their poor Physical Science results.

This part of the chapter provided the reader of the past and present context of South African indigenous learners' science education. It gives a clear idea of how it has evolved from the Apartheid era to the post-Apartheid era. In section 1.1. of this study, the researcher refers to the production of many world-class scientists in South Africa. Achieving this goal requires an understanding of the history of science education in South Africa. Viewing the research through a CHAT lens makes it essential to understand the background of science education of the indigenous South African people. Finding answers by studying the historical development of science education in South Africa helps this research to make a significant and positive difference to the science and education community in South Africa.

4.1.2 CHAT as a research lens for the study

The activity theory (discussed in section 3.2) allows the researcher to examine the ability of learners to work together socially and culturally to create a successful learning situation using their metacognitive skills in the Physical Science class. The theory of CHAT is intertwined with the "object" of the teaching and learning process to promote higher order thinking within the Physical Science classroom.

Grade 11 Physical Science learners and the Physical Science teachers were the subjects (Engeström, 1987:78). Enhanced metacognitive skills in the Physical Science classroom are the goal of the study. Formulation of the objective, enhanced metacognitive skills in South African Physical Science classroom, was only done

after the data analysis phase (see Chapter 5). The researcher refers to this as workable solutions. The object is the product of achieving the goal, which in this case is workable teaching and learning strategies which improve learners' metacognitive skills and the learners Physical Science results.

Scaffold tools guide the learner's efforts, while instructional tools provide a clear explanation of the scientific theory (Clarebout et al., 2013:188). Scaffold tools refer to the brain, book, buddy, and boss system to problem solving (see sectioned 2.10.1, 2.10.2., and 2.10.5), eight phases in metacognitive skills training for Physical Science learners (see section 2.10.1), the learning pit (see section 2.10.4.), SEM (see section 2.10.3.), and the regulatory checklist (see in 2.10.3). The instructional tool refers to the learning intentions (see section 2.10.2., 2.10.5., and 2.11.3.), success criteria (see section 2.10.2., 2.10.5., and 2.11.3.), formal explicit theory (see 2.4.4.), and formative assessment strategies 2.10.4). The researcher evaluated the cognitive tools used by the teachers in the Physical Science classroom during the lesson observation part of the research (see below in section 4.5.5).

The rules or schemas include the conflicting cultural rules versus the rules of science found on the NCS of the Physical Science (DBE, 2011). The teacher and learner interviews (see section 4.5.6) shed some light on the cultural conflict when studying work, where the more able learners and their teachers guide the less able learners by taking the role of principal scientists. Social constructivist theory of learning during the teaching and learning process (see section 2.9.2) will be studied during classroom observations (see section 4.4.5). The implementation of indigenous knowledge within the Physical Science class will be analysed in the context of native culture in modern science.

Division of labour exists between junior scientists (learners) and principal scientists (the teacher and more able learners) (Yamagata-Lynch, 2010:2-3), whilst socially interacting in the ZPD during teaching and learning activities. In this research, the outcome focused on the effectiveness of using metacognitive skills during the problem-solving process. The community of focus consisted of learners in the

Physical Science classroom (see below section 4.4.2), and the way learners personalise and socially construct the meaning of cognitive tools.

With CHAT as a lens, the next part of this chapter focuses on an effective research methodology of the research and the underlying principles and application of the study.

4.2 Underlying principles and application of methods used in the study

The purpose of this section of the study is to describe the underlying principles and application of particular methods to identify, select, and analyse evidence applicable to the research problem. It provides the critical reader with an evaluation of the validity and reliability of the study.

The research problem comprised of evaluating the state of metacognition in a selected sample of South Africa's Physical Science classrooms. The study aimed to determine the Physical Science learners' metacognitive awareness; the Physical Science learner's attitude towards science; the level at which metacognition is promoted during the teaching and learning process; the cultural impact on metacognition; and a generalised workable plan to improve Physical Science attainment based on data from the selected sample.

4.3 Research design

4.3.1 The mixed methods design

This research views metacognition as a consequence of a psychosocial environment which is an interrelation of socio-cultural factors and individual thought and behaviour (Thomas, 2012:133). Metacognition varies across cultures (Thomas, 2012:133), therefore the research design which considers the socio-cultural aspects of the study was effective in researching metacognition in the South African Physical Science classroom. The learners learning environment is crucial to understanding the learners' socio-cultural, cognitive and metacognitive awareness. Metacognition is a cognitive activity which cannot be directly detected but its existence can be inferred (White cited in Thomas, 2012:135).

In this study the verbal responses did not give a clear view of the participants' answers. The participants' could not articulate their views clearly and might know more than they verbally communicate (Thomas, 2012:136). Non-verbal forms of communication such as questionnaires add clarity in this case. The researcher considers this and utilises qualitative and quantitative strategies to add validity and clarity of results. Therefore, the mixed methods approach was pragmatic in this research.

In the past 30 years, mixed methods became ever more popular with researchers and authors (Ary et al., 2010:559). The mixed methods approach to research is a combination of the qualitative and quantitative methods of information gathering wherein each method adds value to the understanding of the researched phenomenon (Creswell & Clark, 2011:5; Cizek, 1998:461; Handrahan, 2002:131-132; Tashakkori & Teddlie, 2010:19). The mixed methods design offers a better understanding of the research problem where a single method fails (Ary et al., 2010:559).

Characteristics of the mixed methods research design is that it is intensive, and the researcher must be skilled in quantitative and qualitative data gathering (Ary et al., 2010:559). The mixed methods approach can be time-consuming and requires extensive resources (Ary et al., 2010:559). The mixed methods design used in this research set the direction of collection and analysis of quantitative and qualitative data (Creswell & Clark, 2011:5), as illustrated in the flow diagram in Figure 4.1 below.

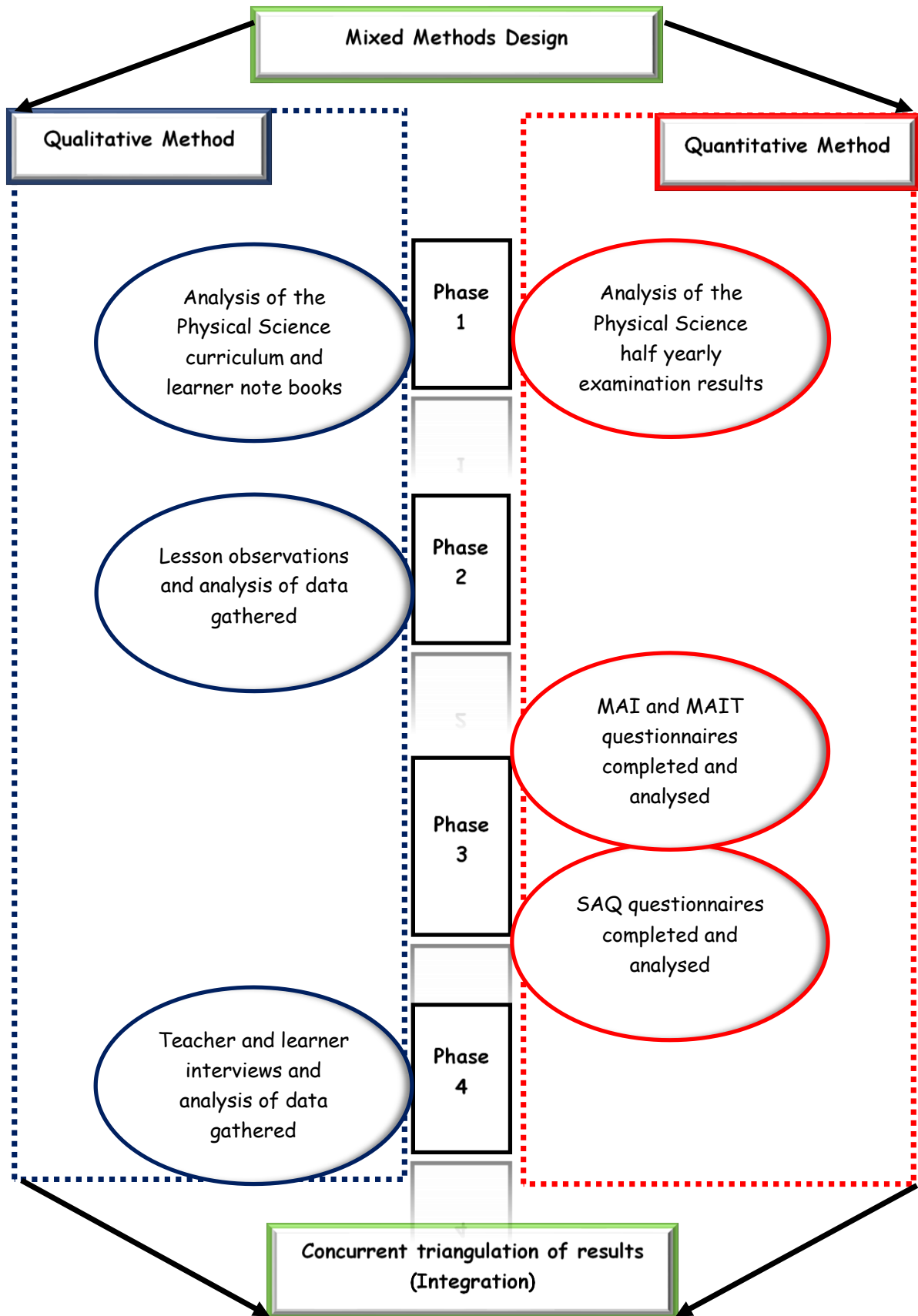


Figure 4.1: Research design

As seen from the flow diagram, the concurrent triangulation type of mixed methods design (see section 4.3.3) was used where the quantitative and qualitative data were gathered separately yet concurrently in four phases during the research. Equal priority was given to both qualitative and quantitative data. The findings were integrated during the final phase of the research (Ary et al., 2014:593). The mixed methods design allowed the researcher to examine research questions from different angles to look for unexpected results and potential contradictions (Vogt et al., 2012:113). Each phase of the research is discussed in 4.3.2 below.

4.3.2 Instrumentation of the mixed methods research

Instrumentation is a collective definition used to delineate all qualitative and quantitative measurements in the research (Cottrell & McKenzie, 2011:146). The research was broken down into four phases, detailed in section 4.3.1. During each of the four phases of data collection, the researcher used qualitative and quantitative methods to analyse the state of metacognition in grade 11 Physical Science classes (see Figure 4.1).

Sources of data in phase 1: During phase 1, the researcher used learners' notebooks, half-yearly results spreadsheet, and the CAPS document for Physical Science as sources of data. The CAPS documents were obtained from the National Education website and were used to answer research question 1.

With the permission of the Physical Science teachers and learners, notebooks were selected. The researcher collected them, under the guidance of the teacher, from high achievers, average ability learners, and weak learners. A minimum of one notebook was collected randomly for each achievement group, however a maximum of 3 notebooks was collected for each learner group where the class sizes were approximately 30 learners. The researcher felt that this would provide a fair indication of the quality of written evidence of metacognitive awareness of the learners. By analysing how the teacher marked the notebooks, the researcher gained an idea of the extent that metacognitive thinking was encouraged by the teacher. The data gathered from this instrument helped in evaluating research aim 3.

The Physical Science teachers gave the researcher a copy of the half-yearly Physical Science examination results. This was based on the marks obtained by the Physical Science learners from paper one and paper two of the externally set examination. During the time of the research, the marked examination papers were in storage and the researcher did not have access to the scripts. The teachers gave the researcher access to the spread sheets and the exam question papers. The data collected was crucial to research aim 2.

Instruments used in phase 2: During phase two of the research, the researcher used the observation protocol sheet (appendix 1) as a research instrument to analyse the state of metacognition during the teaching and learning process (research aim 3). This part of the research consisted of the lesson observations (the qualitative instrument) of grade 11 Physical Science classes. The researcher observed the Physical Science lesson and completed the lesson observation sheet. The observation protocol sheet guided the researcher to look for key features of metacognition during the teaching and learning process.

Instruments used in phase 3: The survey instruments used in phase three of the research were the MAI for learners adapted from Schraw and Dennison (1994:472-474), the MAIT adapted from Tanner (2012) and Balcikanli (2011:1331), and the SAQ adapted from Summers (2012:92-93). Data from the MAI (see appendix 2) and SAQ (see appendix 3) were vital in meeting research aim 5. The MAIT (see appendix 4) provided important data for research aims 6 and 7. The MAI and the SAQ were given to grade 11 learners during their Physical Science lessons. The teacher and the researcher both assisted learners in comprehending certain information and procedures that learners felt challenging. The teachers filled in the MAIT at their convenience and returned it to the researcher.

Instruments used in phase 4: Interviews between grade 11 Physical Science learners and the researcher, as well as the interviews between the Physical Science teachers and the researcher, formed the basis of phase 4 qualitative instruments. An interview is a dialogue between two people (Mohanna et al., 2011:246) where the

researcher seeks awareness of the lived experience of the interviewee and takes an interest in the significance of the interviewee's point of view (Seidman, 2006:9). The information obtained from this phase met research aim 4.

The teacher interviews were done as structured interviews, guided by the teacher interview schedule (appendix 8). The researcher constructed a series of questions used in all the teacher interviews. The learner interviews were focus group interviews (see 4.5.6) guided by the learner's interview schedule (appendix 7). The focus group interview entailed conversations with small groups of three to six learners each. As with the teacher interviews, the researcher did not deviate from the interview schedules.

4.3.3 The dissemination and collection process of the instruments

The researcher drew up an appointment schedule with each of the seven schools visited. Initially, the researcher met with each of the school principals' months before the data gathering process. The researcher provided the principal with a clear description of the research, including the aims and objectives. Upon agreeing to participate in the research, each principal signed an informed consent form for principals (appendix 6). The principals then introduced the researcher to the grade 11 Physical Science teachers. The researcher discussed the research with the teachers and was after that introduced to the science department. The teachers and the researcher exchanged details.

The researcher and the teachers communicated periodically. At the commencement of the data gathering process, the researcher scheduled appointments with the principals and Physical Science teachers of the seven schools. An average of five days was scheduled for each school to complete the data collection. The days scheduled for each school were determined by the grade 11 Physical Science timetable. The initial two days were used to give the teachers and learners informed consent forms for the parents (appendix 9) and informed consent forms for the teachers (appendix 10). The researcher spent time in the schools to become familiar with the grade 11 Physical Science learners. This entailed the collection of notebooks, examination results, and lesson observations. The second schedule of

appointed visits involved the completion of the MAI, MAIT, SAQ, and the interviews. Learners absent during this visit were not included in the research.

4.3.4 Philosophical orientation

Pragmatism, according to Stevenson (2010:1395), is an approach which assesses information regarding the success of its real-world application. The mixed methods approach was a pragmatic choice for this research because the eight critical questions were contained in a single research study (Jurs & Wiersma, 2009:309) investigating the theory of metacognition and its influence in Physical Science learning of the selected sample of South African learners (Tsai, 2005:78). Furthermore, words and numbers were integrated to justify conclusions drawn during the combination of deductive and inductive reasoning used in the analysis of participants and recording their behaviour (Creswell & Clark, 2011:10). Using words and numbers created a more persuasive argument than just words or numbers alone (Creswell & Clark, 2011:10). The research included collection, analysis, and integration of quantitative (test results, surveys) and qualitative (observation, notebooks, curriculum documents, interviews) data. This approach to research was used because the integration of qualitative and quantitative methods provides a better understanding of the research problem than either type alone (Ward, 2005:18).

The mixed methods philosophy connected the theoretical perspectives of the research involved (Creswell & Clark, 2011:5), which were

- collecting and analysing persuasively and rigorously both the qualitative and quantitative data from the research questions;
- integrating the quantitative and qualitative data, and allowing them to build on one another sequentially; and
- giving equal priority to both qualitative and quantitative data.

The five purposes of the mixed methods research according to Ary et al. (2014:561) are

- complementarity: the data gathered using one method in the study complement the elaboration and clarification of the results obtained from another method in the same study;
- initiation: different methods are used to investigate the same phenomena to find similarities and contrasts between the dimensions of the studied phenomena, thereby creating a new framework for existing theory;
- expansion: to expand the scope and depth of the phenomena by using various methods;
- triangulation: different techniques used to test the same phenomenon to reinforce the validity of conclusions;
- development: results from one research method inform another research method.

Perceptiveness obtained from quantitative and qualitative methodologies in the mixed methods design supplement each other to create a more in-depth understanding of the research (Farquhar et al., 2011:749).

4.3.5 Specific mixed methods design

After careful analysis of the research problem, purpose, and questions, the researcher chose to use the fixed mixed methods approach, rather than an emergent mixed methods design. Fixed mixed methods design predetermines, before field research, the methods to be used to gather the data, while emergent methods are more appropriate when issues arise during field research (Creswell & Clark, 2011:54).

The researcher chose the specific mixed methods design based on the following key parameters (Ary et al., 2010:563):

- the number and kind of data gathering approaches being used;
- the number of phases of the research design;
- the execution process of data gathering;
- the extent of data integration; and
- the prioritising of design methodologies.

Mixed methods designs have three categories (Creswell & Clark, 2011:66):

- Concurrent timing: when the researcher uses the qualitative and quantitative data collection techniques in a single phase;
- Sequential timing: when the researcher uses data and analysis of data of one type after the data analysis of another type;
- Multiphase timing: this occurs when the researcher uses the combination of the concurrent timing and sequential timing in a study that has three or more phases.

By referring to section 4.3.1, it is clear that multiphase timing was used in the four phases of data collection.

According to Creswell & Clark (2011:68-70), there are different designs, depending on the order and time of the data collection. The researcher felt the concurrent triangulation design best suited this study. Figure 4.2 below summarises the concurrent triangulation design.

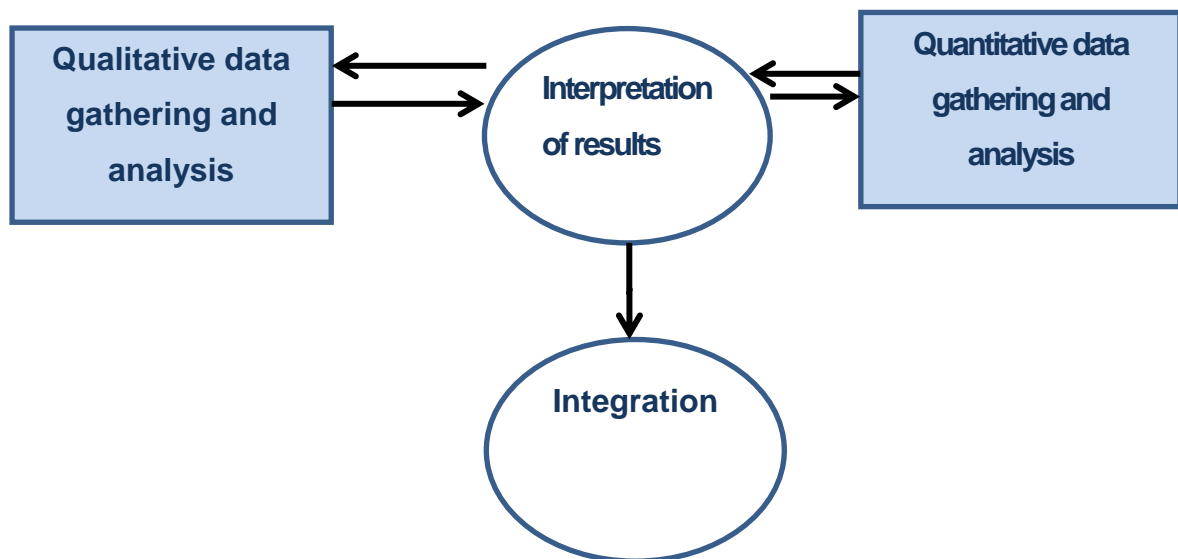


Figure 4.2: The concurrent triangulation design (adapted from Creswell & Clark, 2011:70):

Concurrent triangulation means that qualitative and quantitative data are collected concurrently, in multiple phases of the research, and analysed separately. The results are integrated and critically compared with conclusions.

This research best fitted the concurrent triangulation design because (refer to section 4.3.1)

- the data collection process had four phases;
- each phase collected quantitative and qualitative data concurrently;
- the data were analysed separately;
- the integration of results occurred during the interpretation phase of the study.

4.3.6 Strengths and challenges of the concurrent triangulation design

Concurrent triangulation is the most popular mixed methods design because the gathering of qualitative and quantitative data occurs simultaneously while their analysis is done separately (Manzoor, 2016:88). The research benefited from the combined strengths of qualitative and quantitative methodologies (Ary et al., 2010:23,567). The effectiveness of one approach is used to overcome the shortcomings of the other (Ary et al., 2010:23,567). Conclusive findings with strong validity were drawn from integrated data analysis (Ary et al., 2010:23,567).

Despite this design being the most popular, it is the most challenging mixed methods design, because the researcher needs to be familiar with both the quantitative and qualitative approaches (Manzoor, 2016:88). Sometimes the qualitative and quantitative data do not align, and contradictions arise (Manzoor, 2016:88). This requires new data gathering, or skewed interpretations of the topic could arise (Manzoor, 2016:88).

4.4 Quantitative research

A quantitative method is an approach to testing theories by analysing the relationship between variables, gathering numerical data, and answering closed-ended questions

(Creswell, 2013:4). The quantitative approach to research follows the post-positivist worldview which is hidden in the research but has a great influence on the study (Ary et al., 2010:23; Creswell, 2013:5). The post-positivist worldview is based on careful observations and measurements taken in the natural environment of the study to create numerical measures of the findings (Creswell, 2013:7).

4.4.1 Rationale and purpose of quantitative research

During the quantitative study, the researcher began with theoretical assumptions on metacognition in South African Physical Science classes, collected the numerical data, and made necessary changes to validate the results (Creswell, 2013:7). The assumptions of the post-positivist paradigm considered by the researcher (Creswell, 2013:7-8) are as follows:

- Absolute truth does not exist, and research conclusions are not without errors, so the researcher does not intend to prove a hypothesis but rather to reject failure, however, should the researcher describe the complexity, an acceptance or rejection has no relevance;
- The research aimed to refine claims or replace them with more valid ones (emphasising the state of metacognition in the grade 11 Physical Science classrooms studied);
- Numerical data obtained from research, analysis, and rational considerations determine the outcome of the research;
- The conclusive findings from numerical data resolve the research problem;
- The critical examination of triangulation will reveal possible bias.

The major emphasis of the quantitative part of this study lay on the survey research. The survey research provided a numerical description of learners' attitudes towards science and the metacognitive awareness of both the teachers and the learners. Statistical analysis and interpretation were completed to conclude, with the assistance of the NWU Statistical Consultation Services.

4.4.2 Population and sample

The population consisted of grade 11 Physical Science classes in seven selected schools in the Phoenix and Tongaat central district in KwaZulu-Natal. The schools were labelled school A to school G. Classes were given the number 1 or 2, depending on the number of grade 11 Physical Science classes in the school. The schools are from middle- to lower-income areas in the region, and attract learners from surrounding townships, namely Phoenix, Tongaat, KwaMashu, Bumbai, Inanda, Verlum, Ntuzuma, and Amoati. The schools are located in densely populated areas.

The participants consisted of seven teachers and 151 learners for the quantitative part of the research. The grade 11 learners were ideal for the research as they had done Physical Science in grade 10 and did not have the pressure of completing their National Certificate examinations that year. For the quantitative research, all learners who were present in the classroom took part in the survey. The Physical Science teachers took part in the MAIT survey; however, the Physical Science teacher of school G was not present to participate in the survey. School A had two Physical Science classes. Therefore, both the teachers completed the MAIT survey.

All the Physical Science teachers were nationally certified to teach Physical Science. They all had Physical Science teaching qualifications from recognised universities and colleges in South Africa. They were all SACE (South African Council of Educators) certified. The teachers worked closely with the researcher in supporting the surveys. The researcher had to arrange convenient times for the surveys with the teachers because they played a key role in the success of the quantitative part of the research.

Most of the learners participating in the research were Zulus. Zulus are part of the indigenous Nguni tribe, a major ethnic group in South Africa (Kenkel, 2008:707). South African indigenous learners in all provinces share the same historical disadvantages (Barnard et al., 2009:269) producing an emotional connection between them. The majority of indigenous learners have similar cultures, which drives community connections using shared values (Almond & Verba, 1963:13). This controls the variable of history and culture from a socio-cultural perspective.

Furthermore, it connects with the idea that the indigenous learners in this study are descendants of the original people of South Africa (Gupta et al., 2007:168).

4.4.3 Half-yearly results

The half-yearly Physical Science results of the grade 11 learners in the seven schools visited were analysed (research aim 2). The average mark of learners from each school was obtained from the year 11 Physical Science teachers. The half-yearly examinations tested the scientific claims, evidence, and reasoning of theory covered in class, and provided a quantitative benchmark to critically measure metacognitive thinking (Rooks-Ellis, 2009:90). The spread sheets of results and the exam question papers allowed the researcher to assess the foci of the exams and to determine the forms of learning promoted by the examination. This mark was compared with data collected from MAI and SAQ. Triangulation of data ensured the entirety of the facts and Figures.

4.4.4 Questionnaires used in the research

The NWU Statistical Consultation Services was consulted to assist with the statistical analysis of the MAI, MAIT and SAQ. All the data gathered was put into a spreadsheet using Microsoft Excel. SPSS (SPSS Inc., 2016) statistical software was used for all other statistical calculations. Using the software reduced the effects of a random error during calculations, thereby increasing the validity of the results.

The questionnaires were designed using a 4-point Likert like scale. The Likert scale measures attitudes of participants by asking them to respond to a series of statements with the options taking a continuum from “strongly agree” to “strongly disagree” and normally has 5 points (McLeod, 2008). Figure 4.3 shows an example of a 4-point Likert like scale used in the research.

	Strongly disagree	Disagree	Agree	Strongly agree
1. I enjoy science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Learning science is not important for my future success	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. We do a lot of interesting activities in science class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Most people should understand science because it affects their lives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I will study science if I get into a university	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 4.3: Four-point Likert like scale

Learners were instructed to choose only one option per question. The 4-point Likert scale was used instead of a 5-point Likert scale because the option of “Undecided” was removed which eliminated indecision or neutrality of the participant. Using the 4-point Likert like scale deterred participants from sitting on the fence and encouraged them to think about the options and take a stance. Learners were reminded that this was not a test, but the data collected was to be used as statistical information for the research.

The Likert scale was favourable for the quantitative part of the research because it allowed the participants degrees of opinion, which meant the data could be analysed easily (McLeod, 2008). To minimise the effect of social desirability on the participants’ responses, the researcher emphasised anonymity and gave the participants the option of not including their name on the questionnaire (McLeod, 2008). The participants were also reminded that there is no wrong or right answer; the researcher was interested only in their opinions.

4.4.5 MAI for learners

The MAI for learners was adapted from Schraw and Dennison (1994:472-474) (See appendix 2). The MAI as conceived by Schraw and Dennison (1994) is the most widely used instrument for evaluating metacognitive awareness (Teo & Lee, 2012:93), therefore it was chosen as a research instrument. Furthermore, research done by Panaoura & Philippou (2003:437) showed the post-hoc content analysis verified the factors in the MAI as metacognitive knowledge and metacognitive regulation which was the key factors measured the MAI. According to Schraw and

Dennison (1994:472), the MAI has good psychometric elements which are a reliable test for metacognitive knowledge and metacognitive regulation. Schraw and Dennison's (1994:462-464) work on assessing metacognitive awareness using the MAI had factor analyses with high internal consistencies. The restricted factor analysis found Cronbach Alpha values for the instrument was 0.95 which yielded a high reliability. This further encouraged the researcher to choose the MIA.

The MAI quantified learners' awareness of both knowledge of cognition and regulation of cognition (research aim 5). The two components of metacognition represented in the MAI, discussed in part 2.3 of this study, are metacognitive knowledge and metacognitive regulation. The knowledge factor evaluates the declarative knowledge (understanding about the individual and methods), procedural knowledge (understanding about method use), and conditional knowledge (when and why to use methods) (Teo & Lee, 2012:93). The regulation factor evaluated planning (goal preparation), information management (systematising), monitoring (evaluation of learning and method), debugging (methods to correct inaccuracies), and evaluation (appraisal of the effectiveness of outcome and method) (Teo & Lee, 2012:93).

The findings were the score of all the items of individual construct added together to generate a single scale score which was used to justify conclusions (Gardner, 1995:283). The constructs covered imported elements regarded as crucial for the research. The MAI consists of 52 questions and focuses on assessing metacognitive knowledge and regulation. The measure of the subcomponents, metacognitive knowledge and metacognitive regulation, are structured as follows:

1. Knowledge of cognition:

- declarative knowledge—questions 5; 10; 12; 16; 17; 20; 32; 46;
- procedural knowledge—questions 3; 14; 27; 33;
- conditional knowledge—questions 15; 18; 26; 29; 35;

2. Regulation of cognition:

- planning—nos. 4; 6; 8; 22; 23; 42; 45;

- information management strategies—nos. 9; 13; 30; 31; 37; 39; 41; 43; 47; 48;
- comprehension monitoring—nos. 1; 2; 11; 21; 28; 34; 49;
- debugging strategies—nos. 25; 40; 44; 51; 52;
- evaluation—nos. 7; 19; 24; 36; 38; 50.

The data of the MAI were summarised by finding the mode suitable for easy interpretation of the results (McLeod, 2008). The distribution of the observations was plotted on a bar graph and not on a histogram because the data were not continuous (McLeod, 2008). The results of the knowledge of learners' cognition were broken down to their constituents: declarative knowledge; procedural knowledge, and conditional knowledge. Learners' regulation of cognition was broken down into planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation.

4.4.6 Metacognitive awareness inventory for teachers

Metacognition is not only beneficial to learners, but it is essential for teachers to progress their teaching (Kallio et al., 2017:78). There have been lots of research using MAI focusing on students' metacognition, but only few considered teachers' metacognitive awareness. Metacognitive awareness inventory for teachers by Balcikanli (2011:1321) is popularly used to assess metacognitive awareness of student teachers but is also being used to assess teachers (Kallio et al., 2017:78). MAIT by Balcikanli (2011:1321) has been used by many studies to assess the metacognitive knowledge and metacognitive regulation of teachers. This is the key factor why the MAIT was chosen. Moreover, work done by Kallio et al. (2017:84) on the utility of the metacognitive awareness inventory for teachers among in-service teachers found the internal consistency, using Cronbach Alpha values, to be good. Additionally, the Cronbach Alpha values of the entire questionnaire were 0.90 which makes it very reliable (Kallio et al., 2017:84).

The MAIT (see appendix 4) for this study was adapted using the work on by Tanner (2012) and Balcikanli (2011:1331). From the initial 40 items of the MAI, 24 items were taken from Balcikanli's (2011:1321) MAIT. The measured item from the MAI

such as, “I ask myself periodically if I am meeting my goals”, was replaced with, “I ask myself periodically if I meet my teaching goals while I am teaching” in the MAIT (Balcikanli, 2011:1321). Similar changes were made to suit the teaching context (Balcikanli, 2011:1321). This made the opinion statements clear and had an efficient use of words which adds to the instrument’s validity. The MAIT by Balcikanli (2011:1331) lacked the opinion statements to assess the depth at which the teachers promoted metacognitive assessment. The researcher added 16 more items, adapted from Tanner (2012), to measure the promotion of metacognition by the teacher. This was numbered as items 25-40. The opinion statements of the MAIT adapted using the work on by Tanner (2012) and Balcikanli (2011:1331) were clear, efficient, and assessed a common construct using numerous items having a unidimensional scale so that the data was interpreted clearly (Gardner, 1995:283). The major advantage of using this method, as compared to measuring a single item, is that it increases the reliability of the instrument (Gardner, 1995:283). This further assured the researcher that the instruments were correct for this research.

Similar to the MAI, the findings of the MAIT were the score of all the items of individual construct added together to generate a single scale score which was used to justify conclusions (Gardner, 1995:283). The constructs covered imported elements regarded as crucial for the research. The measure of the subcomponents of metacognitive knowledge and regulation were structured as follows:

Metacognitive knowledge:

- declarative knowledge–nos. 1; 7; 13; 19;
- procedural knowledge–nos. 2; 8; 14; 20;
- conditional knowledge–nos. 3; 9; 15; 21;

Metacognitive regulation:

- planning–nos. 4; 10; 16; 22;
- monitoring–nos. 5; 11; 17; 23;
- evaluating–nos. 6; 12; 18; 24;

Promoting metacognition

- questions 25-40.

MAIT addressed research aims 6 and 7 in which a four-option Likert scale MAIT questionnaire was given to the Physical Science teachers in each of the seven schools visited. It aimed to measure the metacognitive awareness of the Physical Science teachers. The MAIT data were summarised by finding the mode because it was suitable for easy interpretation of the results (McLeod, 2008). Similar to 4.4.5, the distribution of the observations was plotted on a bar graph instead of a histogram because the data were not continuous (McLeod, 2008).

4.4.7 Science Attitude Questionnaire

Scientific attitudes refer to specific methodologies for solving problems, evaluating ideas and facts, and deriving conclusions, and are concerned with a learner's positive or negative feeling towards science (Abd-El-Khalick et al., 2015:5-6). A learner's attitudes towards science are multidimensional, consisting of both evaluative and affective elements (Summers, 2012:12). These elements are shaped by many factors, including variables from personal experiences, and those related to external factors, such as family and friends (Summers, 2012:12). Additionally, many studies show that achievement and motivation directly correlate with learners' positive attitudes towards science (Summers, 2012:12).

There are extensive selections of effective tools available to gather data on learners' attitude towards science. A popular instrument to measure scientific attitude consists of opinion (see section 4.4.4) followed by Likert scale response (Gardner, 1995:283), which was the structure of the SAQ. Unlike most instruments which assess scientific attitudes for English first language learners, the SAQ used was adapted from Summer's (2012:92-93) studies for English second language learners. The learners of this study were isiZulu learners who speak English as a second language. The opinion statements were very clear and had an efficient use of words to improve its validity. This motivated the researcher to use the SAQ to measure the learners' attitudes toward science. During the SAQ survey the isiZulu learners found it easy to understand the instructions and the statements of the SAQ.

The assumption in choosing the instrument is that it assesses a common construct using numerous items having a unidimensional scale so that the data was be interpreted clearly (Gardner, 1995:283). The opinion statements used by Summer's (2012:92-93) displayed unidimensionality and assessed a common construct. The major advantage of using this method, as compared to measuring a single item, is that it increases the reliability. The use of factor analysis yielded the most conclusive evidence to support a claim that the scale used was unidimensional (Gardner, 1995:283) was applied to the SAQ. The confirmatory factor analysis on the research Summer (2012:37) completed on the Arabic speaking students' attitudes toward science showed that domain scores were moderately to highly correlated. Exploratory factor analysis identified a strong core with strong Eigenvalues (Summer, 2012:37). This further motivated the researcher in choosing the SAQ.

The SAQ focused on learners' attitude towards studying science and their cultural attitudes towards the science course (research aim 5). This questionnaire was designed to gather information about learners' perceptions of studying Western science, how motivated they were, and their interest in pursuing a career in science. The SAQ has 54 questions which measure learners' personal experiences as well as external factors relating to the learner's attitude towards science. A four-option Likert scale SAQ was given to the grade 11 Physical Science learners of the seven schools visited. Similar to the MAI, the findings of the SAQ were the score of all the items of individual construct added together to generate a single scale score which was used to justify conclusions (Gardner, 1995:283). The constructs covered imported elements regarded as crucial for the research. The constructs covered imported elements regarded as crucial for the research. Below is a breakdown of opinion statements associated to their respective construct of the SAQ:

- positive attitude towards science—nos. 1; 6; 9; 12; 15; 19; 21; 22; 25; 28; 32; 39; 45;
- negative attitude towards science—nos. 2; 7; 8; 14; 16; 20; 33; 41; 42; 36; 44;
- future intention for study in science—nos. 5; 11; 18; 23; 27; 40;
- impact of science in our daily lives—nos. 4; 17; 26; 30; 34; 37;
- science in school—nos. 3; 10; 13; 35;

- approval by friends and family—nos. 24; 29; 31; 38; 43;
- cultural influence on science attitude—nos. 46-54.

The data of the SAQ were summarised using a frequency table and finding the mode because it was suitable for easy interpretation of the results (McLeod, 2008). The distribution of the observations was plotted on a bar graph and not histogram because the data were not continuous (McLeod, 2008). The results were categorised according to learners' positive or negative attitude towards science; future intention to study in science; the impact of science in their daily lives; science in school; approval from friends and family; and cultural influence.

4.4.8 Reliability and validity of the quantitative research

Reliability in quantitative research is the measure of quality in terms of repeatability and consistency of quantitative data (Scott & Morrison, 2007:208). Validity is concerned with the depth to which the questionnaires determine what they intended to measure (Tavakol & Dennick, 2011:53). In the quantitative study the Cronbach's alpha, the most popular objective measure of reliability was used to measure the internal consistency of the construct (Tavakol & Dennick, 2011:53).

A sample size (N) of approximately 151 Physical Science learners, a fairly good sample size for the reliability test, was used for the Cronbach Alpha reliability analysis of the MAI and SAQ questionnaires (Schermelleh-Engel, 2015). However, a sample size (N) of approximately seven is not a good sample size for a reliability test and was therefore not used for the Cronbach Alpha reliability analysis of the MAIT (Schermelleh-Engel, 2015). The mixed methods research both enriched and compensated the shortcomings in the quantitative results by using the qualitative data analysis (Fung, 2015).

The Cronbach Alpha has a test scale value between 0 and 1. Reported values which between 0.7 to 0.95 are considered high (Zaiontz, 2017; Tavakol & Dennick, 2011:54). Constructs with Cronbach Alpha values between 0.6 to 0.7 have been included, but was used with caution (Zaiontz, 2017). This implies that the constructs

will be thoroughly examined using the qualitative and quantitative data to draw conclusions. Lower alpha values, those approaching 0, was due to a poor correlation between items, and would thus be discarded in the research (Tavakol & Dennick, 2011:54). High alpha values are due to redundancy between items on the questionnaire, and would also be discarded (Tavakol & Dennick, 2011:53). With the help of the NWU statistics team and the use of the SPSS (SPSS Inc., 2016) statistical software, the Cronbach Alpha values were calculated for the MAI, MAIT and SAQ.

4.4.9 Limitations of the quantitative research strategies

Limitations of the quantitative part of this study focusing on surveys and exam results analysis is its absence of emotions, behaviour, and changes of emotions of participants (Queirós et al., 2017:382). This inhibits the gathering of societal and holistic data. Data obtained in this way from surveys are inaccurate or incomplete and was only compensated by qualitative research. Whilst drawing conclusions to findings, the qualitative and quantitative data was triangulated (see section 4.3.5.)

The quantitative research surveys were sometimes subjective and misleading because the Physical Science learners and the teachers sometimes feel positive about certain points of the survey which in a real-world scenario might not be true. For example, when asked to respond to: “I ask myself periodically if I meet my teaching goals while teaching”; many teachers respond positively to this statement, but the qualitative data collected during the observation process show differently. This could be due to the participants not reading deeply into the statement and cause contradictions during the triangulation process.

Results from meta-activity questionnaires very seldom align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). Furthermore, in a quantitative survey people express a certain impression of themselves to others in order to minimize their own uneasiness (Ong & Weiss, 2000:1692). This is called self-presentation (Goffman cited in Ong & Weiss, 2000:1692). It is possible that participants overestimate themselves during completion of the MAI and MAIT. Research published by Huszti et al. (2016:68-80)

and Siegesmund (2016:204-214) found that research participants tend to exaggerate their metacognitive ability when asked to self-assess their metacognitive awareness. The participants feel victimised by responding in a certain way and might lie due to social pressures (McLeod, 2014). There is no way of knowing how truthful the participants were during the quantitative part of the research.

4.5 Qualitative research

Qualitative method is a method for gaining a deeper understanding of a social group by using descriptive words and open-ended questions (Creswell & Clark, 2011:4). The qualitative approach to research follows the socio-constructivist worldview, which is hidden in the research but has a great influence on the study (Ary et al., 2010:29; Creswell & Clark, 2011:5). Social constructivists consider individual interpretations of the environment they live and work in and appreciate the subjective meaning drawn from their experiences (Creswell & Clark, 2011:8). The aim of qualitative research is to study various individual views to draw a broad meaning of the problem at hand (Creswell & Clark, 2011:8).

In this study, the researcher posed open-ended questions to the Physical Science teachers and learners in their natural settings, the school, thereby forming social interactions with the participants (Creswell & Clark, 2011:8). The researcher also took into consideration the historical and cultural setting of the study and recognised that the researcher's background could influence interpretations of the study (Creswell & Clark, 2011:8). Unlike post positivism, in which the researcher starts with a theoretical assumption, the socio-constructivist paradigm aims at inductively generating a pattern of meaning (Creswell & Clark, 2011:8).

During the qualitative study, the researcher identified the following assumptions:

- The participants derived meaning from their social interaction with the world. The researcher used open-ended questions on the premise the participants will share the during the interviews and in informal social interactions during the study;

- Humans engage with the world based on their historical, social, and cultural perspective. The researcher's aimed at understanding the context through visiting and observing the natural setting of the Physical Science classroom;
- The researcher's socio-cultural perspective would influence the qualitative data analysis;

The phenomenological design underpinned the qualitative study of this research. This implies that the qualitative part of the study evaluates structures of perception as experienced by the participants first hand in the natural setting of the Physical Science classroom. This design of enquiry comes from the philosophical and psychological theory of metacognition, allowing the researcher to describe the state of metacognition in the South African grade 11 Physical Science classrooms (Creswell & Clark, 2011:14). The design has a strong philosophical underpinning that involves classroom observations and interviews. The theory of the research design is supported by strong theoretical backing.

4.5.1 The rationale of qualitative research

The rationale for this part of the study was to qualitatively examine attitudes, behaviour, and social process which occur in the Physical Science classroom and its impact on metacognitive awareness. The aim was to get an in-depth understanding by both the grade 11 Physical Science learners and the Physical Science teachers. The researcher conducted classroom observations of seven grade 11 Physical Science classes, interviewed 89 grade 11 Physical Science learners, interviewed seven Physical Science teachers, and analysed the Physical Science curriculum documents as well as the notebooks. The researcher made use of lesson observation protocol sheets (appendix 1), interview schedule for learners (appendix 7), and interview schedule for teachers (appendix 8). These qualitative instruments focused on common items which were fundamental to analysing the state of metacognition during the teaching and learning process.

4.5.2 The participants

The population was the same as for the quantitative part of the research. The participants consisted of seven teachers and 151 learners. For the qualitative research, all learners who were present in the classroom took part in the classroom observations. However, the Physical Science teacher of school G left the country a few weeks before the research started, so his class was not observed, and he was not interviewed. School A had two physics classes. The researcher interviewed all Physical Science teachers from schools' A to F and interviewed 89 learners from A to G.

Learners were selected by choosing 4 to 6 learners of mixed gender and mixed abilities. The teachers selected learners from different tables to get a social mixture. Learners who would not normally sit together were grouped. This system of selection maintained order and discipline during the interviews and encouraged learners to give their individual opinion instead of just agreeing with their friends.

The researcher had to arrange convenient times with the teachers for the interview process and classroom observations. The teachers played a key role in the success of the qualitative research by coordinating the interview process and arranging the classroom observations.

4.5.3 Curriculum document

Document analysis requires the data to be scrutinised and inferred in order to provoke meaning, gain understanding, and develop pragmatic knowledge (Bowen, 2017:27). Data gathered by the document analysis of the Physical Science CAPS on the scope, depth, articulation, progression, and continuity of the curriculum were used to elicit meaning, gain understanding of the design of the curriculum, and to evaluate whether the curriculum-supported metacognition (research aim 1).

An effective enquiry-based Physical Science curriculum promotes metacognition (Schraw et al., 2006:118). Enquiry-based science curriculum promotes metacognition and self-regulation because learners are better able to monitor their

learning and evaluate errors in their thinking of theoretical interpretation of scientific content (Schraw et al., 2006:119). Literature review in section 2.8. showed that the South African Physical Science curriculum promotes scientific enquiry. This implies that the curriculum promotes metacognition through scientific enquiry. However, the document analysis is also focussed on assessing the effectiveness of the Physical Science curriculum.

Ornstein and Hunkins (2009:186-190) state that to sustain a coherent and effective curriculum, the design should achieve articulation, depth, progression, continuity, sequence, balance, and scope. An effective curriculum design for South African indigenous Physical Science learners must include indigenous knowledge. Section 3.4. uses various literatures to emphasise the idea that cultural factors affect learning and including indigenous culture within the curriculum helps enhance indigenous learner motivation, which is an element which supports metacognitive awareness (see section 1.4.3.3. and 2.4.3.). Metacognitive abilities and intelligence are also culturally driven and higher ordered thinking skills could be promoted provided the learners' cultural barriers are taken into consideration (see section 3.5.). Indigenous knowledge within the Physical Science curriculum does consider the learners cultural background. The researcher considered how well the curriculum promoted the culture of indigenous Physical Science learners.

The content analysis of the curriculum document was an in-depth examination through systematic reading and interpretation (Bowen, 2017:32). The content analysis of the curriculum documents was processed by organising information into categories scope, depth, articulation, progression, and continuity of the curriculum. Significant and appropriate data were identified, and the researcher focused on recognising pertinent data and separating it from that which was irrelevant.

The information provided the researcher with the insight of what was expected in the South African Physical Science curriculum before the researcher commenced with the classroom observations (research aim 3) and interviews (research aim 4). The data were used to determine whether the Physical Science curriculum was a holistic

science curriculum which supported metacognitive processes and was also culturally inclusive.

Apart from focusing on cognitive development, the data were used to verify whether the curriculum focused on learners' emotions and culture (Ozda et al., 2014:20). Analysing the data to determine whether the curriculum focuses on higher-ordered thinking determines curricular-orientated metacognitive knowledge (Thomas, 2011:45). An effective curriculum design for South African indigenous Physical Science learners must include indigenous knowledge. Section 3.4. uses various literatures to emphasise the idea that cultural factors affect learning and including indigenous culture within the curriculum promotes the motivational dimension of metacognition. Metacognitive abilities and intelligence are also culturally driven and higher ordered thinking skills may be promoted, provided the learners' cultural barriers are taken into consideration (see section 3.5.). Indigenous knowledge within the Physical Science curriculum does consider the learners cultural background. The researcher considered how well the curriculum promoted the culture of indigenous Physical Science learners.

4.5.4 Physical Science notebooks

Alonzo (2008:98) states the common purpose of a science notebook is to include content, science-process skills, and literacy skills. Worksheets and science activities are written evidence of scientific thinking (Alonzo, 2008:98).

The Physical Science notebooks were collected from selected learners with different academic levels. The teachers selected Physical Science notes from top achievers, average achievers, and low achievers in Physical Science. Photos of parts of the notebooks were taken for the analysis. Analysis of the notes in the notebooks provided information about the learners' knowledge of cognition. The notes taken down by learners gave some understanding of whether learners knew what the teacher expected, and how to organise information. Learners had control of what to learn and knew what information was important. This was used to analyse learners' declarative knowledge. Problem-solving activities done in the notebooks provided

information on procedural knowledge. This gave the researcher information about the strategies used during problem solving.

Analysis of the notebooks also gave the researcher written evidence of the support provided by the teacher, and the extent to which they promoted metacognitive awareness. The researcher critically analysed the marking of the notebook by the teacher. The following criteria guided the researcher in the analysis of the Physical Science notebooks:

- Metacognitive modelling: diagrams/mind maps/plan before problem solving/mnemonics/ key points/ highlighted key concepts;
- Marking for constructive improvement;
- Marking for metacognitive awareness;
- Declarative knowledge: revision notes/ summaries/notes;
- Procedural knowledge: how to use skills in problem solving;
- Conditional knowledge: when use skills in exercise;
- Planning: homework record, test dates; study timetable, example; tips;
- Monitoring: exercisers/unclear concepts/how to overcome difficulty;
- Evaluation: rewards, stickers, stamps, praise, how to achieve goals.

Information obtained here was used to compare the results obtained from the MAI.

4.5.5 Classroom observations

DeWalt & DeWalt (2002:92) state that the aim of classroom observation in qualitative research is to arrive at a holistic understanding of the case under investigation that is as unbiased and precise as possible within the limitations of the research method. This, in turn, increases the validity of the research (DeWalt & DeWalt, 2002:92).

The researcher used the observation protocol sheet (see Appendix 1) to guide him through the observation process. The observation protocol sheet assessed the lesson on the extent to which metacognition was promoted in the Physical Science class. The first page allowed the researcher to note the observed metacognitive components observed within the classroom by ticking or ringing what was observed. The second page allowed the researcher to note a clearer description of what was

observed. The observation of the lesson was broken down into five minutes intervals, where the researcher noted what was observed in the description column. The instrument referred to emotional, classroom, and instructional supports presented by the teacher in the form of positive relationship with learners, behaviour management, interactions and scaffolds that teach learners to think, offering continuous formative feedback and support, and facilitate metacognitive awareness. Indicators refer to observed evidence, such as teacher pupil discussions on feedback, learners putting their hands up, and using models discussed in section 2.10. This part provided a more descriptive overview of what was on the first page of the observation protocol. The researcher took field notes to provide a summary of what was observed during the lesson. The researcher played the role of a passive observer by being as inconspicuous as possible, minimising the disruption to natural teaching and learning during the lesson.

Relevant words, sentences, and phrases that were repeated or were like other responses were coded (Löfgren, 2013). The codes that were frequent and important were categorised, frequency calculated, and critically discussed. The frequency was calculated by dividing the number of coding observed in the seven observations. Table 4.1 below gives an example of the coding and frequency table used in the classroom observations.

Table 4.1 Example of a coding and frequency table used in the classroom

Category	Sub-category	Coding for teachers	Freq	Coding for learners
Metacognition	Developing a plan	Objectives	0/7	Understand objectives
		Starter to pre-requisite knowledge	7/7	Discuss using pre-requisite knowledge
		Direct learners where the thought process should take them	7/7	Question direction of lesson and relevance
	Students metacognition	Encourage learners to explain understanding	7/7	Discussed how and why they learnt concepts Identified difficulties
		Encourage learners to explain in own words	0/7	Questioned understanding
		ZPD	0/7	
		Encouraged questioning	7/7	
		Ask learners input	2/7	

Data collected from classroom observations provided qualitative data on learners' knowledge of cognition and regulation of cognition. Physical evidence of declarative, procedural, and conditional knowledge was analysed using the data collected from classroom observations. Levels of regulation of cognition were described using the qualitative data collected during the problem-solving process in the lessons.

Further to the observational techniques mentioned, the researcher also analysed active learning during the classroom observations. Active learning compliments metacognition in problem-solving coordination, critical thinking, and evaluation of understanding (Monk & Silman, 2013:21). Active learning is a learner-centred method of teaching that better promotes learner participation and knowledge retention than the teacher-centred approach (Bonwell & Eison, 1991:1). Active learning increases attainment of learners (Hake, 1998:39, Giannola & Green, 2011:5, Settles, 2008:52). It is an acclaimed teaching technique that works better than the teacher-centred method (Cambaliza et al., 2001:89-90; Felder et al., 2000:27; Hativah, 2000:63; Kyriacou, 1997:147; O'Sullivan, 2004:585-588). The

important difference between the teacher-centred method and learner-centred method is that the teacher-centred methodology passes on what the teacher knows, whereas the learner-centred methodology allows the teacher to facilitate the teaching and learning processes (Roberts, 2007:3; Sylvia & Barr, 2011:25; Zellner, 2011:11).

The information gathered on knowledge of cognition and regulation of cognition was integrated with the data collected from the MAI. Any data showing the socio-cultural aspect of learning during the lesson was analysed and integrated with the SAQ. The extent to which the teacher promoted metacognition was analysed using data collected during the teaching process and integrated with the information gathered from the MAIT.

4.5.6 Interviews

The teacher interviews were structured interviews. The researcher asked the Physical Science teachers the same series of questions using the interview schedule and did not deviate from the format. The researcher was casual and friendly but played a neutral role by not offering his opinion to the participant (Johnson, 2008).

The learner interviews were focus group interviews. Focus group interviews collect data from many participants at once (Morgan, 1997:3-4). The researcher had group discussions with the learners and used the interview schedule to guide the questioning. As with the structured interview with the teachers, the researcher did not deviate off point and remained neutral. The researcher guided the discussions and monitored and noted the responses verbatim. The groups ranged between 4 and 6 learners. The selection of the focus groups was explained in 4.5.2. The groups were given a chance to discuss their answers, and the group leader conveyed the group's response. In some cases, the responses were split within the group. The researcher noted opposing points of view. School G had only six Physical Science learners. Therefore, the researcher had just one group discussion and noted the point of view for each learner.

Similar to the lesson observations, relevant words, sentences, and phrases that were repeated or were similar to other responses were coded (Löfgren, 2013). The codes that were frequent and important to the research were categorised, frequency calculated, and critically discussed. Frequency was calculated by dividing the number of coding observed by the total number of learners interviewed and then multiplied by 100 to get a percentage. Table 4.2 below gives an example of coding and frequency table used in the classroom observations.

Table 4.2 Example of a coding and frequency table used in the interviews.

	Categorising	Coding	Frequency
Metacognitive knowledge	Skim	search for key words/ highlighted words, equations and summaries/ identify formula/ find equations	38%
	Slow down	pause/read again/ think about information/ read question again/ read and understand/ analyse given information /break down problem	37%
	Active prior knowledge	pause and think about what you already know and what you need to know/ identify problem/ what the question is looking for/ highlight key points	18%
	Mental integration	check which topic/which section relate key points, key words and equations to draw conclusion/ analyse	53%

The results of data analysis were integrated with the collected qualitative and quantitative data.

4.5.7 Trustworthiness of the qualitative research

The most common descriptor to describe trustworthiness of qualitative research is Lincoln and Guba's (1985:300) proposal, which considers credibility, transferability, dependability, and confirmability.

Credibility refers to whether the participant's interpretation of the setting and experience of the environment were aligned with what was reported by the

researcher (Ary et al., 2010:498). The researcher spent approximately five days in each school. Apart from conducting the research, the researcher spent time getting to know the environment and having conversations with learners and their teachers. Learners and teachers became familiar with the researcher before he started the data collection process. The informal conversation between the participants and the researcher allowed some insight into the views and experiences of the participants before the data collection process commenced. The field notes of classroom observations and transcripts of the interviews were meticulously interrogated to align the data with the interpretation. The participants' responses were noted verbatim to enhance credibility.

Transferability refers to the extent of similarity between the study and other sites as arbitrated by the reader. In the context of the research it is the likelihood of the research findings to have relevance to other schools and participants in similar conditions (Henig, 1999:55). The research gathering phase of this study took approximately 35 days. The seven schools were similar in their socio-economic status. The same procedures were repeated in each school. A sample total of 151 learners participated in the research. The research findings were based on the common finding of the data collected at each school. By deductive reasoning, it was assumed that the probability of obtaining similar findings in other schools with the same dynamics as the researched schools would be high.

Dependability of the results is a criterion used to check how reliable the findings of the qualitative research are (Swaminathan & Mulvihill, 2018:17). The method of triangulation, whereby different techniques are used to test the same phenomenon, was employed in this mixed methods research to reinforce dependability of the findings.

Confirmability is the audit trail of research activities. It helps readers to follow the research process through documentation memos, details of participants' perspective, raw data from field notes (Swaminathan & Mulvihill, 2018:17). Throughout the research, the researcher gave a detailed account of procedures and activities. This was well documented systematically and logically.

The validity of this research was enhanced by using interviews, document analysis, and surveys in conjunction with classroom observations (DeWalt & DeWalt, 2002:92). The trustworthiness of the qualitative part of the research was dealt with by using technical strategies of concurrent triangulation (see section 4.3.5 and 4.3.6.). Reliability of the data analysis processes was ascertained by having notes and transcripts (where applicable) checked for correctness, and codes, categories, and themes cross-checked by another expert in the field of study.

4.5.8 Limitations of the qualitative research strategies

The qualitative study involved observations of grade 11 Physical Science classes and interviews with teachers and learners. Learners varied in skills, attitude, motivation, and experience in metacognition in the Physical Science classroom. Furthermore, learners varied in socioeconomic status. The number of learners in each class observed varied, and the teachers had different levels of experience. These variations restricted the qualitative data analysis. The Hawthorne Effect is the reaction to individuals resulting from change in environment causing an adjustment in attitude and effort towards the associated activity (Payne & Payne, 2004:109-110). An effect within the Hawthorne studies which cause participants to modify their behaviour when being observed, was considered in the study (Payne & Payne, 2004:109). This effect is a natural response for the participants and could not be avoided in this study. Sampling was limited to grade 11 Physical Science learners only, which limited generalisation to other learners. Similarly, only Physical Science learners were researched, and this limited generalisation to life science and natural science.

Moreover, despite the careful collection and analysis of the data, factors that inhibit metacognition affected research results. Some of the sampled learners have been disadvantaged by these factors, and it was difficult to avoid despite selecting learners from similar cultural and financial backgrounds. The following factors prohibit metacognition during the investigation:

- Learners with low working memory (Waters & Schneider, 2010:179);
- Learners coming from low-income homes (Waters & Schneider, 2010:179);

- Poor teaching methods (Waters & Schneider, 2010:179);
- Lack of motivation (Baker, 2007:175);
- Poor self-esteem (Baker, 2007:175);
- Poor learning environment (Gettinger et al., 2011:279).

4.6 Ethical aspects of the research

Many researchers view informed consent dialogue as a dialogue with each participant (Bankert & Amdur 2006:247). Kantian moral philosophy, which directs much of the writing on research ethics, prohibits using the participants merely as a means to obtain valuable data for the research, encouraging respect from all those involved in the data collection process (Hasala, 2005).

A letter to higher authority (appendix 5) was submitted to the Tongaat and Phoenix District education officer to obtain permission to conduct research in the schools. The District Education Officer oversees public schools in different regions. The District Education Officer was informed that

- participants were free to respond or not, without prejudice or victimisation;
- participants had the right to withdraw from the study at any time;
- participant's names would be kept confidential, and if a participant is referred to in the study, a pseudonym would be used during the transcription of the comments;
- participants had the right to review the written transcripts of interviews, and would be allowed to delete any portion they felt it did not reflect what they meant;
- documentation regarding interviews and observations would be kept in a secure place by the researcher for seven years, and would be shared with no one other than the university's supervisors;
- interview material would become part of a written academic study and might be published. The publications would most likely be, but not necessarily limited to, scholarly research destined for an academic audience;

Similarly, informed consent forms were given to school principals (appendix 6) and the learners (appendix 9) and teachers (appendix 10), to guarantee their voluntary participation and confidentiality. The parents were required to sign on behalf of learners. The participants would have the right to opt out of the research at any point, and they would not be disadvantaged in any way. Clearance to perform this research was also obtained from the Ethical Committee of the Faculty of Education Sciences at the NWU.

4.7 Delimitations of learners' culture and subject knowledge and the teachers' qualifications

The study was delimited to intact groups of learners and operated under the assumptions that most of the learners were Zulus, and that all learners had prerequisite knowledge from their grade 10 studies. Furthermore, the learners were required to be taught by qualified Physical Science teachers, and that both the teachers and the learners could comprehend the survey and interview questions. It anticipated that answers would be as honest and accurate as possible.

4.8 Administrative procedures

The research proposal was accepted by the NWU, which granted permission to undertake the research study under the supervision of the NWU. A confirmation letter from the NWU gave the researcher permission to conduct the study. The researcher first met with the District Circuit Officer (DCO) for Phoenix and Tongaat and supplied a full description of the research. The DCO granted permission for the research and signed the letter to higher authority (see appendix 5). The original letter of higher authority, together with full disclosure of the research and the role of the school and participants, were presented to the principals of all seven schools researched.

The seven principals permitted the research by signing the informed consent form for principals (appendix 6). The researcher was also granted permission for grade 11 Physical Science learners and their teachers to be involved in the research. Informed consent forms for teachers (appendix 10) and learners (appendix 9) were signed and

later collected. The services of the Statistical Consultation Services (SCS) of the NWU were requested by the researcher for statistically processing data, resulting in a signed agreement between the SCS and the researcher.

4.9 Summary

Chapter 4 details the research's empirical, mixed methods approach. The mixed methods research was shaped by pragmatism. The specific type of mixed methods design, namely, concurrent triangulation design, was described and explained. The chapter lays out the rationale for using the qualitative and quantitative components of the mixed methods approach and lists its limitations.

The purpose, sample, validity, and trustworthiness of the qualitative and quantitative components were discussed. Figure 4.1 summarises the phases of the methodological process of the study. Chapter 4 concludes by informing the reader of the high regard for ethical considerations and administrative processes adhered to during the study.

Chapter 5 provides a comprehensive account of the statistical data analysis of the quantitative data, and the interpretation, critical analysis, and understanding of the qualitative data.

CHAPTER 5

DATA ANALYSIS, RESULTS, AND INTERPRETATION

5.1 Introduction

The schematic Figure 5.1 below, presents an overview of Chapter 5, using the triangulation model discussed in section 4.3.6. It highlights data analysis, results obtained, and interpretation of the results.

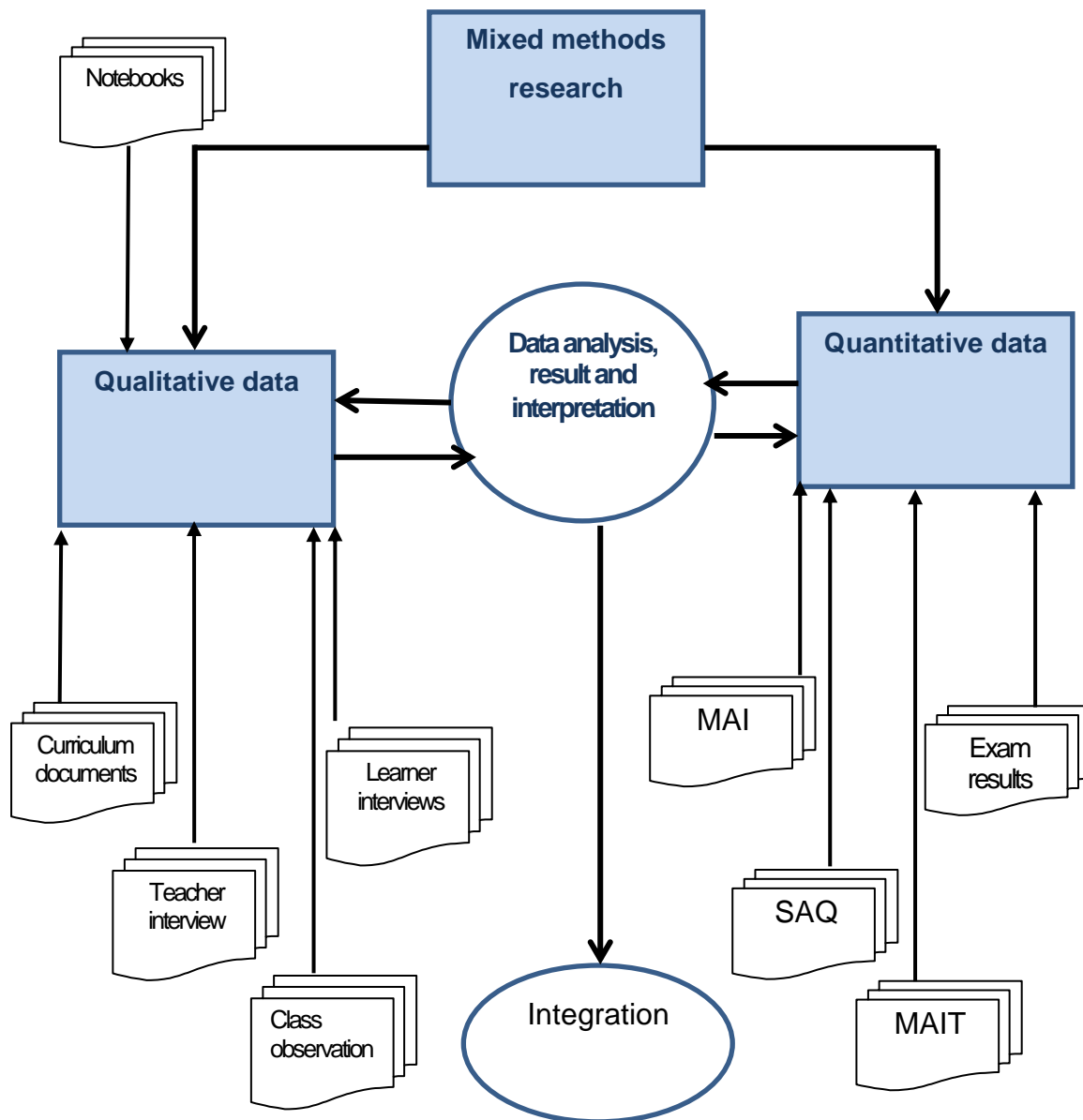


Figure 5.1: Outline of Chapter 5

Chapter 4 deliberated on the mixed methods process and discussed it in detail. The MAI, MAIT, SAQ, and the half-yearly Physical Science results were introduced as quantitative research instruments, analysed with assistance from the NWU statistical consultation team. The curriculum documents, notebooks, learner interviews, teacher interviews, and lesson observations were introduced as sources of qualitative data analysed by the researcher. The main aim of the study was to examine the state of metacognition in South African Physical Science classrooms to infer and exhort practical pedagogical strategies to improve learners' metacognitive awareness, and which might advance their Physical Science attainment. Chapter 5 delineates the results obtained, data analysis, and interpretation of the results of the quantitative and qualitative data.

5.2 Quantitative research data analysis and interpretation

At the outset, the grade 11 Physical Science learners were asked to complete the MAI and SAQ questionnaires (see section 4.4.5 and 4.4.7). Table 5.1 shows a breakdown of the schools and the participants that took part in the research. Each school was designated a letter from A to G. Both school A Physical Science classes took part in the research, categorised as class A1 and class A2.

The Physical Science teachers from each class completed the MAIT questionnaire (see section 4.4.6). Only one teacher (from school G) was not available to take part in the research (see section 4.5.2). The class size for the Physical Science class of school G was exceptionally small. Physical Science as a course was not popular in the school and many learners who chose Physical Science in grade 10 dropped the subject by the time they reached grade 11. Comments by the science teachers were that many learners felt Physical Science was too difficult.

Table 5.1 School and participant breakdown of the quantitative study

School	No. of Learners	No of Teachers
A1	14	1
A2	16	1
B	33	1
C	11	1
D	31	1
E	12	1
F	28	1
G	6	0
Total learners 151		Total teachers 7

The subsequent sections detail the results drawn from the quantitative data from the MAI, SAQ, MAIT, and learners' half-yearly exam results.

5.2.1 Analysis of the MAI

The analysis of the MAI questionnaire was vital in answering secondary research questions 2, 5, and 6.

- Secondary Research Question 2: What is the relationship between grade 11 learners' Physical Science half yearly examination results and their level of metacognitive awareness?
- Secondary Research Question 5: What is the relationship between learners' metacognitive awareness and their attitude towards Physical Science?
- Secondary Research Question 6: How does studying Western science impact on the metacognitive processes of the indigenous learners in South Africa?

This part of the analysis covers the state of metacognition of the learners, as concluded from the MAI results.

5.2.1.1 Reliability of the MAI questionnaire

The MAI was used to assess the metacognitive awareness of the grade 11 Physical Science learners. Table 5.2 illustrates the reliability calculated for the MAI and approved by the SCS of the NWU. The reliability was calculated once learners had completed all the MAI questionnaires. The quantitative data were extracted from the MAI and applied to the SPSS (SPSS Inc., 2016) software to calculate the Cronbach Alpha coefficients for reliability of the constructs of the MAI, SAQ, and the MAIT (see section 4.4.8). The questions referred to in parts 5.2.1.1 and- 5.2.1.11 are from the MAI shown as appendix 2. It is stated simply as a question followed by a number. For example, question 33 refers to question 33 from the MAI in appendix 2.

Table 5.2 Reliability of the MAI questionnaire

Construct	Question numbers	Cronbach's Alpha
	<i>Knowledge of cognition</i>	
Declarative knowledge	5;10;12;16;17;20;32;46	0.66
Procedural knowledge	3;14;27;33	0.45
Conditional knowledge	15;18;26;29;35	0.58
	<i>Regulation of cognition</i>	
Planning	4;6;8;22;23;42;45	0.71
Information management Strategies	9;13;30;31;37;39;41;43;47; 48	0.64
Comprehension monitoring	1;2;11;21;28;34;49	0.51
Debugging strategies	25;40;44;51;52	0.63
Evaluation	7;19;24;36;38;50	0.52

Alpha values from 0.7 to 0.95 are considered high (see section 4.4.8). Table 4.2 includes the Cronbach's Alpha constructs of both knowledge of cognition and regulation of cognition. Values from 0.6 to 0.7 are considered acceptable (see section 4.4.8). Therefore, constructs of declarative knowledge, planning, information

management strategies, and debugging strategies scored in the reliable range, illustrated in Table 5.2 above. However, the procedural knowledge, conditional knowledge, comprehension monitoring, and evaluation constructs scored alpha values too low to be considered reliable and was therefore rejected in the analysis (Fig 5.2).

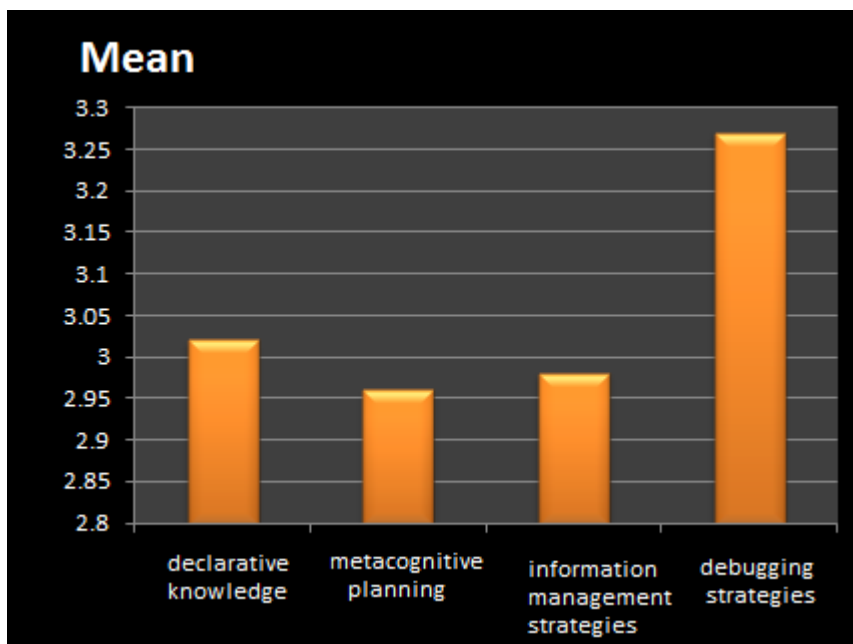


Figure 5.2: Mean values of the constructs of knowledge of cognition and regulation of cognition

Figure 5.2 summarises the mean values of the constructs of knowledge of cognition and regulation of cognition. This Figure provides an overview of the responses for each construct. The researcher used Figure 5.2 to gain a preliminary understanding of the responses before detailed analysis. Figure 5.2 shows that mean responses for the constructs are all above 2.9, and both declarative knowledge and debugging strategies are above 3. This implies that mean responses tend towards “agree”. The analysis below shows the breakdown of responses in greater detail. The validity of the analysis was assured by analysing each question thoroughly.

5.2.1.2 Descriptive statistics for the MAI questionnaire

Tables 5.3, 5.4, 5.5, and 5.6 replicate the descriptive statistics regarding declarative knowledge, metacognitive planning, information management strategies, and debugging strategies, respectively. The tables categorise the subcomponents of metacognition by their question numbers from the MAI. The number of learners responding to each question is denoted by the letter N.

The number 1 represents the option “strongly disagree”, and the maximum number 4 represents the option “strongly agree”. “Agree” is represented by the number 3 and “disagree” is represented by the number 2. The mean was calculated using this scoring system. The mean was taken as a reference point for each question during the data analysis.

The mean of the responses and the standard deviation are also included in the tables. A low standard deviation means the data are closely clustered around the mean, and a high standard deviation means the data are dispersed over a wider range of values. The standard deviation values were analysed to see whether the data are standard and expected, or unusual and unexpected. Standard deviations much above 0.5 are considered high, because they change the result of the mean response when added or subtracted. For example, a mean value of 3 (agree) will tend towards disagree or strongly agree if it is added or subtracted from a standard deviation of 0.6.

The percentage responses for each question were included in the table to give a clear picture of the results. Responses 1 and 2 and responses 3 and 4 were combined to narrow the spread and create a more definitive conclusion.

5.2.1.3 Descriptive statistics for declarative knowledge in the MAI questionnaire

Declarative knowledge is defined as the cognitive skills required to comprehend Physical Science theory that can be conveyed orally or in writing (see section 2.3).

Table 5.3 Descriptive statistics for the declarative knowledge of the MAI questionnaire

Metacognitive declarative knowledge							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
5	150	1	4	3.23	.680	30.0	70.0
10	151	1	4	2.96	.701	21.2	78.8
12	150	1	4	2.76	.711	33.0	67.0
16	150	1	4	2.81	.806	33.0	67.0
17	151	1	4	2.93	.775	30.0	70.0
20	151	1	4	2.83	.773	34.4	65.6
32	151	1	4	3.05	.657	17.0	83.0
46	150	1	4	3.61	.643	26.0	74.0
Average				3.02		28%	72%

Table 5.3 shows mean values calculated using the total number of learners (N) and learners' responses to the declarative knowledge part of the questionnaire (questions 5; 10; 12; 16; 17; 20; 32; and 46). The last row in Table 5.3 shows that the overall average of metacognitive declarative knowledge constructs of the MAI is 3.02. Table 5.3. shows that the mean values for questions 5, 32, and 46 are all above the value 3, surpassing the “agree” option. All the questions (5, 10, 12, 16, 17, 20, 32 and 46) regarding declarative knowledge have a mean above 2.5 (as seen from Figure 5.3), either approaching 3 (questions 10, 12, 16, 17 and 20) or exceeding it (questions 5, 32 and 46). This implies the average response of learners leans towards the “agree” response.

The standard deviation values for the dataset of questions 5; 10; 12; 16; 17; 20; 32; and 46 are larger by comparison to other items of the construct, which means that the responses for each question are further from the mean value than the other items of the construct. Overall, the descriptive statistics for the declarative knowledge part of the questionnaire shows that an average of 72% of learners are confident in their all-around declarative knowledge. This means that the majority of the learners are self-assured that they have acquired sufficient meta-skills to comprehend Physical Science theory during discussions or when written.

5.2.1.4 Descriptive statistics for metacognitive planning of the MAI questionnaire

Metacognitive planning is comprised of the selection of the most effective plan, and provision of resources to solve cognitive problems more successfully (see section 2.3 and 2.5).

Table 5.4 Descriptive statistics metacognitive planning of the MAI questionnaire

Metacognitive planning							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
4	151	1	4	2.91	.760	29.8	71.2
6	150	1	4	3.29	.669	9.0	91.0
8	151	1	4	2.80	.825	33.8	66.2
22	150	1	4	2.72	.696	40.7	59.3
23	151	1	4	2.99	.721	22.5	77.5
42	151	1	4	3.15	.709	16.0	84.0
45	150	1	4	2.84	.828	33.0	67.0
Average				2.96		26.4%	73.6%

Table 5.4 shows the mean values which were calculated using the total number of learners (N) and learners' responses concerning the metacognitive planning part of the questionnaire (questions 4; 6; 8; 22; 23; 42; and 45). The last row in Table 5.4 shows that the overall average of the metacognitive planning of the MAI is 2.96. This implies that the average responses for this construct were pointing towards "agree".

The standard deviation values for the dataset have a large standard deviation which means that the responses for each question are further than the mean value than the of the construct.

Overall, descriptive statistics for the metacognitive planning part of the questionnaire indicate that an average of 73.6% of learners are confident about their all-around metacognitive planning skills. This implies that most learners are self-assured of their ability to select the most effective plan and provide the necessary resources to solve cognitive problems successfully in Physical Science. However, 40.7% of learners felt that they do not ask themselves about the material resources before they start the activity (question 22);

5.2.1.5 Descriptive statistics for information management strategies of the MAI questionnaire

Information management strategies refer to the learners' cognitive ability to strategically access and absorb important information.

Table 5.5 Descriptive statistics for information management strategies of the MAI questionnaire

Metacognitive information management strategies							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
9	149	1	4	3.11	.649	13.4	86.6
13	150	1	4	3.09	.649	15.0	85.0
30	151	1	4	3.11	.572	10.0	90.0
31	151	1	4	2.87	.814	35.1	64.9
37	151	1	4	2.65	.967	45.0	55.0
39	151	1	4	3.20	.712	13.2	86.8
41	149	1	4	2.87	.618	25.0	75.0
43	151	1	4	3.08	.659	16.6	83.4
47	150	1	4	2.99	.839	26.0	74.0
48	149	1	4	2.79	.756	33.0	67.0
Average				2.98		23.2%	76.8%

Table 5.5 shows the mean values which were calculated using the total number of learners (N) and learners' responses, concerning the information management strategies part of the questionnaire (questions 9; 13; 30; 31; 37; 39; 41; 43; 47; and

48). The last row in Table 5.5 shows that the overall average of information management strategies of the MAI is 2.98. This implies that the average responses for this construct are pointing towards “agree”.

The standard deviation values for the dataset of question 30 was low, suggesting the item’s score was close to the mean of the dataset; however, questions 9; 13; 31; 37; 39; 41; 43; 47; and 48 have a large standard deviation by comparison to the rest of the items of the construct, which means that the score for each item are farther from the mean value than the other items of the construct..

Overall, the descriptive statistics for the information management strategies part of the questionnaire point to an average of 76.8% of learners being confident about their all-around information management strategies. Therefore, the majority of the learners felt they have the cognitive ability to strategically access and take in important information in Physical Science. However, 45 % of learners did not feel the need to use diagrams or pictures to understand information better in Physical Science (question 37).

5.2.1.6 Descriptive statistics for debugging strategies of the MAI questionnaire

Debugging strategies refer to learners’ cognitive ability to seek assistance or modify strategies when they have difficulty in the problem-solving task.

Table 5.6 Descriptive statistics for debugging strategies of the MAI questionnaire

Metacognitive debugging strategies							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
25	151	1	4	3.36	.706	9.3	90.7
40	151	1	4	3.03	.702	17.9	82.1
44	150	1	4	3.17	.588	8.7	91.3
51	149	1	4	3.31	.677	9.4	90.6
52	150	1	4	3.50	.610	3.3	96.7
Average				3.27		9.7%	90.3%

Table 5.6 shows mean values calculated using the total number of learners (N) and learners’ responses concerning the debugging strategies part of the questionnaire

(questions 25; 40; 44; 51; and 52). The last row in Table 5.6 shows that overall average of the debugging strategies of the MAI is 3.27. This suggests that average responses for this construct were pointing towards “agree”.

The standard deviation values for the dataset of question 44 is low, suggesting that the score lies closer to the mean of the dataset than the other items of the construct; however, questions 25, 40, 51, and 52 have large standard deviations by comparison, which means that the scores for those questions are much further from the mean values.

Overall, the descriptive statistics for the debugging strategies part of the questionnaire show that an average of 90.3% of learners are confident in their all-around skills for debugging strategies. This shows that the large majority of learners believe they have the cognitive ability to seek assistance or modify strategies when they have difficulty in a problem-solving task in Physical Science.

5.2.1.7 Conclusion of the descriptive statistics for the MAI questionnaire

The analysis for the MAI concludes that the majority of learners feel comfortable in their declarative knowledge, planning, information management strategies, and debugging strategies components of their metacognitive skills. Using the Cronbach Alpha values, the constructs of declarative knowledge, planning, information management strategies, and debugging strategies all scored in the reliable range (see Table 5.2). Tables 5.3, 5.4, 5.5, and 5.6 showed that more than 72% of the responses for each construct of the MAI scored between 3 and 4.

The procedural knowledge, comprehension monitoring, conditional knowledge, and evaluation constructs could not be analysed further due to their low Cronbach Alpha values. These constructs are examined in detail during the qualitative part of the research. All data collected will be triangulated to draw conclusions.

Despite the majority of learners feeling assured in their metacognitive awareness a large minority of

- 40.7% of learners felt that they did not ask themselves about the material before they start the activity (question 22);
- 45 % of learners did not feel the need to use diagrams or pictures to understand information better (question 37).

Overall the learners were self-assured in their all-around declarative knowledge meta-skills (72%), all-around metacognitive planning skills (73.6%), all-around information management strategies (76.8%), and all-around skills for debugging strategies (90.3%).

5.2.2 Analysis of the SAQ

The analysis of the SAQ questionnaire was key in answering secondary research question 5.

Secondary Research Question 5: What is the relationship between learners' metacognitive awareness and their attitude towards Physical Science?

This part of the analysis focused on learners' attitude towards science as concluded from the results of the SAQ.

5.2.2.1 Reliability of the SAQ questionnaire

The SAQ was used to assess learners' attitude towards science and their feelings about their cultural attitudes towards science. Table 5.11 illustrates reliability calculated for the SAQ, approved by the Statistical Consultation Services of the NWU. Reliability was calculated once all the SAQ questionnaires were completed by learners.

The quantitative data were extracted from the SAQ to use the SPSS (SPSS Inc.,2016) software to calculate the Cronbach Alpha coefficients for reliability and was approved by the SCS of the NWU (see section 4.4.4). Questions referred to in part 5.2.2.1 to 5.2.2.7 are from the SAQ in Appendix 3. It is simply stated as a

question followed by a number. For example; question 33 refers to question 33 from the SAQ in Appendix 3.

Table 5.7 Reliability of the SAQ

Construct	Question numbers	Cronbach's Alpha
Positive attitude towards science	1;6;9;12;15;19;21;22;25;28;32;39;45	0.85
Negative attitude towards science	2;7;8;14;16;20;33;36;41;42;44	0.73
Future intention of the study in science	5;11;18;23;27;40	0.82
Science in school	3;10;13;35	0.75
Impact of science on our daily lives	4;17;26;30;34;37	0.71
Approval by friends and family	24;29;31;38;	0.48
Cultural influence on science attitudes	46-54	0.42

The usual interpretation of Cronbach Alpha means alpha values between 0.7 and 0.95 are considered high, and values between 0.7 and 0.6 is considered acceptable to be (Tavakol & Dennick, 2011:54). Therefore, constructs of positive attitude, negative attitude, future intention, science in school, and the impact of science, as shown in Table 5.11, have high Cronbach Alpha values and are considered very reliable. However, the approval of friends and family, and cultural influences scored too low to be considered reliable. Therefore, they were not dealt with as constructs in this part of the research.

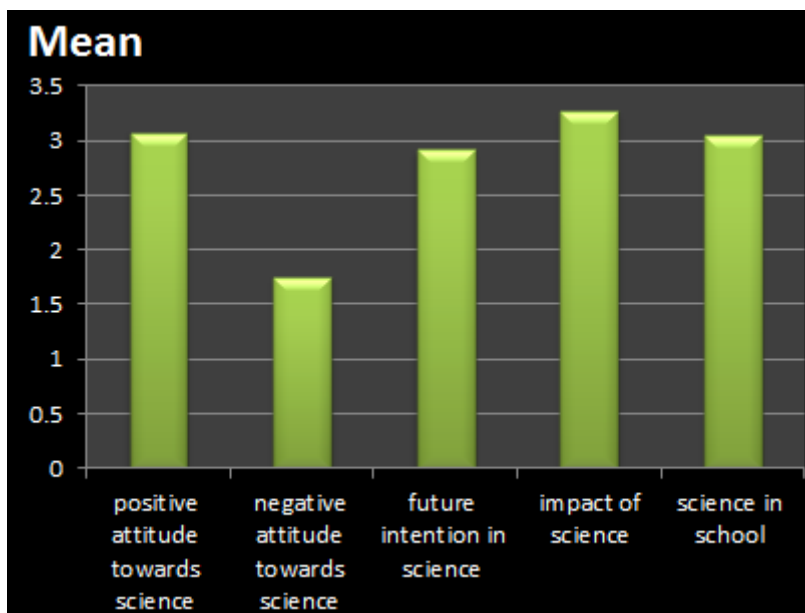


Figure 5.3: Mean values of the seven constructs of the SAQ

Figure 5.3 summarises the mean values of the constructs of the SAQ. This graph provides an overview of the responses for each construct. The researcher used the graph for a preliminary understanding of the responses before it was analysed in detail. Figure 5.3 shows that the mean responses for the SAQ constructs cluster around 3 (agree), except for the negative attitude construct, which approaches 2 (disagree). The analysis below shows the breakdown of responses in greater detail by analysing each question thoroughly, thereby assuring the validity of the analysis.

5.2.2.2 Descriptive statistics for the SAQ questionnaire

Tables 5.8, 5.9, 5.10, 5.11, and 5.12 replicate the descriptive statistics regarding positive attitude towards science, negative attitude towards science, future intention to study science, science in school, and the impact of science in our daily lives. The standard deviation values were handled in the same way that 5.2.1.1 was handled.

As in parts 5.2.1.1 to 5.2.1.11, the Tables 5.8, 5.9, 5.10, 5.11, and 5.12 categorise subcomponents of the SAQ regarding their question numbers. The number of learners responding to each question was denoted by the letter N. Similarly, to 5.2.1.1, the percentage responses were included to give a clear picture of the results concerning the percentage response for each question.

5.2.2.3 Descriptive statistics for the positive attitude construct of the SAQ

The positive attitude construct of the SAQ assesses learner motivation and enthusiasm for science.

Table 5.8 Descriptive statistics for a positive attitude towards science construct of the SAQ

Positive attitude towards science construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
1	147	1	4	3.25	.508	3.4	96.6
6	151	1	4	3.16	.612	10.6	89.4
9	146	1	4	2.98	.906	24.0	76.0
12	150	1	4	2.08	.700	75.3	24.7
15	150	1	4	2.88	.827	28.7	71.3
19	151	1	4	3.21	.686	11.3	88.7
21	151	1	4	3.39	.611	5.3	94.7
22	151	1	4	3.18	.633	8.6	91.4
25	150	1	4	3.11	.719	16.7	83.3
28	151	1	4	2.79	.899	31.8	68.2
32	150	1	4	3.12	.665	14.0	86.0
39	148	1	4	3.68	.498	31.1	68.9
45	150	1	4	3.11	.848	20.0	80.0
Average				3.07		21.6%	78.4%

Table 5.8 shows mean values, calculated using the total number of learners (N) and learners' responses concerning attitude towards the science construct part of the questionnaire (questions 1, 6, 9, 12, 15, 19, 21, 22, 25, 28, 32, 39, and 45). The last row in Table 5.8 shows that the overall average of the positive attitude constructs of the SAQ is 3.07. This implies that the average responses for this construct were tending towards "agree". Questions 1, 6, 9, 15, 19, 21, 22, 25, 28, 32, and 45 are clustered around the value 3, which inclines towards the "agree" option. Question 39 is approaching 4, which is the "strongly agree" option. Question 12 results lie closely around 2, which suggests that the average learner feels science is difficult.

The standard deviation values for the dataset of questions 1 and 39 are low, therefore indicating that the data are closer to the mean of the dataset than other items of the construct. However, questions 6, 9, 12, 15, 19, 21, 22, 25, 28, 32, and 45

have large standard deviations by comparison to other items of the construct, which means that the scores for each question lie further from the mean value.

Despite the majority of learners leaning towards “agree” and “strongly agree”, 75.3% of learners felt that science is not easy (question 12). Overall, the descriptive statistics for the positive attitude construct of the SAQ indicate that an average of 79.4% of learners have a positive attitude towards science.

5.2.2.4 Descriptive statistics for the negative attitude construct of the SAQ

The negative attitude construct of the SAQ assessed learners’ demotivation and disinterest in science.

Table 5.9 Descriptive statistics for negative attitude towards science construct of the SAQ

Negative attitude towards science construct of the SAQ							
Question	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
2	148	1	4	1.43	.766	91.2	8.8
7	146	1	4	1.73	.773	88.4	11.6
8	149	1	4	2.07	.819	75.2	24.8
14	148	1	4	1.76	.762	85.4	14.6
16	150	1	4	1.77	.725	89.3	10.7
20	151	1	4	1.83	.844	82.1	17.9
33	147	1	4	1.75	.826	85.0	15.0
36	148	1	4	1.95	.852	78.4	21.6
41	150	1	4	1.25	.504	97.4	2.6
42	149	1	4	2.21	.910	67.8	32.2
44	149	1	4	1.50	.684	93.0	7.0
Average				1.75		84.8%	15.2%

Table 5.9 shows the mean values which were calculated using the total number of learners (N) and learners’ responses concerning the negative attitude construct part of the SAQ (questions 2; 7; 8; 14; 16; 20; 33; 36; 41; 42; and 44). The last row in Table 5.9 shows that the overall average of negative attitude constructs of the SAQ is 1.75. This suggests that the average responses for this construct were close to “disagree”. The mean values for questions 7, 8, 14, 16, 20, 33, 36, 42, and 44 are clustered around the value 2, which is approaching the “disagree” option. Questions

2 and 41 are closer to 1, which is the “strongly disagree” option. Collectively, the average response of learners’ trends towards “disagree” concerning the statements of the negative attitude construct of the SAQ.

The standard deviation values for the dataset of question 41 are low, suggesting that the data are closer to the mean of the dataset than the other items of the construct. However, questions 2, 7, 8, 14, 16, 20, 33, 36, 42, and 44 have large standard deviations by comparison to other items of the construct, which means that the scores for each question are further from the mean value.

Overall, the descriptive statistics for the negative attitude construct of the SAQ show that 84.8% of learners do not align themselves with a negative attitude towards the science construct. The learners had a positive attitude towards science.

5.2.2.5 Descriptive statistics for the future intention of study in science construct of the SAQ

Future interest in science construct assessed learners’ future intention to further their studies in science.

Table 5.10 Descriptive statistics for future intention in science construct of the SAQ

Future intention in science construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
5	150	1	4	3.06	.936	23.3	76.7
11	150	1	4	3.41	.625	6.0	94.0
18	150	1	4	2.05	.758	78.0	22.0
23	150	1	4	2.91	.843	28.0	72.0
27	150	1	4	3.19	.781	16.0	84.0
40	148	1	4	2.83	.803	33.8	66.2
Average				2.91		30.9%	69.1%

Table 5.10 shows the mean values calculated using the total number of learners (N) and learners' responses, concerning the future intention in science part of the questionnaire (questions 5; 11; 18; 23; 27; and 40). The last row in Table 5.10 shows that the overall average of the future intention in science construct is 2.91. This implies that the average responses for this construct lay close to “agree”. The mean

values for questions 5, 11, 23, 27, and 44 clustered around the value 3, which points towards the “agree” option. Question 18 is approaching 2, which is the “disagree” option. Collectively, the average response of learners is leaning towards the “agree” response concerning future intention in science construct.

The standard deviation values for the dataset of questions are large, which means that the scores for each question are substantially far from the mean.

Despite a 69% majority of the learners’ responses steering towards “agree” and “strongly agree” to considering a future in science, 78% of the learners felt they would not become scientists in the future (question 18). This is concerning, because this implies that most of the learners studying Physical Science don’t see themselves becoming scientists.

5.2.2.6 Descriptive statistics for the impact of science construct of the SAQ

The impact of science construct assessed learners’ awareness of science in their everyday lives.

Table 5.11 Descriptive statistics for the impact of science construct of the SAQ

Impact of science on our daily lives construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
4	148	1	4	3.20	.791	14.9	85.1
17	151	1	4	3.12	.711	17.2	82.8
26	150	1	4	3.46	.701	8	92.0
30	149	1	4	3.32	.658	9.4	90.6
34	148	1	4	3.07	.706	16.8	83.2
37	147	1	4	3.40	.616	5.4	94.6
Average				3.26		12.0%	88.0%

Table 5.11 shows the mean values which were calculated using the total number of learners (N) and learners' responses concerning the impact of science part of the questionnaire (questions 4; 17; 26; 30; 34; and 37). The last row in Table 5.11 shows that the overall average in the impact of science constructs is 3.26. This implies that the average responses for this construct were pointing towards “agree”.

The standard deviation values for the dataset were large, which means that the scores for each question are substantially far from the mean value.

The 88% majority of learners gave responses tending towards “agree” and “strongly concluding that a large majority of learners were aware that science plays a big role in their everyday lives.

5.2.2.7 Descriptive statistics for the science in school construct of the SAQ

The science in school construct assessed learners’ attitudes towards science in their learning environment.

Table 5.12 Descriptive statistics for the science in school construct of the SAQ

Science in school construct of the SAQ							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
3	147	1	4	2.99	.731	21.8	78.2
10	150	1	4	3.09	.854	17.3	82.7
13	150	1	4	3.27	.858	13.3	86.7
35	148	1	4	2.84	.871	29.1	70.9
Average				3.05		20.4%	79.6%

Table 5.12 shows the mean values calculated using the total number of learners (N) and learners' responses concerning the science in school part of the questionnaire (questions 3; 10; 13; and 35). The last row in Table 5.12 shows that the overall average of the science in school construct of the SAQ is 3.05. This implies that the average responses for this construct were pointing towards “agree”, which suggests the average learner has a positive attitude towards science taught in the school.

The standard deviation values for the dataset of questions have a large standard deviation, which means that the scores for each question are substantially far from the mean value.

Overall, the descriptive statistics for the construct suggested that an average of 79.6% of learners had positive attitudes towards science in their learning environment.

5.2.2.8 Conclusion of the descriptive statistics for the SAQ questionnaire

The descriptive statistics for the positive attitude construct of the SAQ indicate that an average response of 79.4% points to the learners feeling motivated and optimistic about science (see section 5.2.2.3.). The 88% majority of learners were aware that science plays a big role in their everyday lives (see section 5.2.2.6.). However, the mindset of the learners regarding their future intention in science is compounded by 75.3% of learners feeling that science is difficult. There seems to be a conflict between learners' attitudes towards science and their mindsets towards science. The positive attitude construct and the negative attitude towards science construct of the SAQ suggested the majority of learners are motivated and optimistic. However, the analysis of future intention in science suggests that learners have negative mindsets with regards to their future interest in science. 78% of the learners felt they would not become scientists in the future (see section 5.2.2.5.). This could be because a majority of 75.3% of learners felt that science is difficult. This will be addressed further in the integration part of the results.

5.2.3 Analysis of the MAIT

Analysis of the MAIT questionnaire was essential in answering secondary research question 7: To what extent are Physical Science teachers metacognitive thinkers?

This part of the analysis focused on the metacognitive awareness of the teachers. Analysis of the MAIT is similar to the analysis completed in part 5.2.1 of this study where Tables 5.13., 5.14., and 5.15. summarise the statistics of the components of the metacognitive knowledge, metacognitive regulation, and promotion of metacognition from the MAIT, also including the percentage responses of each question and the standard deviation values. Due to the small number of teachers represented in this part of the quantitative analysis, all the components of metacognitive knowledge were combined and analysed separately. This was also done for metacognitive regulation and the promotion of metacognitive awareness constructs of the MAIT. This data was briefly summarised for the relevant data required for the study in order to minimise replication of unnecessary data

5.2.3.1 Reliability of the MAIT questionnaire

The MAIT was used to assess the metacognitive awareness of grade 11 Physical Science teachers and the extent to which they promote metacognitive awareness in the classroom. The population sample of teachers was too small to do a factor analysis. However, conclusions drawn from the data were cautiously used in conjunction with other data collected and triangulated to draw valid conclusions. The analysed data were essential for the outcomes of the study. The questions referred to in parts 5.2.3.1 to 5.2.3.5 are from the MAIT shown in appendix 4. It was simply stated as a question, followed by a number. For example; question 33 refers to question 33 from the MAIT in appendix 4.

5.2.3.2 Descriptive statistics for the metacognitive knowledge of teachers

Metacognitive knowledge is described as that part of the teachers stored world knowledge that deals with thinking, attaining goals, activities, and capabilities. Its subcomponents are declarative knowledge, procedural knowledge, and conditional knowledge (see section 2.4.3.).

Table 5.13 Descriptive statistics for the metacognitive knowledge in the MAIT questionnaire

Metacognitive declarative knowledge							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
1	7	1	4	3.14	1.069	29	71
7	7	1	4	3.43	0.535	0	100
13	7	1	4	3.43	0.535	0	100
19	7	1	4	3.71	0.488	0	100
Average				3.43		7.25%	92.75%
Metacognitive procedural knowledge							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
2	7	1	4	3.29	1.113	14	86
8	7	1	4	3.43	0.535	0	100
14	7	1	4	3.29	0.488	0	100
20	7	1	4	3.14	0.690	14	86
Average				3.29		7.0%	93.0%
Metacognitive conditional knowledge							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
3	7	1	4	3.00	1.155	29	71
9	7	1	4	3.43	0.787	14	86
15	7	1	4	3.29	0.756	14	86
21	7	1	4	3.29	0.488	0	100
Average				3.25		14.25%	85.75%

Table 5.13. shows the mean values which were calculated using the total number of teachers (N) and teachers' responses to the items in the metacognitive knowledge constructs part of the questionnaire. Table 5.13. shows the averages of the subcomponents of metacognitive knowledge were all above 3 and below 3.5. This shows that average responses for this construct were tending towards "agree".

The standard deviation values for the dataset of questions 4, 7, 8, 13, 19, and 21 are low, therefore suggesting the scores are closer to the mean of the dataset than the other items of the constructs. On the other hand, question 1, 2, 9, 15, and 20 has a large standard deviation by comparison to the rest of the items of the constructs, which means that the score for its dataset are further from the mean value than the other items of the constructs.

Overall descriptive statistics for the metacognitive knowledge part of the MAIT questionnaire found averages above 85% of the responses selected options 3 or 4 suggesting that the teachers were very confident with their declarative, procedural, and conditional knowledge meta-skills.

5.2.3.3 Descriptive statistics for the metacognitive regulation component in the MAIT questionnaire

Metacognitive regulation facilitates the learning process and is classified as planning, monitoring, and evaluating (see section 1.4.3.1.).

Table 5.14 Descriptive statistics for the metacognitive regulation in the MAIT questionnaire

Metacognitive planning							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
4	7	1	4	3.14	0.378	0	100
10	7	1	4	3.43	0.535	0	100
16	7	1	4	3.00	0.577	14	86
22	7	1	4	3.14	0.378	0	100
Average				3.18		3.5%	96.5%
Metacognitive monitoring							
Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
5	7	1	4	3.29	0.488	0	100

Table 5.14 Descriptive statistics for the metacognitive regulation in the MAIT questionnaire (continued)

11	7	1	4	3.14	0.378	0	100
17	7	1	4	3.57	0.535	0	100
23	7	1	4	3.00	0.577	14	86
Average				3.25		3.5%	96.5%

Metacognitive evaluation

Questions	N	Minimum	Maximum	Mean	Std. Deviation	% response of 1 and 2	% response of 3 and 4
6	7	1	4	3.14	0.378	0	100
12	7	1	4	3.29	0.488	0	100
18	7	1	4	3.00	0.577	14	86
24	7	1	4	3.14	0.378	0	100
Average				3.14		3.5%	96.5%

Table 5.14. show the averages of the metacognitive regulation constructs of MAIT questionnaire are above 3. This implies that the average responses for these constructs point towards “agree”.

A low standard deviation values for all the datasets from the metacognitive regulation questions suggests that the scores are substantially close to the mean.

Overall descriptive statistics for the metacognitive regulation part of the MAIT questionnaire found averages above 96% of the responses selected options 3 or 4. This suggests that the teachers were very confident with their metacognitive regulation.

5.2.3.4 Descriptive statistics for the promoting metacognition component in the MAIT questionnaire

The promotion of metacognition section refers to the teacher’s ability to integrate metacognitive strategies during the pedagogical process of a Physical Science lesson.

Table 5.15 Descriptive statistics for the promoting metacognition component in the MAIT questionnaire

Promoting metacognition					
Questions	N	Minimum	Maximum	Mean	Std. Deviation
25	7	1	4	3.14	0.378
26	7	1	4	3.14	0.378
27	7	1	4	3.29	0.488
28	7	1	4	3.00	0.577
29	7	1	4	3.29	0.488
30	7	1	4	3.43	0.535
31	7	1	4	3.43	0.535
32	7	1	4	3.57	0.535
33	7	1	4	2.86	0.690
34	7	1	4	3.14	0.378
35	7	1	4	3.14	0.690
36	7	1	4	3.29	0.488
37	7	1	4	3.00	0.577
38	7	1	4	3.57	0.787
39	7	1	4	3.71	0.488
40	7	1	4	3.71	0.488
Average				3.29	

The last row in Table 5.15 shows that the overall average of the promoting metacognition component in the MAIT questionnaire is 3.29. This implies that the average responder to this construct were inclined to choose “agree”.

The standard deviation values for the dataset of questions 25-32, 34-37, 39 and 40 are low, therefore suggesting the scores are closer to the mean of the dataset than the other items of the construct; however, questions 33 and 38 have a large standard deviation by comparison, which means the scores are far from the mean value than the other items of the construct.

An average of 94.69% of the responses to the promoting metacognition construct selected 3 or 4 implying that the teachers were confident that they promote metacognitive awareness effectively.

5.2.3.5 Conclusion of the descriptive statistics for the MAIT questionnaire

The overall analysis of the mean values and the frequency of responses to the MAI questionnaires concluded that most teachers' felt confident in their metacognitive awareness and how effectively they promoted metacognitive awareness during teaching.

5.2.4 Analysis of the half-yearly exam results

The analysis of the half-yearly results was vital in answering secondary research question 2.

Secondary Research Question 2: What is the relationship between grade 11 learners' Physical Science half yearly examination results and their level of metacognitive awareness?

This part of the analysis focused on the results of learners' half-yearly Physical Science examination.

The exam question papers were analysed to assess where the foci of the examination were. To assess what forms of learning was rewarded within the examination Table 5.16. was constructed applying Bloom's Revised Taxonomy (see section 2.7.) to the examination questions. The marks awarded were distributed according to the level of thinking required within each question (see Table 5.16. below).

Table 5.16 Percentage of marks allocated to each thinking process associated to Bloom's Revised Taxonomy

Thinking process	Physics %	Chemistry %
Remembering	12.7	16.0
Understanding	14.7	28.7
Applying	51.3	37.0
Analysing	10.0	8
Evaluation	11.3	9.0
Creating	0.0	1.3

From Table 5.16. we see that the Physics examination paper included all the thinking processes of Bloom's Revised Taxonomy except creating. Most of the questions of the Physics examination required applying Physics knowledge. The second most tested thinking process was understanding of Physics theory but only consisted of 14.7% of the marks awarded as compared to 51.3% of the questions associated to the applying thinking process. Remembering, analysing, and the evaluation thinking process were closer to 10% of the marks awarded for each.

The Chemistry examination was similar to the Physics examination with respect to the analysing and evaluation thinking rewarded (see Table 5.16.). However, it emphasised more on the remembering (16%) and understanding (28%) thinking process as compared to the Physics examination (see Table 5.166). The percentage of questions requiring understanding of Chemistry knowledge (28.7%) was much more than the same thinking process tested in the Physics examination (14.7%). Despite the majority of the Chemistry examination requiring application of Chemistry knowledge, it was 14.3% marks lower than the Physics examination. 1.3% of the Chemistry examination tested the learners' ability to generate new ideas, whilst the Physics examination did not test this thinking process. Overall, the examination tested all aspects of the thinking processes associated with the Bloom's Revised Taxonomy, focusing mainly on application of scientific knowledge and to a lesser extent remembering, understanding, analysing, and evaluation thinking processes.

Metacognitive awareness plays a key role if a learner wanted to be successful in answering questions associated with these thinking processes.

As a standalone point, which is important in this study, it is clear from the analysis of the Physical Science examination paper that indigenous knowledge is not rewarded in the examination. This is discussed in more detail in section 5.3.1.

Despite a minority of learners feeling they lack certain key elements in their motivation towards science and their metacognitive ability, the overall quantitative data from the MAI and the SAQ suggest that a significant majority of learners are confident they have a high level of metacognitive awareness (see section 5.2.1), are motivated towards science, and have a positive attitude towards learning science (see section 5.2.1). The teachers felt confident in their metacognitive awareness in the classroom and believed they promoted metacognitive skills effectively in their teaching and learning process (see section 5.2.3).

According to the literature reviewed in this research, the data from the MAI, SAQ, and MAIT (see section 5.2.1.-5.2.3.) suggests that the majority of learners should produce good results in their half-yearly Physical Science examination (see section 1.1.1; 1.3; 1.4.2; 1.4.3.1).

Due to the significant majority of the participants giving similar responses to MAI, SAQ and MAIT, the researcher decided to analyse the half-yearly results collectively instead of breaking it down per school. Table 5.17. summarises the exam results.

Table 5.17 Percentage breakdown of the half-yearly exam results

Highest %	Lowest %	Average %	Below 30%	From 30 to40%	From 41 to50%	From 51 to60%	From 61 to74%	75% and above
80.0	4.0	41.0	24.3	27.1	20.7	15.0	6.4	6.4

It is immediately apparent that results found in Table 5.17. do not meet the theoretical expectations regarding the results of the MAI, SAQ, and the MAIT. Nearly three-quarters (72%) of learners achieved 50% and less in their examinations. Only one learner achieved a mark of 80%, while 6.4% of learners achieve 75% above.

24% of learners achieved 30 % and less. These results admit that the majority of learners achieve poorly in the Physical Science examination.

To endeavour more access for learners obtaining university entrance and becoming world-class scientists, learners achieving below 50% need to be reduced, and those above 50% need to be increased. The centre of attention should be squarely on encouraging more learners to achieve 75% and above. The results from Table 5.17. reflect the research by Barry (2014), Reddy et al. (2015) and HSRC (2011), discussed in section 1.1 and 1.1.1 of this study.

The examination as an assessment tool gauges the degree to which competence is achieved (Novack et.al. 2005:1). A high quality assessment enables high quality knowledge (Novack et.al. 2005:1). The researcher views a high quality assessment as multidimensional, which assess the competence of the learner in Physical Science through real-world context and indigenous knowledge, as well as assessing metacognitive skills. Through assessments Physical Science skills, culture , and higher ordered thinking skills could be encouraged and rewarded.

As discussed in section 1.1.2. the Physical Science examination does not reward metacognitive tasks directly. Moreover, it is evident from the half-yearly examination analysis, the examination does not reward indigenous knowledge and metacognitive skills. Learners may question time and efforts spent on cognitively demanding meta-tasks not being rewarded in their main examination. Thomas (2002:240) further notes that the school and classroom environments can drive learners to greater efforts to achieve academic success in form of high grades in examination, instead of valuing critical thinking (see section 3.5.). This becomes socially acceptable because learners are then examination-driven rather than focused on higher ordered thinking skills. This point will be discussed further in section 6.2.3.3. The perceived metacognitive awareness of the participants contradicts the results attained in their half-yearly examination. The data that were analysed in the quantitative analysis need to be looked at more closely in conjunction with qualitative data to rationalise the conflicting results.

5.2.5 Conclusion of the quantitative data

The analysis of the MAI, SAQ, and the MAIT suggest that the participants have well developed metacognitive awareness and that learners are motivated towards science. The teachers and learners were confident in their metacognitive awareness and the teachers felt they promoted metacognitive awareness effectively (see sections 5.2.1 and 5.2.3).

With reference to the secondary research question 5 (see section 1.5), analysis of the MAI and SAQ suggests that the majority of learners felt confident in their metacognitive awareness (see section 5.2.1) and had a positive attitude towards science (see section 5.2.2). However, 75.3% of learners felt that science is difficult (see question 12 of the SAQ in Table 5.15). This is a crucial point. Despite learners having a positive attitude towards science, they still find science difficult. This leads to answering secondary research question 2 (see section 1.5), namely, what is the relationship between learners' Physical Science examination results and their level of metacognitive awareness?

Noting the learners' apparent confidence in their metacognitive ability using the MAI, their attitude towards science using the SAQ, and the teachers' confidence in effectively promoting metacognition; we find that the analysis of the half-yearly results concludes that their academic examination results is low (see section 5.2.4). The MAI, SAQ and MAIT results did not align with the theoretical assumption that good metacognitive skills result in good attainment (Hartman, 2001:198; Holmes, 2007:15; Jayapraba, 2013:165-166; McCraight-Wertz, 1999:14; Sinatra & Taasoobshirazi, 2011:213-214) or that a positive attitude in science results in good achievement (Holmes, 2007:15; McCraight-Wertz, 1999:14). Table 5.17 shows that the average mark achieved by the 151 learners participating in this research was 41%, with the majority of learners achieving below 50%. With reference to the secondary research question 2, the analysis of the MAI and half-yearly results suggest that despite learners' confidence in their metacognitive skills, they performed poorly in their half-yearly Physical Science examination.

It is possible that participants overestimated themselves during completion of the MAI and MAIT due to an effect known as self-presentation (see section 4.4.9). Research by Huszti et al. (2016:68-80) and Siegesmund (2016:204-214) found that research participants tend to exaggerate their metacognitive ability when asked to self-assess their metacognitive awareness and this may have likely occurred in this research (see section 4.4.9). Furthermore, results from met-activity questionnaires seldom align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). The researcher examined the quantitative and qualitative data carefully during the triangulation process to avoid contradictions in the theoretical assumptions of the MAI, SAQ, MAIT, and the half-yearly results.

5.3. Qualitative research data analysis and interpretation

The following sections critically analyse qualitative data collected from the curriculum document analysis, learner interviews, teacher interviews, classroom observations, and science notebooks. When required, the researcher referred to literature, coded vital information, and selected pictures of science notebooks, to present definitive and valid conclusions.

5.3.1 Curriculum document analysis

The analysis of the CAPS Physical Science document was vital in answering secondary research question 1.

Secondary Research Question 1: To what extent does the South African Physical Science curriculum promote metacognition?

The aim of the document analysis was to analyse the South African Physical Science curriculum to determine the extent to which it promotes metacognition (research aim 1). Due to the multi-dimension nature of metacognition, the curriculum document analysis assessed whether the curriculum promoted metacognitive awareness by evaluating the extent it supported scientific enquiry, the effectiveness of the curriculum design, and the promotion of indigenous knowledge. Scientific

enquiry and inclusion of indigenous knowledge within the Physical Science curriculum promote metacognitive awareness (section 4.5.3.). A successful curriculum design which also includes effectiveness and coherence in the form of articulation, depth, progression, continuity, sequence, balance, and scope and in turn support other components of the curriculum such as metacognitive awareness (section 4.5.3.). The researcher analysed the components of the CAPS Physical Science curriculum to determine whether the curriculum was a theoretically effective design.

Section 2.8. showed that the South African Physical Science curriculum was an enquiry-based curriculum. The Physical Science curriculum is guided by the content of the physical and chemical phenomena in nature through scientific enquiry of scientific models, theories, and laws (DBE, 2011:6). This implied that the curriculum promoted metacognition by promoting scientific enquiry (see 4.5.3.). The following part of the analysis focuses on the components of an effective curriculum design and indigenous knowledge within the curriculum.

5.3.1.1 Horizontal articulation

Horizontal articulation is concerned with the harmonised integration of cross-curricula knowledge and experiences in the curriculum plan (Kridel, 2010:771). To test for the horizontal articulation of the South African Physical Science curriculum, the researcher analysed the CAPS for Physical Science, mathematics, and biology. Learners might choose between science with mathematics, or the two science options, or the two science options with mathematics. Therefore, successful horizontal articulation reinforces key skills required in science and mathematics.

Key skills like graph interpretation and analysis are essential in Physical Science units, such as

- graphs of motion (DBE, 2011:56);
- ideal gas law graphs (DBE, 2011:11);
- exothermic and endothermic graphs (DBE, 2011:91);
- general types of graph analysis of practical work (DBE, 2011:98);

- graphs showing rates of reaction (DBE, 2011:123);
- chemical equilibrium graphs (DBE, 2011:126) etc.

Knowledge and skills in graph interpretation and analysis are horizontally articulated in mathematics units such as functions and graphs, which progress from grade 10 to grade 12 (DBE, 2011:10). Life science (biology) introduces graphs in

- orientation to biology (DBE, 2011:22);
- use of micrographs to find the size of the specimen (DBE, 2011:25);
and
- practical work (DBE, 2011:16; 32; 42; 49).

Trigonometric ratios in mathematics (DBE, 2011:17) are horizontally articulated, in the section on vectors in physics (DBE, 2011:61). Organic chemistry and inorganic chemistry are crossed over in both biology (DBE, 2011:10) and Physical Science (DBE, 2011:104; 138).

Modelling Physical Science, mathematics, and biology education at all levels is crucial in building problem-solving competency during the teaching and learning process (Michelsen, 2015:489-491). Horizontal articulation provides learners with the ability to articulate crucial problem-solving skills in mathematics (Michelsen, 2015:493). Modelling problem solving in mathematics and science, similar to Figures 2.9 and 2.10, triggers cognitive and metacognitive thinking skills such as setting goals; defining problems; recalling; encoding; inferring; verifying; predicting; elaborating; restructuring; ordering; classifying; observing, and formatting questions (Barbacena & Sy, 2015:18). Horizontally articulated modelling in mathematics, Physical Science, and biology promote metacognitive skills in problem solving.

The Physical Science curriculum in South Africa is horizontally articulated with mathematics and biology. This allows learners to experience relevance in those subjects by ensuring that science and mathematics are not stand-alone subjects and showing that key problem-solving skills are required throughout the curriculum. Modelling in problem solving, key skills, and content is crossed over during the implementation of the mathematics, Physical Science, and biology curricula.

5.3.1.2 Scope and depth

The scope of the curriculum denotes all that is covered by the curriculum plan and is focused on the activities selected and the goals set (Lund & Tannehill, 2010:46).

The South African curriculum sets a clear overall scope for curriculum design and guides for teaching and learning activities (DBE, 2011:4-5). Some of the key elements in the scope of the curriculum, as set out by the general aims of the curriculum, include (DBE, 2011:4-5):

- learning skills and knowledge that have real-life applications;
- giving skills and knowledge that allow learners access to higher education;
- encouraging social transformation to eradicate the ripple effects of apartheid;
- having high expectations in obtaining skills and knowledge; and
- valuing indigenous knowledge.

The scope reinforces motivation for active learning, critical thinking, and problem solving (DBE, 2011:5). Active learning includes activity-based tasks that stimulate cognitive skills, such as critical thinking, creativity, and problem solving that lead to effective learning (Rusbult, 2007). Active learning during problem solving encourages learners to plan strategies and become self-aware, thereby stimulating metacognitive awareness (Rusbult, 2007). Bransford et al. (2003:12) suggest that active learning techniques during tasks promote “sense-making, self-assessment, and reflection on what worked and what needs improving”, thereby associating active learning to metacognition. The general aims of the South African Physical Science curriculum set a clear scope which promotes metacognition and acknowledges indigenous knowledge.

The specific aims of the curriculum also define its scope. The specific aims emphasise scientific enquiry (designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising) and reflective skills (DBE, 2011:8). Reflective skills facilitate metacognition by getting learners involved in goal setting (informal activities to evaluate learning goals) and summative (formal) assessments

(Desautel, 2009:2002). The nature and practise of scientific enquiry are highly dependent on metacognitive skills to understand and regulate scientific activities (Barbara et al., 2009:175). Integrating metacognitive skills into the “thinking curriculum” is an effective way in fostering higher ordered thinking (Gilbert, 2005:21; Renick & Klopfer 1989:3-4; Schraw et al., 2006:119; White & Frederiksen, 1998:5-6). A “thinking curriculum” in Physical Science is an enquiry-based curriculum which promotes metacognition (Schraw et al., 2006:118, White & Frederiksen, 1998:4-5). The South African Physical Science “curriculum is a thinking curriculum”.

The six main knowledge areas covered by the Physical Science curriculum are matter and materials; chemical systems; chemical change; mechanics; waves, sound and light; and electricity and magnetism (DBE, 2011:8). The content, concepts, and skill statements provide the basis of the scope of the topics to be covered and limit their levels of complexity. The statements act as a guide to the curriculum’s depth. The scope of the curriculum provides the teacher with ideas on how to plan activity-based tasks and reinforce scientific enquiry, as well as metacognitive awareness. To test whether the Physical Science curriculum has a clear scope, the researcher evaluated, as an example, the scope of the topic motion from grade 10. In grade 10, the depth to which motion should be taught is specified by task words “know”, “describe”, “recall”, “explain”, “apply”, “define”, “calculate”, and “state” (DBE, 2011:54-55). The goals of lesson activities are described by statements, for example, “define average velocity as the...” (DBE, 2011:55). Practical activity statements inform the teachers of practical activities, as in “use a long straight track, a curved track, a toy car, and a metre rule to illustrate...” (DBE, 2011:42).

The South African Physical Science curriculum has clear scope and depth to support metacognitive awareness. The scope of the curriculum recommends practical work and the detail in which topics are to be taught. The scope of topics is essentially directed by the content, while concepts and skills focus the teaching and learning processes. It does not prescribe lesson activities; it allows the teacher flexibility to plan lessons to suit their teaching styles.

5.3.1.3 Progression

Consideration of progression in the design of the science curricula allows for coherent science lessons. When progression is taken seriously, the science content presents a latent path for learners to advance their understanding of a vast body of ideas.

The curriculum promotes short-term progression whereby the teacher arranges content and context activities from simple to complex (DBE, 2011:5). Examples of short-term progression in each topic are not prescribed, allowing the teacher the flexibility to creatively structure their activities.

Long-term progression is revealed as the learner progresses from grade 10 to 11, and then to grade 12. The complexity of content, context, and skills increases as the learner advances. To show long-term progression in the Physical Science curriculum, the researcher used the topic of motion discussed in 5.3.1.2. In grade 10, the topic motion refers to motion in one direction only (DBE, 2011:54-55). The task words used to show the depth of the content include “know”, “describe”, “recall”, “explain”, “apply”, “define”, “calculate” and “state” (DBE, 2011:54-55). In Bloom’s revised taxonomy (discussed in part 2.1.4), the task words are “define”, “state”, “recall”, “describe” and “know”. They fall into the level of remembering, which is the least complex level. The task word “explain” is categorised as understanding, which is the next level up. Most of the task words fell into the lower two levels of Bloom’s taxonomy. “Apply” and “calculate” were placed into the applying part of the taxonomy. This is situated in the lower middle of the taxonomy scale.

At the start of grade 11, learners study the laws of motion in greater complexity (DBE, 2011:64-65) Most of the task words are in the apply level of the Bloom’s revised taxonomy scale, for example, “draw”; “apply”; and “calculate” (DBE, 2011:64-65). Learners were also exposed to the analysing level of Bloom’s revised taxonomy scale. This is more complex, instructed by the task words “investigate”; “distinguish”, and “verify” (DBE, 2011:64-65). Unlike grade 10, the application activities involve both equilibrium and non-equilibrium problems; horizontal motion; inclined planes;

surfaces with friction; and vertical motion (DBE, 2011:65). There is a clear progression in complexity of content and tasks from grade 10 to grade 11.

In grade 12, learners are introduced to new concepts, like momentum and impulse (DBE, 2011:98-100). The progression in content and context is that learners are expected to solve problems for elastic and inelastic collisions (DBE, 2011:100). The task words that guide the progression are similar to those of grade 11 and lie in the application and analysing parts of Bloom's revised taxonomy scale. Despite no clear progression from using Bloom's revised taxonomy scale, the complexity of the application and analysing tasks are apparent. Even though the progression in content and analysing skills is clear, the researcher feels that at the grade 12 level, there should be more opportunities for learners to be exposed to the evaluation and the creating levels of the Bloom's revised taxonomy scale.

Higher-order thinking skills like metacognition are embedded in lower-order skills, such as a simple application, analysis, and cognitive strategies, which are developed when facilitated activities move from simple to complex (King et al., 1998:35). The short-term progression and long-term progression within the curriculum promote higher-order thinking skills such as learner persistence, self-monitoring, and creative thinking (King et al., 1998:35). The South African Physical Science curriculum progresses in the complexity of content, context and skills, thereby promoting metacognition.

5.3.1.4 Continuity

Continuity is the vertical connection in complete curriculum design (Research and Training Centre, 1998:74). Continuity can also be viewed as the vertical articulation of the curriculum (Deco, 2011:169). Learners excel when higher-order thinking is continually being reinforced in the teaching and learning processes (Moshman 1995:354; Kuhn 2000:178). Continuity was discussed in detail in part 5.3.1.3 of the analysis, using the concept of motion as an example. The concept progresses in difficulty each year and is studied in different contexts; vertical motion, horizontal motion, motion on inclined planes and during collisions among others.

The South African physics curriculum allows comparable concepts to be learnt and applied at different stages of learning and with increasing complexity as the learner progresses. The South African curriculum can be described as a spiral curriculum, wherein the content and skills are taught in order of increasing complexity (Bentham, 2003:44). It expresses learning continuity by the progression of the same concepts from one year to the next.

5.3.1.5 Sequence

A sequential curriculum has a logical order of topics which are taught and has progression and continuity (Westwood, 2013:31). Goodlad & Su (1992:330) emphasise that each successful experience within the curriculum builds on the previous one.

Ornstein and Sinatra (2004:153) state that sequence in a curriculum should be based on the logic of the subject matter or the way learners develop. Thomas (2014) states the four popular sequencing approaches as:

1. Simple-to-complex learning associated with progression of the curriculum design.”
2. Successive identification of prerequisite learning: similar to simple-to-complex learning, however, the sequence of the prerequisite knowledge is important, just as long as it precedes the complex concepts.
3. Teaching from whole to part: learners are provided with an overview of the topic which is given before learning specific concepts.
4. Chronological learning: The topics are arranged to reflect the chronological order of historical experience.

To test whether this sequential approach in curriculum design was used, the researcher analysed the atomic structure topic in grade 10 (DBE, 2011:20-21). The topic starts by explaining that “everything is made of matter”. Information about all the different atoms is displayed in the periodic table of elements (DBE, 2011:20). This is the kind of prerequisite knowledge that learners should know. The next part of the topic consists of the different models of the atom, as viewed by early philosophers and scientists (DBE, 2011:20). Discoveries are presented in

chronological order. The topic then progresses to more complex content, such as atomic mass and elementary sub-atomic particles (DBE, 2011:21). The topic of the atomic structure increases in complexity to a more cognitively demanding application, requiring calculation of relative atomic mass, comparing isotopes, and drawing the electronic configuration of atoms (DBE, 2011:22).

The chronological sequencing is applied to historically related parts of the topics, such as the development of atomic structure (DBE, 2011:20). There is no evidence of whole-to-part sequencing. The simple-to-complex learning structure (progression) is apparent throughout the South African Physical Science curriculum, as well as in the prerequisite learning (see section 5.3.1.3 and 5.3.1.4). The curriculum follows the simple-to-complex and prerequisite learning sequence.

5.3.1.6 Balance

Balance is the weighting ascribed to each feature of the curriculum design about time allocation, skills, concepts, and learning involvements (Lunenburg & Ornstein, 2012:386).

The Physical Science curriculum gives the time allocation for all subjects per week in hours (DBE, 2011:7). It also informs teachers and readers of the number of weeks allocated, the time taken to cover content, concepts and skills required, and time required to cover formal assessments (DBE, 2011:9). The overview of each Physical Science topic, its concepts, and time allocated for each topic are given (DBE, 2011:10-11).

The prescribed practical activities for formal assessment and recommended practical activities for informal assessments are tabulated and state the term in which it should be completed (DBE, 2011:12-13). The percentage weighting of each topic is also tabulated (DBE, 2011:13). The overview of formal assessment and recommended informal experiments give the reader information about the recommended number of formal and informal experiments. The Physical Science content of the curriculum provides time allocated in hours for the topics, concepts and skills (DBE, 2011:15-

142). The formal assessment table provides the percentage weighting of formal, school-based assessments in the end of year examinations (DBE, 2011:144).

The recommended weighting of the cognitive levels of examinations and control test tables give a cognitive level number related to cognitive skill (Bloom's taxonomy), and a percentage allocation for paper 1 (physics) and paper 2 (chemistry) (DBE, 2011:144). The practical work table provides several activities for prescribed experiments, projects, and informal experiments (DBE, 2011:146). The programme of assessment gives a percentage breakdown in formal assessment tasks throughout the term, as well as the percentages for cognitive levels per topic for the end of year examinations (DBE, 2011:146).

The Physical Science curriculum informs the reader clearly of the time allocation and the weighting of skills, concepts, and learning experiences. It is a balanced curriculum.

5.3.1.7 Culture

Section 1.4.3.2 discusses how science embeds European values, history, and philosophy. Sections 1.2.3.2, 1.4.3.4 and 3.3 discuss how Western dominance in science conflicts with many non-Western cultural views and demotivate non-Western learners studying science. Studying science in its traditional form emphasises aims, logic, facts, and is depersonalised. South African learners are motivated by the beauty, social interconnectedness, compassion, and spiritual nature of science in their society (Keane, 2015). Learners are more motivated in science if their values and culture are included. Motivation plays a crucial role in promoting and stimulating metacognition (Efklides et al., 2001:303; Hartman, 2001:99; Larkin, 2009:85; Myers, 2008:37). A holistic curriculum that motivates indigenous learners would include indigenous values and culture through indigenous knowledge in the curriculum (Fien, 2010), thereby promoting metacognitive awareness.

The general aims of the South African Physical Science curriculum promote the inclusion of indigenous knowledge out of respect for the rich history and heritage of South Africa and also promote the values in the South African Constitution (DBE,

2011:5). Scientific and technological knowledge in the Physical Science curriculum acknowledges the knowledge systems of the indigenous people as a source of many innovations and developments, even though some concepts conflict with Western scientific principles (DBE, 2011:8).

Despite the Physical Science curriculum promoting indigenous knowledge systems, the only advice given on teaching indigenous knowledge is found in the guidelines for teachers referring to “the first people to make fire did so using friction” (DBE, 2011:62). This gives Physical Science teachers flexibility to include indigenous knowledge in their teaching, although some teachers do not include indigenous knowledge in their lessons due to lack of guidance from the curriculum. The argument for supporting indigenous knowledge in the curriculum, apart from supporting the motivational domain of metacognition, is that it values indigenous knowledge which relies on observations in a naturalistic environment, it includes principles of equality and respect, underpins multiculturalism, and antiracist education (Web, 2012:90).

5.3.1.8 Conclusion of the curriculum document analysis

To answer research question 1, the South African Physical Science curriculum is designed to support the promotion of metacognition by encouraging scientific enquiry, including indigenous culture within the curriculum, and having the key sub-components for an effective and coherent curriculum. However, it was concluded that the curriculum lacked guidance on how to support indigenous knowledge within the teaching and learning process in Physical Science which will be considered in this study. The lack of guidance in teaching indigenous knowledge could be attributed to the examination not rewarding indigenous knowledge in the curriculum (see section 5.2.4.). One could question the agenda of the Physical Science curriculum in terms of indigenous knowledge. If indigenous knowledge was an important focus of the curriculum, then it should have better guidance in integrating the indigenous knowledge within the Physical Science theory, as well as rewarding it in the examination.

5.3.2 Analysis of the learner interviews

The interview analysis was discussed in detail in part 4.5.6. Analysis of the learner interviews focused on describing and calculating the frequency of the 89 learners' responses. Relevant words, sentences, and phrases that were repeated, or were similar to other responses, were coded in the interview schedule (Löfgren, 2013). The codes that were frequent and important were categorised, frequency calculated, and discussed. The learner interview analysis achieved research aims 4 and 6 (see section 1.6).

5.3.2.1 Analysis of question one of the learner interview

Question one: List the steps you take before and while solving a problem.

For this question, the emphasis is on the SEM (Schraw, 1998:120) shown in Table 2.3 and the regulatory checklist (Schraw, 1998:121) shown in Table 2.4. The SEM was used to analyse learners' metacognitive knowledge, and the regulatory checklist was used to analyse learners' metacognitive regulation. The evaluation part of metacognitive regulation was ignored because the focus was based on occurred before and during problem solving. Categorising and coding were formalised to cover the elements of the SEM and the regulatory checklist. Table 5.18 below summarises the data. Examples of quoted responses from the participants are included in the table.

Table 5.18 Coding and frequency of question 1

Metacognitive knowledge			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Skim	“use appropriate formula”; “analyse question”; “find relevant information”; “highlight key points”; “underline important words and number”; “search for what is known and unknown”; “identify SI units”.	search for key words/ highlighted words, equations, and summaries/ identify formula/ find equations	38%
Slow down	“read the question again”; “read twice”; “read again.”	pause/read again/ think about information/ read question again/ read and understand/ analyse given information /break down problem	37%
Active prior knowledge	“what the question wants us to find?”; “relate problem to topic”; “know what is asked”	pause and think about what you already know and what you need to know/ identify the problem/ what the question is looking for/ highlight key points	18%
Mental integration	““relate problem to topic”; “analyse question”; “use keywords”; “use relevant equations”; “identify section.”	check which topic/which section relate key points, keywords and equations to conclude/ analyse	53%
Diagrams	“draw diagram.”	draw a diagram/connect the main ideas with supporting details and pictures	8%

Table 5.18 Coding and frequency of question 1 (continued)

Diagrams	“draw diagram.”	draw a diagram/connect the main ideas with supporting details and pictures	8%
Planning	“find relevant information”; “search for what is known and unknown”; “easy and best way to solve problem”; fastest way to solve problem”; “consider different ways to solve problem”; “look at similar problems.”	nature of the task or goal/ time and resources needed/ different methods/easiest method/ fastest method/ write relevant information/ write known and unknown	35%
Monitoring	“check what I am doing is correct.”	clear understanding / I am on task/ make sense/ reaching my goals/ make a change	12%

Discussion

The categories skim (38%), slow down (37%), and mental integration (53%) were most frequently found in the analysis of metacognitive knowledge. Many learners used important metacognitive skills to search for keywords, identify relevant formulae, reread questions, break down information, and link prior knowledge and relevant scientific information. Few learners realised the importance of activating prior knowledge (18%) or using mind map diagrams to connect key ideas (8%).

Overall responses show that learners are aware of important metacognitive skills linked to metacognitive knowledge, but it is clear that those key skills need to be made more accessible to all learners. Each category needs to have a much higher response frequency to show good metacognitive awareness. The highest frequency was only 53% (mental integration), and the lowest was 8% (diagrams). Metacognitive awareness linked to metacognitive knowledge can, therefore, be substantially improved. Monitoring key factors in achieving self-regulation had a response of only 12%.

Improvements in formalising these key skills are imperative for promoting metacognitive skills during problem solving that lead to improvements in Physical Science attainment. Teachers need to promote all key metacognitive skills during the teaching and learning process. These skills could be extended beyond the classroom environment by giving worksheets on metacognitive strategies and marking notebooks with constructive feedback on promoting metacognitive skills. The use of mind maps to improve conceptual understanding during the problem-solving process and to encourage activation of prior knowledge to link the known to the unknown during problem solving needs to be improved.

Similar to metacognitive knowledge, metacognitive regulation during problem solving had relatively weak responses. The response to planning was 35% and monitoring only 12%. Again, some learners are aware of planning and monitoring strategies, but the majority of responses show that learners don't have the required level of metacognitive awareness to regulate their learning. Teachers should promote the importance of setting goals and monitoring progress during problem solving. Metacognitive regulation could be taught formally (Griffiths, 2008:104; Israel et al., 2006:5; and Li & Zhao; 2014:35).

5.3.2.2 Analysis of question two of the learner interview

Question two: What do you think about after you have solved a problem?

For this question, the focus is on the regulatory checklist (Schraw, 1998:121) shown in Table 2.4. The regulatory checklist was used to analyse learners' metacognitive regulation, focusing on evaluation. The regulatory checklist was also used to code and categorise the data collected. The results are summarised in Table 5.19 below, along with examples of quoted responses.

Table 5.19 Coding and frequency of question 2

Metacognitive regulation			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Evaluation	“prove if it is right quickly”; “check whether it is wrong or right”; “check equation and substitution”, “double check working”; “work backwards to check”; “check again.”	have I reached my goal? correct/ verify/work backwards/check formula/method /double check answers/ requirements/did I achieve	61%
	“other way to solve it”; “other methods to solve”; “consider whether I applied the physics correctly”; “check answer”; “ask teacher”; “compare answers with friends”; “test using another method”; “verify answer”; “verify using maths”; “check with tutor”	What worked? What didn't work? another way to solve/ prove if right/ correct physics/ ask teacher/friends/ different ways/other methods /compare answers/ possible failures	84%
	“check for faster method.”	Would I do things differently next time? ways to improve	3%

Discussion

The learner responses were much stronger for evaluation strategies; 84% mentioned they would look for what worked well and what did not, and 61% questioned whether their goals had been reached. The high frequencies of metacognitive evaluation responses counterbalance the low metacognitive monitoring responses. The majority of learners do not see the importance of monitoring their progress while they are solving a problem, but they start worrying only after completion of the problem about

whether they reached their goals. Only 3% of learners mentioned they would think about ways to improve. Overall responses were satisfactory for question two, but formalising evaluation strategies would lead to significant improvements in evaluation skills like improvement and reflection strategies.

5.3.2.3 Analysis of question three of the learner interview

Question three: What would you do if you felt you have not understood the lesson?

The analysis of this question focused on learners' levels of self-direction in learning. The skill of learners who have a high level of self-directedness is reliant on the progress of their metacognitive awareness (Rodak, 2013). Self-directed learning is the initiative which learners undertake, with or without support from people, to

- identify learning difficulties,
- articulate learning aims,
- identify resources for learning,
- apply applicable strategies, and
- evaluate results (Knowles, 1975:18).

Question 3 was initially examined using the category about whether they dealt with problems with or without assistance. The highest frequency responses calculated were that learners felt teachers (67%), friends and peers (55%), and tutors (38%) were the preferred people to turn to if they found concepts difficult. They also referred to internet searches (40%); past paper questions and answers; and textbooks (17%).

However, to get an overall view of learners' self-directed learning ability, it is essential to include all the aspects of self-directed learning (Knowles, 1975:18). The analysis of this question was thus categorised and coded by

- identifying learning difficulties;
- articulating learning aims;
- identifying learning resources;
- application of learning strategies; and

- evaluation of the process.

The results are summarised in Table 5.20. Examples of quoted responses from the participants were included in the table.

Table 5.20 Coding and frequency of question 3

Self-directed learning			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
identifying learning difficulties	“difficult section”; “hard problem”; “confusing lesson”; “mistakes”; “wrong”; “incorrect”; “topic”;	weakness in skill/ knowledge/ topic/ theory	100%
articulating learning aims	no response	setting goal/ timescale/ targets or deadlines	0%
identifying learning resources	“textbook”; “teacher”; “classmate”; “friend”; “expert”; “internet”; “YouTube”; “Google”; “library”; tutors; “past papers.”	activities/ resources/ method for learning	100%
application of learning strategies	“study on my own”; “revise from textbook”; “study from the physics notebook”; “ask the teacher for help after the lesson”; “go for tuitions”; “speak to my friends.”	implementing learning strategies	100%
evaluation of the process	no response	evaluate the learning goals/targets/ deadlines met	0%

Discussion

All learners gave responses that showed they identified learning difficulties and learning strategies and applied learning strategies. No learner articulated learning by setting goals and deadlines. Learners did not have any responses to evaluating the process.

All learners showed a clear idea of what to do when they do not understand a lesson. They used only self-directed learning strategies they were comfortable with.

However, they need to improve the setting of targets and to evaluate their goals, which are key to achieving metacognitive regulation (see 2.3 and 2.5).

5.3.2.4 Analysis of question four of the learner interviews

Question four: How do you prepare yourself for a test or exam?

This question addresses the learner’s revision techniques. The question investigates effective study techniques in physics models "cognitive and metacognitive strategy for learning". It concentrates on the following learning strategies (Rusbult, 2011): memory tricks; effective cramming; planning; gathering information; and problem solving. These metacognitive learning strategies encourage learners to think about their cognition (Rusbult, 2011). The categorising and coding were drawn using the physics models "cognitive and metacognitive strategy for learning". The results are summarised in Table 5.21. Examples of quoted responses from the participants are included.

Table 5.21 Coding and frequency of question 4

Self-directed learning			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
effective cramming	“mind maps”; “write down important equations”; “summarise notes in my own words”; “write a breakdown of theory.”	Flashcards	0%
		mnemonics	0%
		flow diagrams / summarise /own words	53%
		formulae equations	11%
Planning	“predict the type of questions”; “possible questions”; “make a study timetable”; “plan study time”; “sufficient time”; “prepare in advance”; “make a roster”; “study plan.”	study timetable	49%
		predict questions	3%
		weak or hard areas	32%
		time management	32%

Table 5.21 Coding and frequency of question 4 (continued)

gather information	“concentrate on my weak areas”; “look at the syllabus”; “organise notes of the section.”	Notebook	0%
		Textbook	0%
		syllabus	5%
		ask teacher	0%
		materials to be studied	6%
problem solving	“go over past exam questions”; “past papers questions”; check solutions to past paper problems”	past papers	84%

Discussion

Learners indicated that the learning technique of problem solving using past papers (84%) was the most popular response to question four. Going over past examination questions is metacognitive by nature because the learners practise their procedural and conditional knowledge skills during problem solving (see section 2.6.1). Declarative knowledge is used when the learners use declarative techniques to interpret questions and read to remember theoretical knowledge. This is be connected to the meta-skills acquired during independent problem solving as suggested by Kontos and Nicholas (cited in Baker, 1994:209) (see section 2.10.). The past examination papers were constructively aligned with the questions expected in their summative assessments. The “predict question” (3%) appears to be an irrelevant response when so many learners rely on revisiting past papers.

Summarising key points in words or flow diagrams (53%) was found to be crucial in effective cramming while memorising formulae and equations was just 11% of the responses. More creative ways of cramming using metacognitive learning strategies such as flash cards and mnemonics had no responses. There was a lot of focus on learning how to solve problems using past papers, and much less emphasis on conceptual understanding in physics through effective cramming considered vital for problem solving. More emphasis is needed on teaching learners to be effective crammers.

The study timetable (49%), working on weak areas (32%), and time management (32%) were considered important metacognitive revision planning techniques. The responses were low in the metacognitive planning category and need improvement.

There were minimal responses in the “gathering information” category. Learners did not mention the importance of getting information from teachers, textbooks, syllabus, etc. before revising.

Learners felt they were doing enough by simply going over past papers to achieve well in the examinations. However, there is more to effective study skills than simply completing past papers. There seemed to be a lack of focus on conceptual understanding. From the responses, learners indicated that mastering mathematical logic for problem solving is sufficient when revising Physical Science. Focus on all other aspects of effective metacognitive learning strategies should be encouraged. Formal training needs to be given to learners on effective learning strategies on metacognitive approaches to learning.

5.3.2.5 Analysis of question five of the learner interview

Question five: To what extent does the Physical Science curriculum respect your culture?

Question five analysed whether the Physical Science curriculum was culturally sensitive. The coding led to two categories: respects my culture and does not respect my culture. The coding was formulated using associated quotes describing the categorising. Table 5.22 summarises the results, including examples of quoted responses from the participants.

Table 5.22 Coding and frequency of question 5

Culture in the Physical Science curriculum			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
respects my culture	“the curriculum does not force views on us”; “nothing about disagreeing with my culture”; “textbook does not have anything that offends me”; “unbiased”; “respects culture as a whole”; “yes”; “does not say God does not exist”; “does not say religion is wrong”; “physics books have informed us about culture”; “does not affect culture”	“unbiased”/“does”/“ does not force views”/ “does not disagree”/“ don’t say God does not exist.”	84%
does not respect my culture	“no”; “it does not include my culture.”	does not/ not mentioned in textbook/evolution	9%
Neutral	“no comment”	don’t agree and don’t disagree	7%

Discussion

Aikenhead & Jegede (1999:269) conclude that learners’ everyday life experiences and school science are “cultural border-crossing”; whereby learners’ cognition conflicts with cultural differences between their lived-world and values embedded in the school science curriculum (see section 3.4.). The indigenous learners experience cultural border-crossing when they change their cultural views to accommodate the Western values embedded in the Physical Science curriculum. By referring to the work completed by Aikenhead and Jegede (1999:269), Cobern (1996:287) and Sutherland (2005:597), it is reasonable to assume that indigenous learners in KwaZulu-Natal who follow the South African Physical Science curriculum may also experience some form of cultural conflict in the Physical Science classroom (see section 3.4.).

However, only 9 % of learners responded to the Physical Science curriculum not respecting their culture, while 84% stated that the curriculum is unbiased, does not force cultural views, and does not dismiss the existence of God. This response is different from the studies done by Aikenhead and Jegede (1999:269), Cobern (1996:287), and Sutherland (2005:597), who state that indigenous learners feel conflicted between the Western values embedded in science and their cultural views. From the interviews, it is clear that the majority of learners who participated in the study do not have cultural conflicts with the Physical Science curriculum.

5.3.2.6 Analysis of question six of the learner interview

Question six: Would you be more inspired if there were more African values and culture in the Physical Science curriculum?

Question six was a follow up to question five. The two categories used in analysis were: “More African culture is needed in the Physical Science curriculum” and “The Physical Science curriculum is fine the way it is”. The results are summarised in Table 5.23. Examples of quoted responses from the participants are included in the table.

Table 5.23 Coding and frequency of question 6

Culture in the Physical Science curriculum			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
more African culture is needed in the Physical Science curriculum	“yes”, “more interesting”; “more aware of African culture”; “proud of African culture”; “makes Physical Science easier to understand.”	more African culture/ interesting/culturally aware	61%

Table 5.23 Coding and frequency of question 6 (continued)

The Physical Science curriculum is fine the way it is	“no”; “makes no difference”; “still feel the same”; “no difference”; “leave culture out”; “may offend others”; “Physical Science does not require culture.”	Culture does not have much impact/ influence/	39%
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Discussion

Despite 84 % of learners stating the Physical Science curriculum did not disrespect their culture, 61% of learners felt that African culture should be included in the curriculum because it would make the course more exciting and learners could become more culturally aware. The researcher felt the formulation of question 6 may be leading learners to their responses because 39% of learners stated that culture should be left out of the curriculum because it might offend learners.

5.3.2.7 Analysis of question seven of the learner interview

Question seven: What changes do you think is needed in the Physical Science course to encourage more learners to excel and be more motivated in Physical Science in the future?

This question examined learners’ views on what needs to be improved in the Physical Science course. Improvements were the only category viewed. The results are summarised in Table 5.24. Examples of quoted responses from the participants are included in the table.

Table 5.24 Coding and frequency of question 7

Improvements in the Physical Science course			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Improvements	“more practical”; “more experiments”; “more chemicals”; “outlook that science is not hard”; “more equipment”;	practical/ equipment	60%
	“interesting”;	interesting	1%
	“stop thinking physics is hard”; “remove stereotypical views”; “negative attitude must be removed.”	promoted more/ not difficult/ love/	37%
	“computers and projectors”; “better facilities” “more technology”; “internet”;	visual aids/ technology	43
	“teachers that are more qualified”; “teachers that make lessons more enjoyable”; “more experienced teachers.”	more skilled teachers/ passionate teachers	8%
	“teach lesson in isiZulu”; “find it easy when things are explained in isiZulu.”	teach physics in isiZulu	35%

Discussion

Sixty percent of learners suggested the Physical Science course needs more emphasis on practical work, 43% stated that the course requires information and communication technology in the classroom. Thirty-seven percent of learners felt that physics is stereotyped as being inaccessible and difficult. They felt that teachers and learners should promote the course as being more accessible to all, and also felt that the course should be more fun.

Thirty-five percent of learners felt that physics should be taught in isiZulu and examinations should be set in isiZulu. This suggestion to improve the curriculum referred to the inclusion of African culture. Learners asked why the course was not in

isiZulu but in English and Afrikaans. The researcher feels that first language learners have an advantage over indigenous learners. The issue about the language might have been mentioned because it could be easier for these learners to learn in their mother tongue. This will be considered in the study.

5.3.2.8 Conclusion for the analysis of the learner interviews

The learner interviews were constructed to examine the views of learners of Western science (research aim 4) and to deduce the impact of studying the Physical Science curriculum on the metacognitive processes of learners (research aim 6).

Taking research aim 4 into account, the analysis of learners' interviews concluded that most learners do not have cultural conflicts while studying Physical Science. A majority of 84% of learners stated the Physical Science curriculum does not disrespect their cultural beliefs. Despite that, 61% of learners stated the Physical Science course would be more exciting, and learners would become more culturally aware if the African culture were included in the course. Furthermore, 35% of learners stated they would prefer to be taught Physical Science in isiZulu.

Also, 60% of learners felt their Physical Science lessons lacked practical activities and equipment to support practical work, while 43% of learners also mentioned that to improve the course, information technology is required in the classroom. Thirty-seven percent of learners stated that Physical Science should be promoted better and the negative stereotype of Physical Science as difficult and uninteresting should be stopped.

Research aim 6 took learners' state of metacognition into account. Despite not being formally taught metacognitive skills, some learners displayed signs of awareness of both metacognitive knowledge and metacognitive regulation. It seems that metacognitive skills are developed naturally during the teaching and learning processes of Physical Science, despite learners not being formally trained in these skills. This is due to tacit influences in the learning environment (see 2.4.4) together with the higher ordered thinking skills associated with independent problem solving (see section 2.10).

During problem solving, the metacognitive knowledge strategies of skimming (38%), slowing down (37%), and mental integration (53%) were mentioned. Metacognitive regulation components of planning and monitoring strategies were not discussed competently by learners. The response to planning was 35% and monitoring was just 12%. However, the metacognitive regulation components of evaluation during problem solving were discussed in better detail. This might have been due to learners not monitoring their progress but focusing instead on their achievement of goals upon completion of the task. A further 84% mentioned that they would look for what worked well and what did not, and 61% questioned whether their goals had been reached.

With regard to self-direction in learning, learners seemed to lack vital metacognitive regulation skills such as planning and evaluation. Summarising key points in words or flow diagrams (53%) was found to be crucial in effective cramming, but lots of learning focus was directed at solving problems in past papers. There was much less emphasis on conceptual understanding in physics through effective cramming, which is crucial in problem solving.

To conclude, from the interview analysis, it is inferred and exhorted those metacognitive skills, and the inclusion of African culture within the South African Physical Science curriculum needs to be addressed. Teacher training programs on promoting social constructivism of learning, independent problem-solving skills, and explicit instruction of metacognition using models as an effective intervention will be the way forward to effectively promote metacognitive awareness (see section 2.9.2. and 2.10). There needs to be more focus on the importance of conceptual understanding in Physical Science, and the focus should not only be on mastering solutions to past exam papers to produce a well-rounded Physical Science learner.

5.3.3 Analysis of the teacher interviews

The method for the teacher interviews was discussed in detail in section 4.5.6. The analysis of the teacher interviews focused on describing and calculating the frequency of recurring statements in the seven teacher responses. The analysis procedure was similar to that discussed in section 5.3.2. The sample was too small

to express the response as a percentage so was expressed out of 7. The research aims 4, 6 and 7 were addressed in this section.

5.3.3.1 Analysis of question one of the teacher interviews

Question one: What training have you been given in promoting and teaching metacognitive skills?

This question was asked to get a clear idea of any formal training the teachers received on metacognition. It was also aimed at finding out the support that science advisers provide for promoting metacognition. The analysis of this question was categorised into training by science advisers, training during curriculum development programmes in schools, and training provided by tertiary institutions. Science advisers, experts in science education, arrange regular cluster meetings in the form of workshops and presentations. It was, therefore, necessary to enquire about their role, if any, in the promotion and training of metacognitive awareness. The results are summarised in Table 5.25. Examples of quoted responses from the participants are included in the table.

Table 5.25 Coding and frequency of question 1

Training in metacognition			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Training by science advisers	“no training”; “I did not come across the term metacognition”; “no.”	no training provided	<i>7/7</i>
Training during curriculum development programmes in school	“no training”; “I did not come across the term metacognition”; “no.”	no training provided	<i>7/7</i>
Training provided by tertiary institutes	“no training”; “I did not come across the term metacognition”; “no.”	no training provided	<i>7/7</i>

Discussion

All the teachers mentioned that there was no training on metacognition provided by the science advisers, tertiary institutes, or the schools. None of them had heard of the word metacognition. As discussed in section 1.1.2., a major problem lies in the average science teacher having no notion of metacognition, and the ones who do lack the resources such as time and effort to promote metacognitive awareness effectively (Georghiades, 2004:379). Despite this, it was apparent from the learner interviews that there was the promotion of some metacognitive skills by the teachers. The analysis of the learner interviews and the analysis of question one of the teacher interviews reinforced the idea of formal training being needed on metacognition, and the importance thereof in effective teaching and learning of Physical Science.

To make teachers aware of the importance of promoting and teaching metacognitive skills, teacher training institutes, the department of education, and the schools' management needed to provide adequate training. This would improve the metacognitive awareness of learners, thereby improving their attainments in Physical Science, as discussed in parts 1.3 and 1.4.3.

5.3.3.2 Analysis of question two of the teacher interviews

Question two: Please provide details on how the Physical Science curriculum encourages thinking skills that would develop world-class scientists?

The teachers gave their view on the effectiveness of the curriculum concerning promoting effective thinking skills. The frequency of the responses directed the categorisation towards gaps/structure; teaching environment; examinations, and time. The codes relate to what the teachers experience as wrong with the curriculum and its implementation. The codes added clarity to the conclusion. The results are summarised in Table 5.26. Examples of quoted responses from the participants are included in the table.

Table 5.26 Coding and frequency of question 2

Thinking skills within the curriculum			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Gaps Structure	“old curriculum is better....” “section on vectors is haphazard”; “the structure of the curriculum is too vast to be completed properly”; “Electrodynamics does not have enough detail.”	haphazard/ poor structure/ gaps/ brief in certain topics	2/7
Teaching environment	“poor attendance”; “poor learner attitudes”; “worldwide problem of learner discipline”; “disadvantaged learners”; “don’t come to class with proper equipment.”	discipline/ lack of equipment/ lack of resources/ poor attitudes/attendance	4/7
Exam	“lots of content to be studied for the exam”; “emphasis is more about passing exams instead of learning thinking skills”; “examination is quite challenging for learners”;	Theoretical/ content driven/ difficult	7/7
Time	“too much content”; “weekends”; “lunch breaks”; “more time to complete syllabus”; “no time for revision and remedial work”; “not enough time to complete prepare for examination.”	Teach during free time/ catch up absent/ time for remedial work	7/7

Discussion

The general impression was that there is a gap between the written curriculum and its implementation. Four out of seven responses mentioned that a negative teaching environment hinders success in the curriculum. Lack of motivation, poor resources, and poor attendance of learners makes it difficult to implement the curriculum successfully, thereby stifling the development of crucial thinking skills in science.

All teachers felt the curriculum was too content-driven, making the examinations too difficult for learners. They also mentioned the amount of content as being too extensive to complete during the teaching time frame. The ripple effect of the highly

extensive, content-driven curriculum causes unnecessary stress on both learners and teachers. All the teachers complained about lack of time to complete the syllabus.

Teachers mentioned that curriculum timings do not take into consideration repetition of difficult concepts, remedial work, the natural learning pace of learners, and absenteeism. All the Physical Science teachers had to teach lessons after school, during breaks, and sometimes during the weekend to keep on track.

From the responses to question two, it is apparent that despite the conclusions drawn from the curriculum analysis that the Physical Science curriculum supports metacognition, the factor of time to complete an extensive, content-driven curriculum hinders the teaching and promotion of important thinking skills required for learners to become world-class scientists.

5.3.3.3 Analysis of question three of the teacher interview

Question three: To what extent does the Physical Science curriculum respect the cultural views of the indigenous learners?

Question three considers how the teacher uses the Physical Science curriculum to promote indigenous knowledge. The categories in question three are: science is not cultural, indigenous knowledge, and does not respect culture. The results are summarised in Table 5.27. Examples of quoted responses from the participants are included in the table.

Table 5.27 Coding and frequency of question 3

Indigenous culture within the curriculum			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Science is not cultural	“science is science, it is not cultural”; “science is without culture and religion”; “culture does not affect science “; “Physical Science is a culturally neutral course”;	science is science/ no religion/ no culture/ focus on science/ neutral	5/7
Indigenous knowledge	“grade 10 sound; traditional music instruments”; “a little about traditional healers in chemistry”;	traditional instruments/ traditional healers	1/7
Does not respect culture	“physics is taught in English, but the majority of learners are Zulu”; “not enough respect is given to other cultures”;	Not enough respect	1/7

Discussion

Only one teacher acknowledged the need for indigenous knowledge in their teaching. There was only one response directed at the curriculum not respecting indigenous culture. The majority of the teachers, four out of seven, viewed science as neutral, unbiased, with no cultural element. Most of the teachers interviewed did not see the importance of indigenous knowledge in Physical Science.

5.3.3.4 Analysis of question four of the teacher interviews

Question four: Describe any signs of resentment or demotivation shown by learners in studying a Western science?

Question 4 considers learners’ attitudes in studying Western science, using the categories negative attitude and positive attitude. The results are summarised in Table 5.28. Relevant words, sentences, and phrases that were repeated or were similar were coded and categorised in the table. Examples of quoted responses from the participants are included.

Table 5.28 Coding and frequency of question 4

Learners attitude towards Western science			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Negative attitude	No response		0/7
Positive attitude	“no problem”; “no resentment”; “Learners are more interested in the scientist instead of their nationality”;	no problem/ interested in science/ no signs of resentment	7/7

Discussion

None of the teachers saw any sign of learners resenting the Western science curriculum. There seemed to be a positive attitude among learners according to the teachers.

5.3.3.5 Analysis of question five of the teacher interviews

Question five: Elaborate on any conflict in cultural views displayed by learners in the Physical Science classrooms?

Question 5 considers cultural conflicts displayed by learners. The results are summarised in Table 5.29. Relevant words, sentences, and phrases that were repeated or were similar were coded and categorised in the table. Examples of quoted responses from the participants are included.

Table 5.29 Coding and frequency of question 5

Conflict in cultural views of the learner			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Conflict	No response		0/7
No conflict	no”; “they decided to study physics, so they should accept it as it is”; “no conflicts.”	No conflict between cultural views	7/7

Discussion

This question was a follow up to question four and produced the same results. All teachers mentioned that they had not experienced any signs of learners showing a conflict in cultural views. This result reinforces the results discussed in part 5.2.7 of the analysis of learner interviews, where many learners did not see a conflict between cultural views and the Physical Science curriculum.

5.3.3.6 Analysis of question six of the teacher interview

Question six: To what extent have you been trained in promoting indigenous culture in Physical Science?

Question 6 considers the training provided to teachers in promoting indigenous knowledge during the teaching and learning process in Physical Science. The results are summarised in Table 5.30. Relevant words, sentences, and phrases that were repeated or were similar are coded and categorised in the table. Examples of quoted responses from the participants are included.

Table 5.30 Coding and frequency of question 6

Training in promoting indigenous knowledge			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
Conflict No conflict	“I did not receive any training...”; “no training received in college”; “we did not receive any training in school and cluster workshops”; “school’s management need to provide training on indigenous knowledge”; “no.”	No training provided	6/7
	“I did attend a workshop many years ago.”	Training provided	1/7

Discussion

Six out of the seven teachers mentioned that they had not received any training in promoting indigenous knowledge in the Physical Science class. It would appear the promotion of indigenous culture in Physical Science teaching and learning is not emphasised in schools, despite being included in the Physical Science curriculum. Despite the examination not having any questions in the examination on indigenous knowledge (see section 5.2.4.), the curriculum does make mention that it promotes metacognition (see section 5.3.1.7). There seems to be no reward in the examination in learning about indigenous knowledge. This could be the reason for the lack of focus on indigenous knowledge by the teachers. However, teachers must be made aware of the cultural and motivational factors associated with including indigenous knowledge in the teaching and learning of Physical Science (see section 3.4. and 3.5.). Similar to part 5.3.3.1, the researcher felt that educational institutes, Physical Science advisers, and the school management need to promote the importance of including indigenous knowledge in the Physical Science curriculum.

5.3.3.7 Analysis of question seven of the teacher interviews

Question seven: Please give your views on what is working and what is not working in science?

The aim of question seven was to look at improvements to the Physical Science curriculum, as suggested by the teachers. The two categories are: what is working and what is not working? The results are summarised in Table 5.31. Relevant words, sentences, and phrases that were repeated or were similar are coded and categorised in Table 5.31. Examples of quoted responses from the participants were included in the table.

Table 5.31 Coding and frequency of question 7

Improvements in the curriculum			
Categorising	Examples of relevant words, sentences and phrases	Coding	Frequency
What is working?	“The department provides the schools with useful information regarding the syllabus, exams, exemplar problems in the form of booklets and worksheets.”	Department provides important worksheets	1/7
What is not working?	“Colleges and universities do not choose the best students in to study science education, unlike the past”;	Teacher training/tertiary education	1/7
	“teachers are burdened with lots of paperwork”;	Administration	1/7
	“time to complete the syllabus”; “there is no time to go over grade 11 concepts in grade 12 although the learners are tested on grade 11 and grade 12 work in their national examination”; “time to finish content”;	Time constraints	4/7
	“...grade 11 concepts in grade 12 although the learners are tested on grade 11 and grade 12 work in their national examination”;	Testing grade 11 and 12 content in one exam	1/7
	“curriculum is very rigid”;	lack of flexibility	1/7

Table 5.31 Coding and frequency of question 7 (continued)

	“learners do not have the mathematical skills to do Physical Science”;	Mathematics	1/7
	“the language in the course and examination is of a high level, and learners find it difficult.”	Language	1/7

Discussion

Teachers had their own opinions of what needs to be improved in the curriculum. From the responses, it seems that teachers are not happy with the time constraints on completing the curriculum. Four of the seven responses mentioned the aspect of time again. There was only one mention of what is working. From the responses, it is clear that teachers want improvements to the curriculum to give them ample time to implement it effectively.

5.3.3.8 Conclusion for the analysis of the teacher interviews

A lot of important information was collected from the teacher interviews. The teachers were experienced and passionate about Physical Science. The researcher focused on information relating to research questions one, four, six, and seven.

Initially, to analyse research question 1, the researcher focused on the curriculum document analysis, which concluded the curriculum-supported metacognitive awareness. However, all seven teachers shared the idea that the content of the curriculum is too extensive, and they did not have time to complete the curriculum properly in the time allocated. They worked with learners during their free time to cover the curriculum. The curriculum does not seem to allow learners to learn at their natural pace; it is covered at a fast pace, using learners' free time, when they should be getting on with their independent learning activities after school, during breaks, and at weekends. Teachers mentioned that learners are put under tremendous stress.

The teacher interviews suggested a conflict between the theoretical aims of the written curriculum and the implementation. From discussions with the seven teachers, the researcher concluded that curriculum designers did not take into

account the time required to complete it effectively, time to do remedial work, planning creative lessons, implementation of indigenous knowledge, and teaching of metacognitive skills. Furthermore, all the teachers mentioned that they had not heard of the term metacognition, and there was no training provided by the science advisers, tertiary institutes, or the school on metacognition awareness. The results of the learner interviews and question one of the teacher interviews reinforced the idea of a need for formal training in metacognition.

The teacher interviews also helped answer questions 4 and 6. Research aim 4 looked at the view of the teachers of Western science. From the responses, it was clear that teachers viewed Western science as an empirical science that had no cultural bias. The teachers did not observe any conflict between learners studying a Western science and their own culture. These observations contradict literature studies by the researchers Aikenhead and Jegede (1999:269), Cobern (1996:287) and Sutherland (2005:597) (as discussed in 5.3.2.5) and are similar in results to part 5.3.2.5. Deductively, these results help to conclude research aim 6, where there is no apparent link to Western science impacting on the metacognition of learners.

From answers to research aim 7, the results indicate that teachers do not understand the concept of metacognition. They have some level of metacognitive awareness, but they did not have any training in metacognition. The teachers' metacognitive awareness would improve with training, thus enhancing the promotion of metacognitive awareness. With proper support, the metacognitive awareness of learners would also improve, thereby improving Physical Science attainment.

5.3.4 Analyses of the classroom observations

Before going on to the analysis of active learning and metacognition, the researcher would like to point out a few terms which were similar throughout all analyses. All teachers showed a high level of competence and confidence in teaching Physical Science. They all earned the respect of learners, and had excellent class discipline, even with some teachers having classes of approximately 35 learners. The researcher respected the hard work, passion, and commitment the teachers put into their teaching.

It must be noted that most of the schools being observed had a stable Physical Science department. Internationally, there is a shortage of Physical Science teachers. Some countries, like Qatar and the United Arab Emirates, pay South African teachers handsomely to work abroad. The Physical Science teacher of school G left to teach in Abu Dhabi before this research was conducted. Many of the Physical Science teachers were making enquiries about teaching elsewhere and hinted they were not happy with aspects of the South African teaching situation. The physics teacher from school A, class 2, was applying for early retirement due to stress. If South Africa loses more Physical Science teachers due to better prospects internationally and stressful working conditions, the problem we have with the low Physical Science examination results will worsen.

During the lesson observation, the researcher did not expect to have all the components in Table 5.3.4.1 included with their lesson, with each teacher being observed twice. A teacher might not have certain components during the lesson observation but might implement the strategy in other lessons. The aim of the observation was to assess whether the teacher promoted metacognitive skills; the learners showed signs of metacognitive awareness; and whether active learning took place.

5.3.4.1 Classroom observation

The classroom observation was discussed in detail in section 4.5.5 of the research. The results of the classroom observation analysis were directed at concluding research aim 3. The results evaluate the extent to which metacognitive skills are promoted in class activities as well as the overall effectiveness of the lesson. The basic lesson structure that supports metacognition and effective teaching and learning was critically analysed.

In addition to the metacognition part of the analysis, the researcher added the active learning analysis of the lesson (see section 5.5.5). Despite the analysis of active learning not being initially considered in the research methodology, the researcher felt that it added more meaning to the results.

Table 5.32 Coding and frequency of the classroom observations of metacognition

Categorising Metacognition				
	Coding for teachers	Freq/ teacher	Coding for learners	Freq/ learner
Developing a plan	Objectives	0/7	Understand objectives	0/7
	Starter to prerequisite knowledge	7/7	Discuss using prerequisite knowledge	7/7
	Direct learners where the thought process should take them	7/7	Question direction of lesson and relevance	0/7
Students metacognition	Encourage learners to explain understanding	7/7	Discussed how and why they learnt concepts	0/7
	Encourage learners to explain in own words	0/7	Identified difficulties	7/7
	ZPD	1/7	Questioned understanding	7/7
	Encouraged questioning	7/7		
	Ask learners input	2/7		
	Ask learners whether they understood the concepts	7/7		
Reflection of learning	Formative assessments	0/7	Plan how to understand difficult concepts	0/7
	Inquired about lesson understanding	2/7	Strategies problem-solving techniques	7/7
	Asked whether learners wanted anything to be repeated	4/7	What could be done differently?	0/7

Table 5.32 Coding and frequency of the classroom observations of metacognition (continued)

Modelling metacognition thought	Think aloud	2/7	Highlight	3/7
	Highlight key points	4/7	Brainstorm	0/7
	Teacher-expert model	7/7	Key point	7/7
			Ask questions	7/7

5.3.4.2 Analysis of the classroom observation focusing on metacognition

Table 5.32. includes key aspects of metacognition in Physical Science lessons. Table 5.32. uses an adaptation of the table format used in the interview analysis and is directed towards analysing metacognition awareness. There is an added column, “coding for learners”, which focuses on those metacognitive skills that are observed. The coding for learners was adapted from the observation protocol used to analyse metacognition during classroom observations. The frequency column shows how often the analysed aspects of metacognition by the teacher were observed. Another column was for the frequency of the coding for learners per class observation. The technique used is a two-way analysis of the teaching and learning processes, focusing on both the teacher and the learners. The coding for learners and teachers was designed to include what was supposed to happen during the teaching and learning process to promote metacognition.

5.3.4.3 Analysis of metacognitive planning

The results of planning show that all the teachers had starter activities which were based on the prerequisite knowledge that made learners aware of where the thought process of the lesson should take them. Learners were involved in discussing prerequisite knowledge during all lesson observations. However, due to the teachers’ lack of training in metacognitive planning, part 5.3.3 of the study indicates that, the teachers did not effectively motivate metacognitive planning.

In general, starter activities concentrated on conceptual understanding of the topic but did not encourage learners to plan knowledge strategies to reach the goals of the lesson. For example, the teacher from school A, class 1, had a teacher-led discussion on electric field lines, and explained the equation $E=F/Q$, but did not encourage learners to plan lesson goals using their prerequisite knowledge. Similarly, the teacher from school D introduced Faraday's law by referring to the equation. From that point on, the teacher proceeded with the lesson, neither motivating lesson goals setting nor stating the lesson aims.

The teachers did explain verbally what activity was going to take place in the lesson, but more emphasis could be placed on informing learners of the aims and objectives of the lesson. During all the observations, none of the teachers wrote the objectives of the lesson on the board, nor did they inform learners of the aim of the lesson. At the start of the lesson, learners could not plan their lesson goals because the teachers did not adequately inform them.

The writing down of objectives is a helpful first step for learners to plan goals to achieve the aim, reflect on the purpose of the lesson activity, have clarity on why they are doing the activity, and most importantly, whether they have reached the objective of the lesson (Monk & Dillon, 1995:28-29). There were no observations made to support learner understanding of the objectives of the lesson, and no questioning of the direction and relevance of the lesson. It thus seems that teachers need more training and guidance in promoting metacognitive planning in their lessons.

5.3.4.4 Analysis of metacognitive monitoring

The primary method used by all teachers observed was the "chalk-and-talk method". All teachers were observed asking learners whether they understood the concepts before progressing. This was the most popular technique teachers used to monitor the progress of learners during activities. All teachers encouraged selected learners to explain concepts during the teacher-led discussions. Learners did not discuss how and why they learnt concepts.

None of the teachers encouraged learners to explain concepts in their own words. However, during the teacher-led discussion, learners did explain concepts in their own words. Learners could not monitor their progress in reaching objectives because the objectives were not given to them. Learners were encouraged to ask questions when they did not understand the concepts. Learners identified difficulties and questioned understanding, but the teacher-led approach did not personalise this activity for learners who might have preferred to discuss problems individually or in smaller groups.

Two out of seven teachers were observed asking learners for their input. The chalk-and-talk method does not encourage learners to receive guidance in their ZPD (see section 2.8.2.; Figure 2.8). Six out of seven teachers did not encourage construction of knowledge and skills in learners' ZPD. The teachers could improve their collaborative learning techniques to guide and monitor progress in learners' ZPD. The teachers could also use Hollingworth and Mcloughlin's (2001:57) "Eight phases in metacognitive skills training for Physical Science learners" to improve metacognitive monitoring during problem solving (see Figure 2.10).

Learners listened to the teacher passively during the lesson and only spoke when responding to the teacher's questions. Learners were not encouraged to discuss how and why they learnt concepts, identified difficulties, or questioned understanding. Some aspects of metacognitive monitoring were observed during the lesson observations. Learners identified difficulties and questioned the understanding of concepts. However, the researcher felt that formal training of teachers in the promotion of metacognitive monitoring would improve the quality of metacognitive monitoring awareness.

5.3.4.5 Analysis for metacognitive evaluation

During observation, four out of the seven teachers asked learners whether they needed to repeat any points that were not clear. Two out of seven teachers enquired about lesson understanding towards the end of the lesson. Not much emphasis was placed on learner reflection. In all the classes, there was no way for learners to gauge whether they reached the aim of the lesson because the lesson objectives

were not displayed. No teacher had a way of effectively assessing the success of the lesson, apart from asking learners whether they understood the lesson, or asking whether they should repeat certain points. There were no attempts by learners to plan their understanding of difficult concepts or to ask what could be done differently. All learners were observed strategising problem-solving techniques during problem-solving activities.

None of the classes showed any evidence of the use of effective formative assessment to evaluate understanding of the lesson. Formative assessments are activities that guide the teacher towards adapting teaching to ensure learners meet lesson goals (Black & William, 1998:2). Research has shown that formative assessment improves attainment (see section 2.9.2). General formative assessment strategies use reflection questions, indicator systems, diaries, and goal setting (see section 2.9.2). Formal training in implementing formative assessment strategies and metacognitive evaluation would assist the teachers to improve attainment.

5.3.4.6 Analysis of metacognitive modelling

Two out of the seven teachers used think-aloud techniques while solving problems on the board. Four out of seven teachers highlighted key points using different colours of chalk. The most popular model, used by all the teachers, was the “teacher-expert” model. Teachers showed learners step-by-step how to solve problems, stressing key points and emphasising problem-solving techniques. Learners were relatively passive during the problem-solving process. They watched the teacher diligently and followed instructions.

The teachers used the “teacher-expert” model effectively, showing their in-depth knowledge of the subject. There was, however, no evidence of modelling strategies such as brainstorming, mind maps, mnemonics, etc. This was perhaps because the teachers did not feel they were necessary during the lesson. One teacher used an analogy of the local streets and highways to explain series and parallel circuits. Learners responded well to this teaching method.

The modelling utilised by the teachers encouraged learners to highlight or underline key information. This was observed in 3 out of 7 classes. Key points were copied from the board, and learners were then questioned on key concepts.

The metacognitive modelling used by the teachers was partially effective. Nevertheless, it could be improved by using active learning techniques instead of the teacher-led “chalk-and-talk” methods. This will be discussed in the next part of the lesson observation analysis.

5.3.4.7 Analysis of active learning strategies

Active learning and teacher-centred learning were discussed in part 5.3.4.1. It was noted that active learning was a more effective teaching strategy than the teacher-centred approach. It was also noted that active learning compliments the acquisition of metacognitive skills. The researcher looked for learner participation, class participation, and collaborative activities as basic evidence for active learning. The chalk-and-talk method observed in all lessons encouraged learners primarily to listen. This steered teaching away from the active approach. Table 5.33 summarises the active learning elements of the lesson observations. The frequency of the teacher and learners observed active learning techniques were combined because the active learning strategies were seen as a two-way process, which involves both teacher and learner during the activity.

Table 5.33 Coding and frequency of active learning observed

	Coding for teachers	Freq/ teachers and learners	Coding for learners
Active learning	Collaborative learning	1/7	Group work
	Discussions	6/7	Discussions
	Roleplay	0/7	Roleplay
	Games	0/7	Games
	ZPD	1/7	ZPD
	Problem solving	7/7	Problem solving
	Other		Other

Despite the teacher-centred approach dominating all lessons, there were some elements of active learning taking place (see Table 5.33). Discussions and problem-solving activities shaped the active learning process. All theory and problem-solving activities lacked collaborative work. The theory was taught by the teacher talking and learners being passive listeners. Problems were given to learners, and most learners worked independently, while some learners worked together. Collaborative activity was observed only during a practical lesson. There were plenty of opportunities during the teaching and learning process for collaborative work, but the teachers did not encourage it. The teacher and the more able learners assisted other learners in their ZPD during practical activity.

Six out of seven lessons had teacher-led discussions. The discussion activity could have been prompted and led by learners to make the lesson more active. All teachers encouraged learners to be engaged and participate during the problem-solving process by referring to key information and equations to solve the problem. Learners were actively engaged in attempting structured questions (as opposed to multiple choice) during the problem-solving process. Other elements of active learning strategies (discussed in 5.3.4.1) were not observed.

From the lesson observations, it was found that teacher-led and learner-led strategies were fused into all lessons, but the teacher-led approach dominated the teaching and learning process. The lessons could be improved by using more collaborative and active learning strategies, where the teacher guides and facilitates activities, instead of “chalking and talking”. Teachers need training on formal explicit theory, for example, by the educational department and the management of the school, on active learning techniques to improve on the learner-centred approach to teaching.

5.3.4.8 Conclusion for the analysis of lesson observations

Lesson observations focused on research aim 3 which looked at the extent to which metacognitive activities occurred during the teaching and learning process. Further to this aim, the researcher looked for active learning during the lesson observations.

This was done because active learning and metacognition supplement each other (see section 5.3.4.1).

From the results, it was concluded that despite the teachers having starter activities linked to prerequisite knowledge, and verbally mentioning what was to take place during the lesson, they did not encourage strategies for metacognitive planning, such as setting goals to achieve success. Learners were not encouraged to construct and develop their prerequisite knowledge by referring to the lesson's aims and objectives. The teachers did not display the lesson objectives on the board. This hindered the metacognitive planning component of learning (see section 5.3.4.3).

The results of the metacognitive monitoring part of the observation showed the dominance of the "chalk-and-talk" method in the teaching and learning process. There was little facilitating of activities taking place. The dominance of the chalk-and-talk method meant that collaborative learning and group activities were not encouraged. There was little guidance in learners' ZPD. The teachers used teacher-led discussions to monitor the progress of learners' understanding. They did not encourage learners to monitor their own learning by explaining concepts in their own words, question the thought process, or make the lesson objectives apparent. Learners learnt passively (see section 5.3.4.4)

No formative assessment strategies were used to evaluate learner achievement of the lesson objectives. The teachers asked learners from time to time whether they needed anything to be repeated. The teachers did not encourage reflection and metacognitive evaluation effectively (see section 5.3.4.5). The lesson ended with learners passively completing key points.

The dominant model used during problem solving was the teacher-expert model. The teacher solved problems by explaining each step. Teachers also referred to common mistakes by learners and focused on examination settings. During problem solving, the teachers used think-aloud strategies to highlight important points. This was done well, and it showed the knowledge and experience of the Physical Science

teachers. However, this could improve if the teachers allowed collaborative learning strategies and if they helped learners in their ZPD (see section 5.3.4.6).

Active learning took place from time to time during the problem-solving process (see section 5.3.4.7)

Despite some elements of metacognitive planning, monitoring, and evaluation taking place, there was a definite need for improvement, which would add more effectiveness and value to the teaching and learning process. Active learning strategies should replace the dominant, yet less effective, teacher-led approach. Training needs to be given to teachers, and this needs to be continuously monitored, assessed, and developed by the head of the science department, school management, and the science advisers.

5.3.5 Analysis of learners' notebooks

Learners' Physical Science notebooks showed written evidence of the metacognitive awareness displayed by learners and revealed the extent to which metacognitive thinking was encouraged by the teacher. The methodology was discussed in 4.5.4 in greater detail. The researcher analysed 50 notebooks. During the analysis, the researcher concentrated on

- metacognitive modelling;
- marking for constructive improvement;
- marking for metacognitive awareness;
- declarative knowledge;
- procedural knowledge;
- conditional knowledge;
- planning;
- monitoring; and
- evaluation (see section 4.5.4).

5.3.5.1 Analysis of metacognitive modelling and declarative knowledge in learners' notebooks

Diagrams

The 50 books analysed showed that the learners used a variety of diagrams while problem solving. They used Figures that labelled information to deconstruct problems. Also, they used diagrams in a variety of applications, including ray diagrams, vector diagrams, and molecular structure diagrams. The analysis revealed that diagrams were used effectively to pictorially represent vital information during the problem-solving process. Figure 5.4. below show examples of how various learners used diagrams during problem solving to visualise information and extract scientific meaning from the problems.

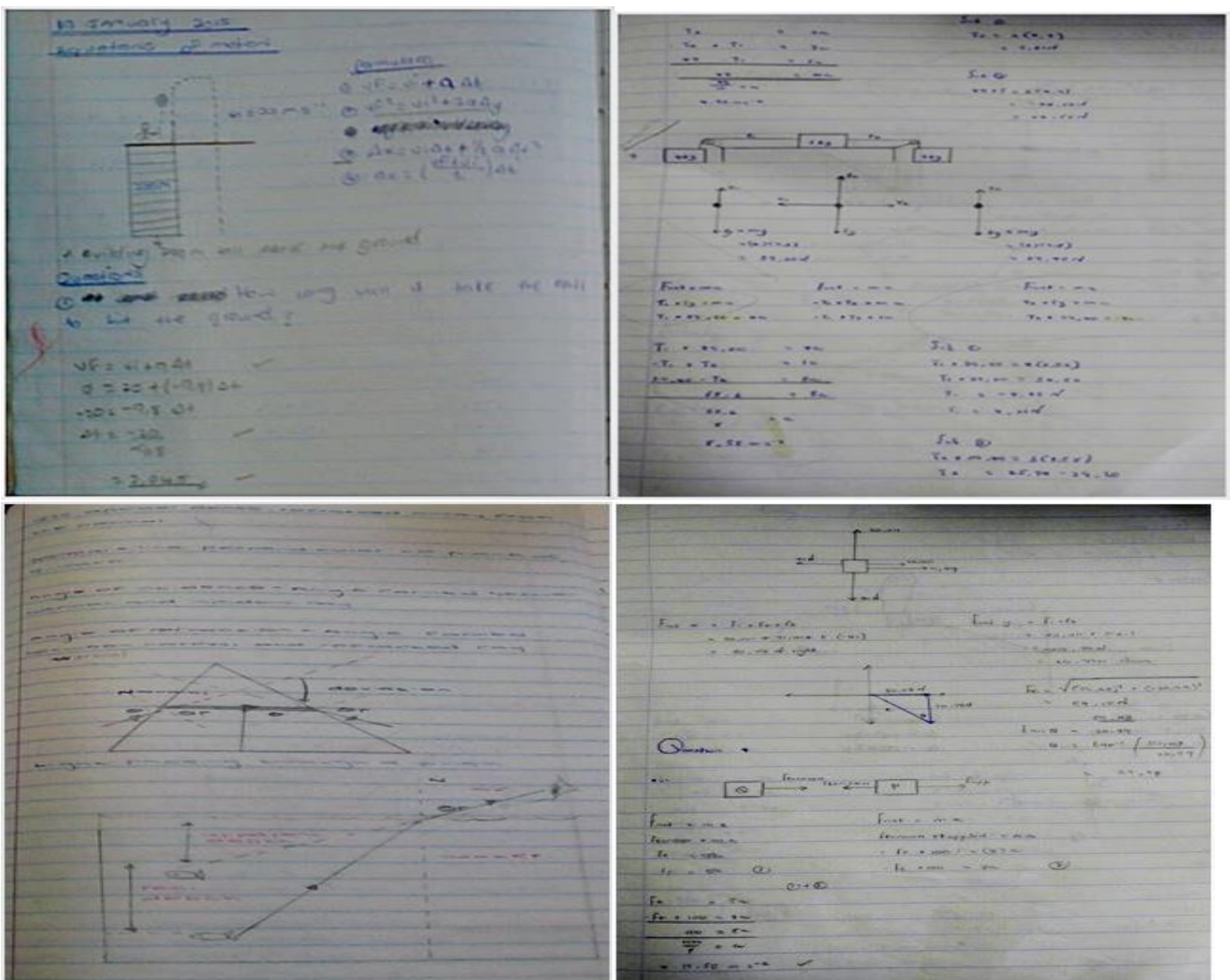


Figure 5.4: Diagrams used by learners during problem solving

Key points

All books analysed summarised key information and equations. In 38 out of 50 books there was evidence of tabulating key information. In 34 out of 50 books, learners showed they boxed key equations. The equations were written in symbol form, and the meaning of each symbol was described. Learners used different colours to emphasise key points in 18 out of 50 books, while no books showed colouring of key information using highlights. The key information showed important terms and definitions, along with a summary of key areas studied. There was no written evidence of brainstorming, mind maps, or mnemonics. Figure 5.5 below shows examples of strategies used by learners when writing key information.

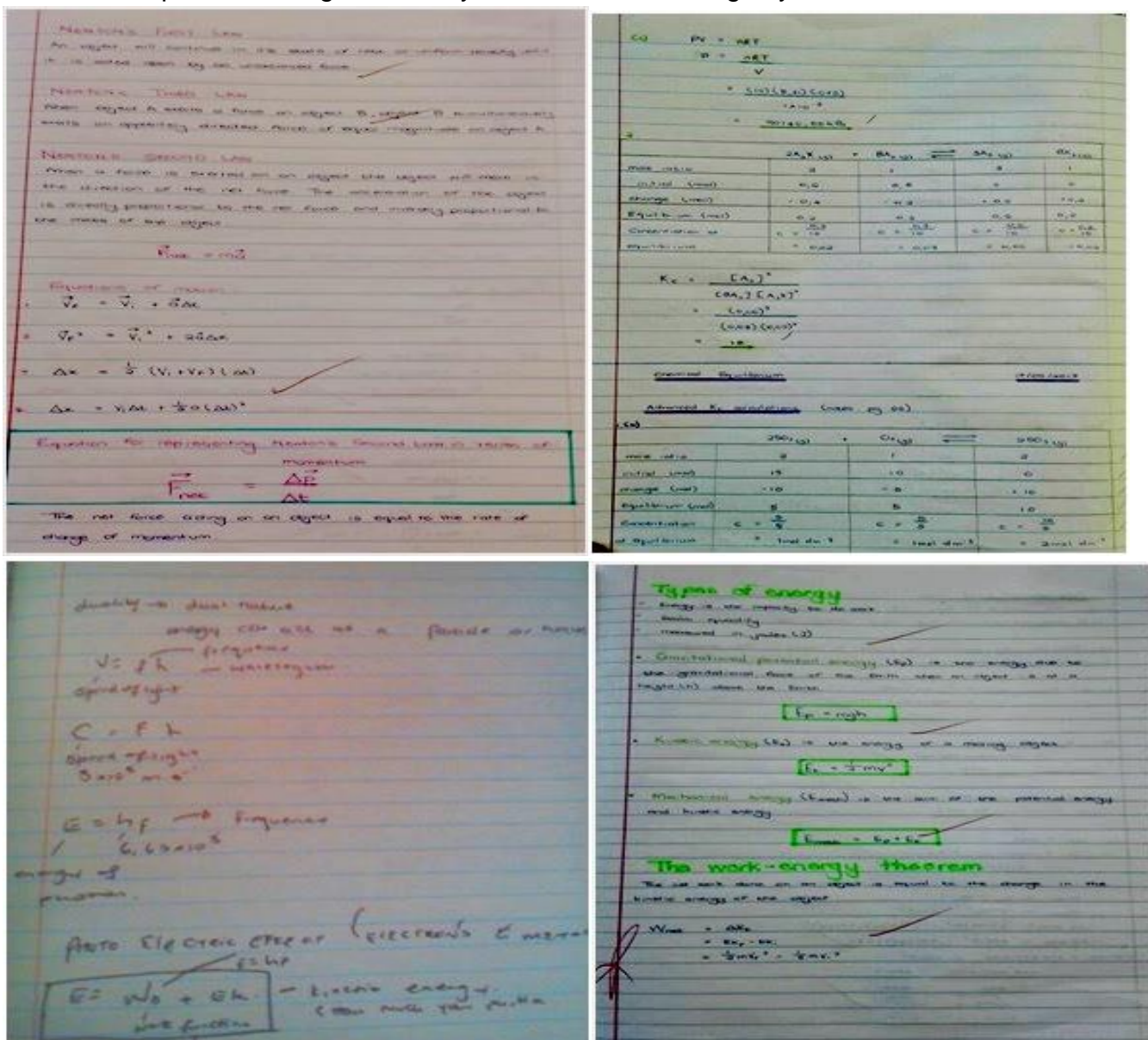


Figure 5.5: Strategies used by learners to write and highlight key information

Part of the problem-solving strategies was discussed during the diagram analysis. There was evidence of step-by-step planning for selected problems in all notebooks. The most common planning strategy was writing out the “known” and “unknown” information. Diagrams were also used for selected problems. There was no highlighting of information during problem solving. Figure 5.6. below shows how step-by-step planning, writing the known and unknown information, and using diagrams were used to plan problem solving.

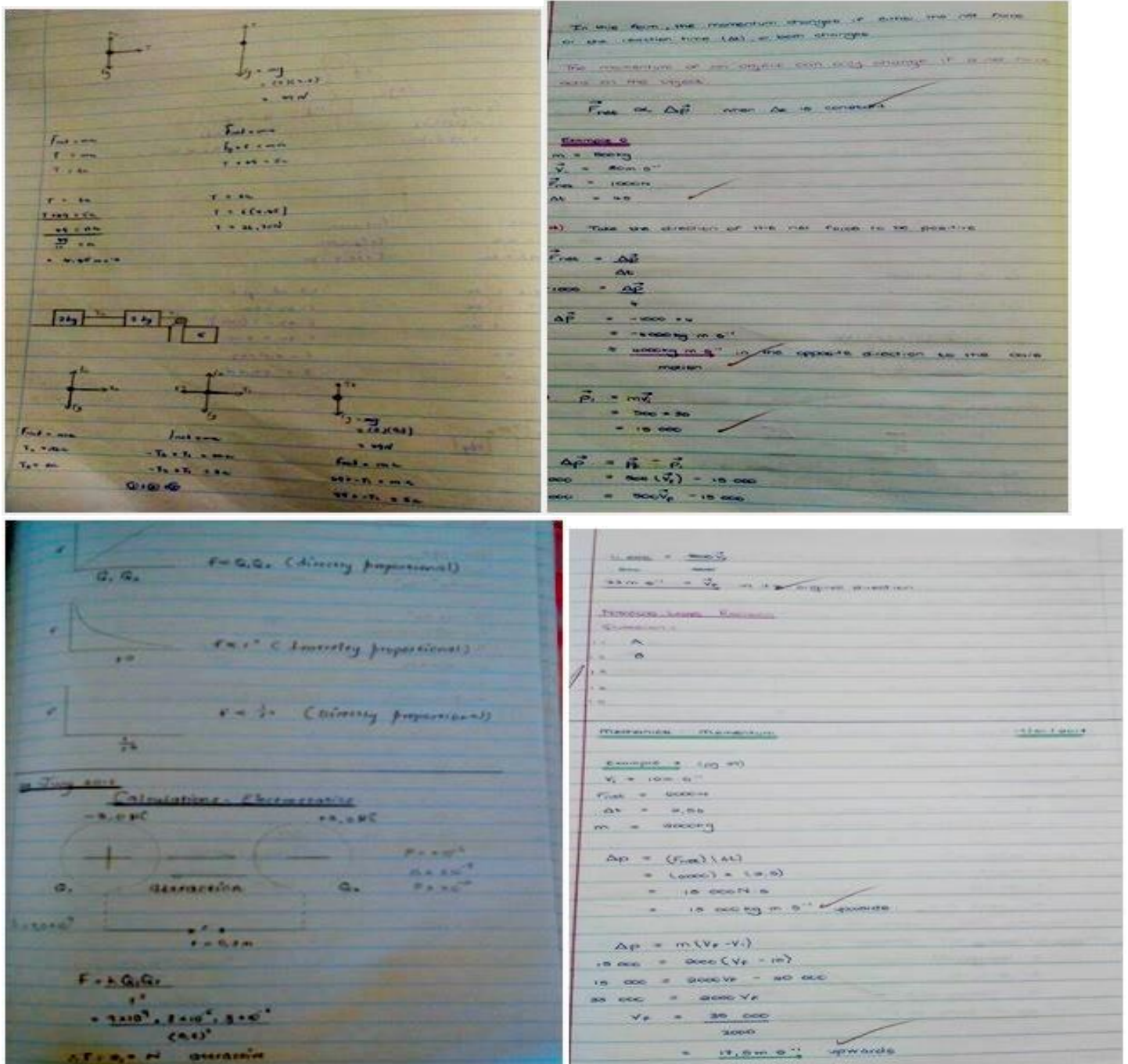


Figure 5.6: Written planning observed during problem solving

Conclusion

The notebooks analysis concluded that learners summarised the declarative information regarding key points, summaries, and equations. There was an inadequate use of highlighters, an important technique in the understanding and learning of knowledge (Boch & Piolat, 2005:104). Tables were used to summarise selected key information. Diagrams were used effectively. However, the more able learners used diagrams in problem solving more regularly to visualise and deconstruct scientific meaning from the problem.

All books showed the major problem-solving plan was to note the known and unknown information in writing. From the information in the notebooks, together with observed problem-solving strategies, the researcher ascertained that learners reflected the popular teacher-expert model of the teaching and learning process, as discussed in part 5.3.4.6 of the analysis.

There was no evidence of brainstorming of ideas and mnemonics, which suggested to the researcher there was a greater focus on problem solving than on a conceptual understanding of scientific information. Emphasis on conceptual learning strategies, such as flow diagrams, mnemonics, and highlighting of key information needs to be promoted. There was satisfactory and effective written content in the notebooks, empowering learners to learn and apply their declarative knowledge at a much higher level.

5.3.5.2 Marking for improvement and promoting metacognition

All books were ticked using a red pen (see fig. 5.21-5.23). No constructive feedback was given to learners. The teachers did not provide adequate comments while marking the learner's notebooks to promote improvements in conceptual understanding, metacognition, and problem solving. Providing feedback to learners about the quality of their work, together with advice on how they might improve, is a type of formative assessment that helps improve the learner's attainment (Black & William, 1998:6). Similarly, advice on how to improve metacognitive skills would help learners to improve their metacognitive awareness. Furthermore, there was no

evidence of positive reinforcement by writing motivational comments or awarding stickers, stamps, or merits to learners. Teachers need to be trained on the effective use of constructive feedback and positive reinforcement when marking learners' notebooks.

5.3.5.3 Procedural and conditional knowledge

It was evident that learners knew when and how to use a scientific skill during problem solving. Figures 5.4 and 5.6 shows the ability of learners to use their procedural and conditional knowledge during problem solving. More able learners use more detail in showing the solution to the problem, while less able learners provide slightly less detail. Sometimes the inclusion of the formulae is missing, and learners simply put in the numerical information. Similar to the results of declarative knowledge in part 4.3.5.1 of the analysis, the notebooks emphasised the teacher-expert model, where learners tried to solve the problem the way the teacher had shown them. There was satisfactory and effective written content in the notebooks for learners to learn and apply their declarative knowledge at a high level. Figures 5.4. and 5.6. show examples of learners using their declarative and procedural knowledge. Notebooks could be used to practise declarative and procedural skills.

5.3.6 Conclusion of the qualitative data

The Physical Science CAPS document is designed effectively and coherently as it demonstrates articulation, depth, progression, continuity, sequence, balance, and scope (Ornstein & Hunkins, 2009:186-190) and also promotes scientific enquiry which helps in the promotion of metacognition (Schraw et al., 2006:19, White & Frederiksen, 1998:4-5). These attributes of curriculum design assists in supporting metacognitive awareness (Schraw et al., 2006:19, White & Frederiksen, 1998:4-5). The Physical Science curriculum acknowledges indigenous knowledge systems, which promotes the motivation dimension of metacognitive awareness; however, the curriculum does not include sufficient guidance for teachers to refer in order to incorporate indigenous knowledge in their Physical Science lessons. The curriculum document analysis concluded the South African Physical Science curriculum has features to support metacognition (research aim 1).

The data from the learner interviews concluded that the majority of learners do not have cultural conflicts while studying Physical Science, even though 61% of learners stated that the Physical Science course would be more exciting, and learners would become more culturally aware if the African culture were included in the course (see section 5.3.2.5). Furthermore, 35% of learners stated that they would prefer to be taught Physical Science in isiZulu (see section 5.3.2.7).

The majority of learners felt their Physical Science lessons lacked practical activities and equipment to support practical work (see section 5.3.2.7). This is due to insufficient resources in the school, and not because of the curriculum design. Nearly half of the learners (43%) also mentioned that to improve the course, information technology is required in the classroom (see section 5.3.2.7).

Despite not being formally taught metacognitive skills, it was seen that learners show awareness of both metacognitive knowledge and metacognitive regulation (see section 5.3.2.1 and 5.3.2.2). This is due to the nature of the Physical Science curriculum, which promotes metacognitive awareness naturally during the teaching and learning process, and the tacit influences in the learning environment (see section 2.4.4.).

The learner interviews revealed that the metacognitive regulation components of planning and monitoring strategies were not discussed well (see section 5.3.2.1 and 5.3.2.2). However, evaluation during the metacognitive regulation component of problem solving was discussed in finer detail. This is due to learners not monitoring their progress but focusing instead on their achievement of goals upon completion of the task.

All the learners had a clear idea of what to do when they did not understand a lesson. They used self-directed learning strategies appropriately. However, they need to improve in setting targets and evaluating their goals (see section 5.3.2.3). Learners' responses showed they possess some aspects of self-directedness in learning but focused a lot on solving problems using past papers instead of

conceptual understanding in physics through effective cramming, which is crucial in problem solving (see section 5.3.2.4).

From the teacher interviews, it is evident that although the Physical Science curriculum supports metacognition, the teachers felt the content of the curriculum is too extensive, and they do not have time to complete the curriculum effectively (5.3.3.2). All the teachers mentioned they have not heard of the term metacognition and there was no training provided by the science advisers, tertiary institutes, or the school's management on metacognitive awareness (see section 5.3.3.1). From the responses, it was clear that teachers viewed Western science as an empirical discipline with no cultural bias (5.3.3.3). The teachers did not observe any conflict between learners studying a Western science and their culture, which is similar to the learners' responses (5.3.3.4).

The lesson observations concluded that learners were not encouraged to construct and develop their prerequisite knowledge by referring to the lessons aims and objectives. The teachers did not display the lesson objectives on the board (see section 5.3.4.1). This hindered the metacognitive planning component of learning. The results of the metacognitive monitoring part of the observation showed the dominance of the chalk-and-talk method in the teaching and learning process. There was little facilitating of activities. Furthermore, there was minimal guidance in learners' ZPD.

No formative assessment strategies were used to find out whether learners had reached the lesson objectives (see section 5.3.4.3). The dominant model used during problem solving was the teacher-expert model. During problem solving, the teachers employed think-aloud strategies to focus on important points. Despite some elements of metacognitive planning, monitoring, and evaluation taking place, metacognitive awareness in lessons could be improved.

Analysis of the notebooks showed that learners knew when and how to use a scientific skill for problem solving. Sometimes, the inclusion of the formulae was missing, and learners simply put in the numerical information. The results of the

declarative knowledge shown in part 5.3.5.1 of the notebook analysis emphasised the teacher-expert model, where learners try to solve the problem the way the teacher had shown them. There was sufficient effective written content in the notebooks for learners to learn and apply their declarative knowledge at a high level. Figures 5.4. to 5.6. show examples of learners using their declarative and procedural knowledge. The notebook can be used to practise declarative and procedural skills. The notebook analysis also concluded that there was no marking of books for motivation and improvement of learners' metacognitive awareness.

5.4 Integration of the quantitative and qualitative results

In the integration of the data results, the researcher used the secondary research questions to guide the discussions towards a conclusion.

5.4.1 Integration of results in answering secondary research question 1

Secondary Research Question 1: To what extent does the South African Physical Science curriculum promote metacognition?

From the curriculum document analysis in part 5.3.1, the researcher concluded the curriculum design is effective and coherent, and therefore promotes metacognition (Schraw et al., 2006:19). The Physical Science curriculum recognises indigenous knowledge, which promotes motivation and better attitudes towards the science, which in turn leads to encouraging metacognitive awareness (Kruglanski & Nelson, 1998:150). The curriculum promotes scientific enquiry which encourages the promotion of metacognition (Schraw et al., 2006:19).

However, further analysis of the curriculum revealed a lack of guidance on how to include indigenous knowledge in the teaching and learning process in Physical Science (see section 5.3.1.7). Teachers require guidance and training on the implementation of indigenous knowledge. Six out of seven teachers mentioned not receiving any training in promoting indigenous knowledge in their Physical Science classes (see section 5.3.3.6). Analysis of the learner interviews in 5.3.2.6 found 61% of learners felt that African culture should be included in the curriculum because it

would make the course more exciting and improve learners' cultural awareness. The teacher interviews showed that 6 out of 7 teachers did not feel a need to implement indigenous knowledge during their implementation of the curriculum (see section 5.3.3.3). The researcher concluded that despite the curriculum including indigenous knowledge in the curriculum; it does not effectively guide and encourage teachers to implement the indigenous knowledge.

All teachers interviewed felt the curriculum was too content-driven, thereby making the examinations too difficult for learners and the amount of content too extensive to complete during the allocated time frame. All teachers mentioned the time aspect repeatedly as a major requirement for improving the curriculum (see section 5.3.3.2 and 5.3.3.7).

The conclusion drawn from the analysis of curriculum documents suggests that while the Physical Science curriculum does support metacognition, it does not contain detailed guidelines for the implementation of indigenous knowledge to motivate indigenous learners and further support metacognition. Theoretical analysis of the Physical Science curriculum reveals key features, such as articulation, depth, progression, continuity, sequence, balance, and scope (Ornstein & Hunkins, 2009:186-190). The curriculum promotes scientific enquiry which encourages metacognition (Schraw et al., 2006:19). Furthermore, analysis of the teacher interviews indicates that the curriculum does not take the time constraints of the teaching and learning environment into account. Time to complete the curriculum and indigenous knowledge within the curriculum are variables considered in Chapter 6, along with workable solutions to these variables.

5.4.2 Integration of results in answering secondary research question 2

Research question 2: What is the relationship between learners' Physical Science examination results and their level of metacognitive awareness?

The MAI analysis suggests that the majority of learners were confident in their ability to implement declarative metacognitive knowledge, planning, information

management strategies, and debugging strategies (see section 5.2.1). Theory suggests that having good metacognitive skills would allow learners to produce successful academic results (Hartman, 2001:198; Holmes, 2007:15; Jayapraba, 2013:165-166; McCraight-Wertz, 1999:14; Sinatra & Taasoobshirazi, 2011:213-214). Analysis of the results showed the average mark achieved by the 151 learners was 41%, with most of the learners achieving less than 50% (see section 5.2.4.) These results did not meet expectations of the conclusions drawn from the MAI, SAQ, MAIT, and the literature studied.

Analysis of the MAI further suggests that learners feel confident in their metacognitive abilities, but analysis of the learner interviews found that:

- Despite learners being aware of important metacognitive skills linked to metacognitive knowledge, it was evident from their responses that key skills, such as mental integration (frequency of 53%), activation of prior knowledge (frequency of 18%), skimming (frequency of 38%), and slow down (frequency of 37%), all need to be made more accessible to all learners (see section 5.3.2.1);
- Planning and monitoring skills linked to metacognitive regulation had low-frequency responses of 35% and 12% respectively (see section 5.3.2.1);
- Ways to improve coding of the metacognitive categories had an extremely low-frequency response of 3% (see section 5.3.2.2);
- The interview question on self-directed learning showed that no learner articulated learning by setting goals and deadlines (see section 5.3.2.2);
- Metacognitive planning techniques for revision using study timetables (49%), working on weak areas (32%), and time management (32%) all scored low-frequency responses (5.3.2.4).

The analysis of lesson observations found that:

- There were no clear lesson goals or observations to encourage metacognitive monitoring and planning during the lesson (see section 5.3.4.3 and 5.2.4.4);

- There was no evidence of effective formative assessment being used to evaluate whether learners understood the lesson (see section 5.3.4.5);
- The teacher-led approach to teaching dominated the lesson, instead of the active learning approach which complements metacognitive awareness (see section 5.3.4.1 and 5.3.4.7).

The analysis of learners' notebooks showed that:

- Despite evidence of planning, problem solving, and declarative information being recorded, there was inadequate use of highlighters, an important technique for acquiring and understanding knowledge (Boch & Piolat, 2005:104) (see section 5.3.5.1);
- There was abundant evidence of problem solving; there was, however, no evidence of brainstorming of ideas or mnemonics, which suggests that there is a greater focus on problem solving than on conceptual understanding of scientific information (see section 5.3.5.1);
- There was no constructive feedback on ways to improve metacognitive skills in learners' notebooks (see section 5.3.5.2).

The analyses of learner interviews, classroom observations, and learners' notebooks all indicate frequent gaps in metacognitive awareness. The qualitative analysis suggests clear areas for improvement in the learners' metacognitive awareness. Learners' half-yearly results are better aligned with conclusions drawn from the analysis of the learner interviews, the classroom observations, and the learners' notebooks, than with the results obtained by the MAI. Furthermore, half-yearly examination analysis concluded that the examination does not reward indigenous knowledge and metacognitive skills.

The results from the MAI seem to suggest that learners have inflated confidence in their metacognitive ability, which would need to be addressed to improve their metacognitive skills, and consequently, their attainment. As mentioned in section 4.4.9 research done by Huszti et al. (2016:68-80) and Siegesmund (2016:204-214) also found that research participants tended to exaggerate their metacognitive ability when asked to self-assess their metacognitive awareness (see section 4.4.9).

Results from meta-activity questionnaires very infrequently align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). The researcher overestimated what the MAI could validly take to show. The variable of metacognition within the learning process has to be examined to promote workable solutions. This will be discussed in further detail in Chapter 6.

5.4.3 Integration of results in answering secondary research question 3

Research question 3: To what extent is metacognition promoted by the teacher in the Physical Science classroom?

The analysis of the MAIT determined that teachers feel confident in their metacognitive abilities and their ability to promote metacognition (see section 5.2.3). However, the teacher interviews revealed that none of the teachers had heard of the term metacognition and had not been given training in promoting metacognition in the classroom (see section 5.3.3.1). As discussed in section 1.1.2. a major problem lies in the average science teacher having no notion of metacognition, and the ones who do lack the resources to facilitate metacognitive awareness effectively (Georghiades, 2004:379). These conflicting sentences is a result of the teachers exaggerating their metacognitive abilities and maybe expressing a certain impression of themselves to in order to minimize their own uneasiness (see section 4.4.9.). Furthermore, the lesson observations revealed that crucial elements of metacognition lacked in the lessons. Despite teachers not being formally trained in metacognition, the lesson observation showed that they (Table 5.59)

- modelled metacognitive thought process with frequencies of two out of seven (think-aloud); four out of seven (highlight key points); and seven out of seven (teacher-expert model);
- had elements promoting reflection of learning, with frequencies of two out of seven (enquired about lesson understanding), and four out of seven (asked whether learners wanted anything to be repeated);

- promoted students' metacognition with frequencies of seven out of seven (encouraged questioning); two out of seven (ask for learner input); and one out of seven (ZPD);
- had elements of promoting planning, with frequencies of seven out of seven (starter to prerequisite knowledge); and seven out of seven (direct learners to where thought process should take them).

The Physical Science teachers exhibited aspects of metacognition despite not being aware of the concept and not being trained in promoting metacognition. Acquiring declarative, procedural, and conditional knowledge is essential during problem solving in Physical Science (see section 2.5), therefore those skills are naturally occurring in the teaching and learning of Physical Science due to tacit influences (see section 2.4.4.).

The teachers exhibited several elements of metacognition during their teaching of Physical Science because their focus was on problem solving and examination preparation (see section 5.3.4.3 to 5.3.4.7). However, the level of metacognition observed was markedly less than the results of the MAIT suggested (see section 5.2.3.). The contrast in results of the MAIT, lesson observations, and teacher interviews suggest that

- even though the teachers were not familiar with metacognition and did not have any training in promoting metacognition, they nevertheless promoted elements of metacognition;
- in answering the MAIT, the teachers appeared to over-state their metacognitive awareness.

It is evident from the lessons that, to answer research aim 3, there are elements of metacognition being promoted during the teaching and learning process (see section 5.3.4.3 – 5.3.4.7). However, the state of metacognition could be improved because:

- teachers have not been trained in promoting metacognitive awareness (see section 5.3.3.1);
- no teacher was observed setting objectives to promote metacognitive planning (see section 5.3.4.3);

- no teacher encouraged learners to explain in their own words to monitor understanding (see section 5.3.4.4);
- no teacher used structured, formative assessment strategies to encourage metacognitive evaluation (see section 5.3.4.5);
- the teacher-led approach to teaching dominated the lesson, instead of the active learning approach which supplements metacognitive awareness see section 5.3.4.1 and 5.3.4.7).

The variable of metacognition in the teaching and learning process has to be considered to promote workable solutions. This will be discussed in further detail in Chapter 6.

5.4.4 Integration of results in answering secondary research question 4

Secondary Research Question 4: What are the views held by indigenous learners and teachers regarding Western science?

This research was examined from a social-cultural perspective, using the third-generation Cultural-Historical Activity Theory (CHAT) theoretical framework to understand and analyse the interacting systems that influence indigenous learners' education (see section 1.4.2). Through this, it was noted that metacognition is influenced by socio-cultural factors (Hacker & Bol, 2004:292-293; Helms-Lorenz & Jacobse, 2008:14; Kurtz, 1990:185; Kruglanski & Nelson, 1998:77, Thomas, 2002:242). Data analysis of the teacher interviews (see section 5.3.3.3 to 5.3.3.6) was used to answer secondary research question 4. The analysis of the curriculum document was referred to at times.

The curriculum analysis revealed that the focus of the curriculum was on European scientists, and the results from the analysis of question 4 of the teacher interview concluded that none of the teachers experienced learner resentment of the Western science curriculum (see section 5.3.3.4). Furthermore, analysis of the learner interview question 5 showed that 84% felt that the curriculum is unbiased, does not force cultural views, and does not dismiss the existence of God (see section 5.3.2.5). However, 61% of learners felt that African culture should be included in the

curriculum because it would make the course more exciting, and help learners become more culturally aware (see section 5.3.2.6). The curriculum analysis, on the other hand, found there was little assistance within the curriculum to support and motivate the teachers to implement indigenous knowledge in their Physical Science lessons (see section 5.3.1.7).

It is noteworthy that a large minority of learners (39%) felt that including culture in the curriculum might offend other learners (see section 5.3.2.6) and the 35% of the learners would prefer the Physical Science taught in isiZulu. These learners are possibly not aware that Western culture is embedded in the science we study, as discussed in part 3.3 of the literature review.

The data analysis confirmed that there is a place for local and indigenous culture in the science curriculum, with 61% of learners indicating that African culture should be included in the curriculum. On the other hand, a large majority of teachers and learners felt the curriculum is unbiased and respects their culture. The majority of teachers felt there is no need for indigenous knowledge in the science curriculum (see section 5.3.3.2), and six out of seven teachers stated they did not receive any training in the implementation of indigenous knowledge in teaching science (see section 5.3.3.6). The variable of indigenous knowledge within the Physical Science curriculum is discussed in more detail in Chapter 6.

5.4.5 Integration of results in answering secondary research question 5

Secondary Research Question 5: What is the relationship between learners' metacognitive awareness and their attitude towards Physical Science?

The motivation of learners plays an important role in the metacognitive process (Efklides et al., 2001:303; Hartman, 2001:99; Larkin, 2009:85; Myers, 2008:37). The SAQ analysis quantitatively gauged the motivation of learners to study science. Overall, the descriptive statistics of the SAQ indicate that an average of 84.8% of learners do not align themselves with the negative attitude towards science construct of the SAQ, with an average of 79.4% of learners exhibiting a positive attitude towards science (see section 5.2.2.3 – 5.2.2.4).

The analysis of the MAI suggested that most learners were confident in their metacognitive declarative knowledge, conditional knowledge, planning, information management strategies, and debugging strategies (see section 5.2.1). These results align with the results of the SAQ concerning the theory suggested by Efklides et al. (2001:303), Hartman (2001:99), Larkin (2009:85), and Myers (2008:37). The analysis of the MAI and the SAQ suggests that learners felt assured about their metacognitive awareness and had a positive attitude towards Physical Science. This further reflected the results of the MAIT, whereby the teachers felt confident in their metacognitive awareness (see section 5.2.3).

Despite learners being so confident in the metacognitive ability and having a positive attitude towards science, the analysis of the classroom observations together with the teacher interviews suggested a significant need for improvement in the promotion of metacognitive awareness in the Physical Science classroom (see section 5.3.3.1; 5.3.4.3 to 5.3.4.7; and 5.4.4). Moreover, the majority of learners found Physical Science difficult (see section 5.2.2.3). There was no evidence of a reward system to motivate and promote metacognition in learners' science notebooks (see section 5.3.5.2), and the classroom observations showed no evidence of a positive behaviour system to improve motivation. The positive behaviour system is discussed in Chapter 6. Even though there seem to be high confidence levels in science attitudes and metacognitive awareness stemming from the SAQ, the MAI and the MAIT, further analysis suggests a crucial need for improvements in practise.

The variable of improving learners' mindset in Physical Science has to be considered. This, together with promoting metacognition, is discussed in greater detail, in Chapter 6.

5.4.6 Integration of results in answering secondary research question 6

Secondary Research Question 6: How does studying Western science impact on the metacognitive processes of the indigenous learners in South Africa?

Part 5.4.4 integrated the results derived from the data from the SAQ, the learner interviews, and the teacher interviews, to conclude that the majority of learners felt their culture and history did not deter them from studying Physical Science (84% according to the learner interviews, (see section 5.3.2.5)). The factors addressed had a substantial impact on the learners' attitude towards Physical Science, which reflects the learners' metacognitive awareness (Efklides et al., 2001:303; Hartman, 2001:99; Larkin, 2009:85; Myers, 2008:37). The ripple effect from motivation and metacognition would affect the attainment of learners (Landine & Stewart, 1998:200; Nongtodu & Bhutia, 2017:54-55; Owo & Ikwut, 2015: 6). There was insufficient evidence to conclude that learners' metacognition was directly affected in studying Western science. They were motivated to study Physical Science, but found it difficult, as discussed in 5.4.5.

5.4.7 Integration of results in answering secondary question 7

Secondary research question 7: To what extent are Physical Science teachers metacognitive thinkers?

Part 5.4.3 emphasised that the analysis of the MAIT concluded that teachers felt confident in their metacognitive abilities (see section 5.2.3). Conversely, the results from the teacher interviews showed that none of the teachers had heard of the term metacognition and had no training in promoting metacognition in the classroom (see section 5.3.3.1). The lesson observations showed that crucial elements of promoting metacognition in the classroom needed to be improved (see section 5.3.4.3 to 5.3.4.7). It would seem the teachers overestimated themselves during completion of the MAIT. Research done by Huszti et al. (2016:68-80) and Siegesmund (2016:204-214) found that participants tended to overrate their metacognitive ability when asked to self-assess and this is due to the self-presentation effect (see 4.4.9.). Furthermore, results from meta-activity questionnaires very infrequently align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). These elements were discussed in greater detail in part 5.4.3 of this chapter and in parts 5.3.4.3 to 5.3.4.7 of the classroom observation. The variable of metacognition in the teaching and learning process has

to be considered to promote workable solutions. This is discussed in further detail in Chapter 6.

5.4.8 Integration of results in answering secondary question 8

Secondary Research Question 8: What workable teaching and learning strategies can be exhorted to improve learners' metacognitive skills?

This question is laid out in greater detail in Chapter 6 in the suggested recommendations of the research. However, it is noteworthy from the analysis of the SAQ that despite 94% of learners feeling science classes prepared them well for university, and 84% feeling they would enjoy a science-related career, 78% of learners felt they would not become scientists in the future (see section 5.2.2.5). This is greatly concerning, considering that South Africa needs world-class scientists. Learners studying Physical Science did not see themselves in a science-related career. This further compounded the sentiment that science is difficult (see section 5.2.2.3), with teachers, under lots of pressure to complete the syllabus in a short timeframe, cramming work during class time. These impacts on the normal teaching and learning of Physical Science (see section 5.3.3.2). Learners displayed a fixed mindset when it came to the challenges they face in the study of Physical Science. There should be systems put in place to promote growth mindsets. Fixed mindsets suggest that learners who had not succeeded in a task felt unable to succeed, while learners with growth mindsets take risks, believe in themselves, and try harder when they do not succeed the first time (Dweck, 2006:10-11). This is discussed in greater detail in Chapter 6.

The Physical Science course needs more focus on practical work, according to 60% of learners, while a further 43% stated that the course requires information and communication technology in the classroom. Another 37% of learners felt that physics is stereotyped as inaccessible and difficult (see section 5.3.2.7). Learners would feel more motivated if there were more access to practical work and more up-to-date technology in the teaching and learning environment. The issue of Physical Science being difficult was mentioned again in the learner interviews (see section 5.3.2.7). These issues would be a factor in improving the number of learners

studying Physical Science. It is counterproductive to spend all the time and effort to achieve better results, if learners are not choosing to pursue Physical Science in the first place.

The research in the schools took place in 2016. When the researcher had followed up discussions with the Physical Science teachers of the selected schools, it was found that schools C and G did not offer Physical Science in 2017 because of poor intake of learners wanting to do Physical Science. Furthermore, teachers either left teaching in South Africa to work internationally or were considering teaching internationally, and some considered early retirement due to stress (see section 5.3.4.1). This inevitably compounds the motivation, metacognition, and attainment of the Physical Science learners.

Integrating the results of the triangulation design led to the conclusion that the following variables need to be addressed to answer the primary question (see Chapter 6):

- Promoting metacognition in the teaching and learning process (see section 5.4.2; 5.4.3; and 5.4.7);
- Improving teachers' mindset to promote metacognition (see section 5.4.5);
- Integrating indigenous knowledge within the teaching and learning process (see section 5.4.1; and 5.4.4);
- Time to complete the curriculum (see section 5.4.1).

5.5 Summary

This chapter provided a comprehensive account of the statistical data analysis of the quantitative data, and the interpretation, critical analysis, and understanding of the qualitative data. Chapter 5 showed the integration of the mixed methods data using triangulation analysis to draw findings. Discussions of the findings follow in chapter 6, with suggestions, recommendations, and conclusions to answer the primary research question, "What is the state of metacognition within indigenous learners' Physical Science classrooms in KwaZulu-Natal?"

CHAPTER 6

SUMMARY, DISCUSSIONS, AND RECOMMENDATIONS

6.1 Summary of the previous chapters

The mixed methods, multiphase, concurrent triangulation design (Creswell & Clark, 2011:66) used a combination of concurrent timing and sequential timing in the study that consisted of four phases (see section 3.3.6). Chapter 5 presented the empirical set of quantitative data and the qualitative information, it also analysed data to draw conclusions, and finally used triangulation to integrate the data. This chapter will summarise the findings to answer the research questions, discuss key ideas and the limitations of the research, and make recommendations.

In Chapter 1, the research paradigms and viewpoints were defined, leading to the formation of the primary and secondary questions. Using the mixed methods approach, the methodology was corroborated by a short assessment of the data collection methods and analysis techniques. Essential keywords were defined in terms of their relevance to the study, and were further justified by a short literature review.

In Chapter 2, the researcher delivered an in-depth assessment of those academic articles, research, and books written about the definitions of metacognition, epistemological assumptions, metacognitive theories, components of metacognition, and models of metacognition, citing pertinent work by many authors.

Chapter 3 delivered an in-depth assessment of pertinent work by numerous authors, including academic articles, research, and books on the cultural influences of metacognition, CHAT, the environment interacting systems model, and the conflict felt by non-Western learners studying Western science.

In Chapter 4, theoretical positions and detailed description of the research methodology was laid out. This led to a justification of the entirety of the findings, and to confirmation of the validity and rationale of the data in the research methodology. This chapter confronted the research problem, considered metacognition in the South African Physical Science classroom, and moved towards a conclusion. The

research methodology lent weight to the validity, reliability, and explanation of the results.

Chapter 5 presented the quantitative analysis of the data of the MAI, SAQ, MAIT, and the half-yearly Physical Science examination results. Descriptive analyses of the data in the form of means, standard deviations, percentage frequencies, and bar graphs were used to draw conclusions. Cronbach Alpha values were calculated to show the reliability of the data. Chapter 5 also included the results of the qualitative data analysis. This was in the form of data analyses of the Physical Science curriculum document, learner interviews, teacher interviews, classroom observations, and science notebooks. Triangulation of the quantitative and qualitative data was completed in order to draw conclusions.

The following section is a discussion of the findings in Chapter 5, to answer the research questions.

6.2.1 Answering the secondary research questions

Section 5.4. integrated the results in order to answer the research questions through triangulation of the data. The discussions of the secondary research questions characterised a contextualisation of the conclusions. The literature and triangulated data clarified the results within the discussion and served as answers to the research questions. Each question was examined quantitatively and qualitatively. The following briefly summarises the overview of the results found in Chapter 5 of the study starting with the secondary research question 1 as seen below.

Secondary Research Question 1: To what extent does the South African Physical Science curriculum promote metacognition?

Conclusions drawn from the analysis of curriculum documents showed that the Physical Science curriculum is balanced because it features articulation, depth, progression, continuity, sequence, balance, and scope (Ornstein & Hunkins, 2009:186-190). The curriculum supports scientific enquiry which helps in the promotion of metacognitive awareness (see section 2.8). The Physical Science

curriculum acknowledges indigenous knowledge systems, which can promote motivation and positive attitudes dimensions of metacognition. However, the curriculum does not include sufficient guidance for teachers to refer to or incorporate indigenous knowledge into their Physical Science lessons. A major concern among all the teachers was that the rigorous content driven curriculum could not be completed effectively during the teaching time frame. This belief by the teachers conflicts with the analysis of the curriculum document which was found to fit an effective curriculum design and promote scientific enquiry (see sections 4.1.1. and 5.3.1.). The researcher thus concludes that the theoretical aims of the curriculum do not fit with what actually occurs in the Physical Science classroom. This needs to be considered when discussing the workable solutions in 6.2.3.

Secondary Research Question 2 What is the relationship between grade 11 learners' Physical Science half yearly examination results and their level of metacognitive awareness?

The analyses of learner interviews, classroom observations, and learners' notebooks all indicate frequent gaps in metacognitive awareness on the part of the learners. These gaps need to be addressed. Learners' half-yearly results, which were low (see section 5.2.4.), are better aligned with conclusions drawn from the analysis of the learner interviews, the classroom observations, and the learners' notebooks, than with the results obtained by the MAI. The analysis of the MAI showed similarities to the research done by Huszti et al. (2016:68-80) and Siegesmund (2016:204-214) where participants tended to exaggerate their metacognitive ability. The researcher overestimated what the MAI could validly show. Results from meta-activity questionnaires very seldom align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). Despite not being explicitly taught metacognitive skills, it was seen that learners showed awareness of both metacognitive knowledge and metacognitive regulation (see sections 5.3.2.1 and 5.3.2.2). This could be attributed to the nature of the Physical Science curriculum, which promotes metacognitive awareness naturally through problem solving and scientific enquiry (see section 2.10.), and the tacit influences in the learning environment (see section 2.4.4.). Furthermore, going over past

examination questions could activate the learners' procedural and conditional knowledge skills during problem solving (see 5.3.2.4). Declarative knowledge could be used when the learners use declarative techniques to interpret questions and read to remember theoretical knowledge. This might be connected to the meta-skills acquired during independent problem solving (see section 2.10.).

Secondary Research Question 3: To what extent is metacognition promoted by the teacher in the Physical Science classroom?

Similar to the MAI, the MAIT showed parallels to research done by Huszti et al. (2016:68-80) and Siegesmund (2016:204-214), where participants tended to overestimate their metacognitive ability. Results from meta-activity questionnaires very rarely align with the actual behaviour of participants observed during the qualitative part of the research (Veenman et al., 2006:9). The researcher overvalued what the MAIT could validly take to show. The teachers exhibited several examples of promoting metacognitive awareness during their teaching of Physical Science. This could be attributed to their focus being on problem solving and examination preparation (see section 2.10.) and the tacit influence of metacognition in the learning environment (see section 2.4.4). The teacher interviews revealed that none of the teachers had heard of the term metacognition and that they had not been given training in promoting metacognition in the classroom (see section 5.3.3.1). As discussed in section 1.1.2. a major problem lies in the average science teacher having no idea of metacognition, and the ones who do lack the resources such as time and effort to facilitate metacognitive awareness effectively (Georghiadis, 2004:379). However, the levels of metacognition observed were markedly less than the results which the MAIT suggested (see section 5.2.3.). The contrast in results between the MAIT and the lesson observations, and teacher interviews suggest that, even though the teachers were not familiar with metacognition and did not have any training in promoting metacognition, they nevertheless promoted elements of metacognition informally.

Secondary Research Question 4: What are the views held by indigenous learners and teachers regarding Western science?

It was noted in this study that metacognition has a socio-cultural influence (Hacker & Bol, 2004:292-293; Helms-Lorenz & Jacobse, 2008:14; Kurtz, 1990:185; Kruglanski & Nelson, 1998:77, Thomas, 2002:242). The curriculum analysis revealed that the focus of the curriculum was on European scientists. However, there was some focus in the curriculum of the need to fuse indigenous knowledge within the Physical Science curriculum.

Analysis on the learner interviews showed that 84% of the learners felt that the curriculum was unbiased, did not force cultural views, and did not dismiss the existence of God (see section 5.3.2.5), but 61% of learners felt that African culture should be included in the curriculum because it would make the course more exciting, and help learners become more culturally aware (see section 5.3.2.6). These opinions about including indigenous culture by indigenous Physical Science learners in South Africa will be viewed from the perspective of “cultural-border-crossing” (see section 3.4.) within the Physical Science classroom and will be discussed in section 6.2.3.3. of this chapter.

A significant minority of the learners felt that the Physical science course should be taught in isiZulu (see section 5.3.2.7). Apart from the cognitive conflict associated with cultural-border crossing, the conflict of indigenous language and scientific terms was discussed in section 1.4.3.2. and 3.4. This point will be noted whilst discussing the cultural implications of the research.

Secondary Research Question 5: What is the relationship between learners' metacognitive awareness and their attitude towards Physical Science?

Motivation of learners plays an important role in the metacognitive process (Efklides et al., 2001:303; Hartman, 2001:99; Larkin, 2009:85; Myers, 2008:37). Overall, the descriptive statistics of the SAQ indicated that an average of 84.8% of learners did not align themselves with the negative attitude towards science construct of the SAQ, with an average of 79.4% of learners exhibiting a positive attitude towards science (see section 5.2.2.3 to 5.2.2.4). According to the literature discussed in sections 2.4.3. and 2.5.1., a strong motivation in studying science as concluded by the SAQ results in high metacognitive awareness. This was not the case.

The results from the SAQ also showed that 75.3% of learners found Physical Science difficult (see section 5.2.2.3.) and 78% of learners felt they would not become scientists in the future (see section 5.2.2.5.). This implies that the learners have elements of a fixed mindset regarding their feelings about the difficulty of the Physical Science course, which in turn discourages them from studying science in the future. The variable of improving learners' mindset in Physical Science will be considered when discussing workable solutions in section 6.2.3.2. below.

Secondary Research Question 6: How does studying Western science impact on the metacognitive processes of indigenous learners in South Africa?

The variables of motivation and metacognition affect the attainment of learners (Landine & Stewart, 1998:200; Nongtodu & Bhutia, 2017:54-55; Owo & Ikwut, 2015: 6; Vrugt & Oort, 2008: 123), and section 5.4.4 integrated the results derived from the data from the SAQ, the learner interviews, and the teacher interviews, to conclude that the learners' culture and history did not deter them from studying Physical Science. However, the major issue, as discussed in research question 5 above, was that the learners had a fixed mindset, found Physical Science difficult, and were reluctant in to pursue a career in science. Discussion on research question 4 above showed that 61% of learners felt that African culture should be included in the curriculum because it would make the course more exciting, and help learners become more culturally aware. This implies that the Physical science course lacked effective cultural inclusion of the indigenous learners. This highlights the points raised above on the indigenous knowledge and improving the learners' mindset. Overall, the motivational levels, a dimension of metacognition, would be improved if the learners changed from a fixed mindset to a growth mindset and if indigenous knowledge was integrated to be effectively within the Physical Science curriculum.

Secondary Research Question 7: To what extent do Physical Science teachers think metacognitively?

Part 5.4.3 emphasised that the analysis of the MAIT concluded that teachers felt confident about their metacognitive abilities. Conversely, the results from the teacher

interviews showed that none of the teachers had heard of the term metacognition and had no training in promoting metacognition in the classroom (see section 5.3.3.1). The lesson observations showed that crucial elements of promoting metacognition in the classroom needed to be improved (see sections 5.3.4.3 to 5.3.4.7). It would seem teachers overestimated themselves during completion of the MAIT. There are many areas in which the teachers could improve on their metacognitive skills. Physical Science teachers need to be highly metacognitive (Thomas, 2012:140).

Secondary Research Question 8: What workable teaching and learning strategies can be exhorted to improve learners' metacognitive skills?

Academic success is attributed to good metacognitive knowledge and metacognitive regulation (Akin, 2016:392; Jayapraba, 2013:165-166; Nongtodu & Bhutia, 2017:57; Owo & Ikwut, 2015: 6; Thomas, 2012:132) and this research points to metacognition improving success in the Physical Science classroom (Hartman, 2001:198; Jayapraba, 2013:165-166). Considerable research on metacognition suggests that greater achievement in learning takes place when metacognitive skills are promoted as part of classroom instruction (Schraw & Moshman, 1995:355, Schraw et al., 2006:119; White & Frederiksen, 1998:5-6). This was not the case in the South African Physical Science classrooms studied. Effective teaching and learning strategies to improve metacognitive abilities of both the teachers and the learners are achieved through informed training as opposed to blind training (Hollingworth & McLoughlin, 2001:55).

This research views merging Vygotskian theory of social interaction and the non-Vygotskian approach of independently solving problems as an effective approach in fostering metacognition. Therefore, this researcher promotes the three-way approach as workable teaching and learning strategies this includes social constructivism, explicit instruction using models, and independent problem solving as workable teaching and learning strategies could be implemented to improve learners' metacognitive skills (see section 2.9.2. and 2.10.). Given the multidimensional nature of metacognition, the motivational factors (see secondary research question 5 above) and cultural factors (see secondary research question 4 above) will have to

be considered in formulating the workable solutions. Furthermore, the factor of time will need to be considered in discussing the workable strategies to foster metacognition effectively (see secondary research question 1 above).

This researcher suggested models which could drive the three-way approach to foster metacognition and its multidimensional components as:

- the eight phases in metacognitive skills training for Physical Science learners which explicitly promotes meta-activities of metacognitive knowledge and metacognitive regulation (see section 2.10.1.);
- the assessment triangle which encourages formative assessment within the eight phases in metacognitive skills training for Physical Science learners (see section 2.10.2.);
- SEM and regulatory checklist to foster metacognitive knowledge and metacognitive regulation during the teaching and learning process (see section 2.10.3.);
- the learning pit to promote a growth mindset within the eight phases in metacognitive skills training for Physical Science learners (see section 2.10.4.);
- Marzano's six levels of educational objectives model to set explicit learning intentions and success criteria which guide the metacognitive regulation within the eight phases in metacognitive skills training for Physical Science learners (see section 2.10.5.); and
- visible learning model to incorporate interventions significantly improve attainment (see section 2.11.2.).

Sections 6.2.3.1. to 6.2.3.3 discuss these workable solutions in greater detail.

6.2.2 Synthesis of data focusing on the primary research question

The primary research question was: What is the state of metacognition within indigenous learners' Physical Science classrooms in KwaZulu-Natal?

The intention of the research was to analyse the state of metacognition in South African Physical Science classrooms to infer workable teaching and learning strategies to improve learners' metacognitive skills, which might improve their

Physical Science results. During the integration phase of the research analysis, the researcher used triangulation of the qualitative and quantitative data to answer the secondary research questions (see section 5.4) to reach the aim of the research and answer the primary research question.

Data analysis of Chapter 5 shows that, despite elements of metacognition being evident in the teaching and learning process, steps need to be taken to improve levels of metacognition. The key variables, mentioned in 5.4.8, shaped the research to improve the state of metacognition, as suggested in the primary research aim. The research sought workable teaching and learning strategies to improve learners' metacognitive skills, with the emphasis being on improving attainment.

The primary research question was answered in fragments in Chapter 5, by analysing and answering the secondary research questions during the integration phase of data analysis.

To conclude, the state of metacognition is fundamentally in disorder and has significant potential for improvement in the in the selected samples of the South African Physical Science classroom. This fact can be generalised to represent South African Physical Science classes.

The next part of this chapter will discuss the implementation of appropriate and effective formal structures to improve metacognitive awareness in the Physical Science classrooms.

6.2.3 Recommendations: workable solutions to promote metacognition during the teaching and learning process

In this research metacognition is viewed through a socio-cultural lens and is considered to be multidimensional. When proposing the workable solutions, the socio-cultural element of meta-thinking, motivational factors, metacognitive knowledge, and metacognitive regulation were the key focus. The key variables below were highlighted during the data analysis process whilst answering the secondary research questions in sections 5.4. and 6.2.1 and these were:

- fostering metacognition within the teaching and learning process;
- encouraging a growth mindset to promote metacognition;
- integrating indigenous knowledge within the teaching and learning process;
- having time to complete the curriculum; and
- the examination does not reward indigenous knowledge and metacognitive skills.

Teachers are the driving force in promoting metacognitive awareness in the Physical Science classroom. Research has shown that metacognition is best facilitated when teachers extend some control to the learners during the process (Baker, 1994:232), therefore learner involvement will be essential. In section 2.9.2., it was discussed that steering away from the approach characterised by didactic teacher exposition and encouraging learners to have a certain level of control in the learning environment was imperative in promoting metacognition (see section 2.9.3.). This could foster a sense of trust between the teacher and the learner, whereby teacher credibility is strengthened. The impact of teacher credibility was emphasised in section 2.11.1. Section 2.10. highlights the point that the teacher needs to have considerable metacognition, have a broad understanding of the nature and structure of Physical Science, be able to converse with the learners on the cognitive and metacognitive activities, and be able to model metacognitive strategies (Thomas, 2012:140). Specialised teacher training programmes is required to ensure teachers acquire the crucial skills and characteristics to promote metacognition effectively. To formally promote workable solutions, the researcher studied carefully researched theories in these areas which explicitly integrated metacognitive strategies within models which could be practicable in the South African Physical Science context.

The researcher defined the social aspects of the teaching and learning process as being the interaction between learners, and between teachers and learners (see section 3.1). Using activity theory, the researcher examined how teachers and learners could work together to create a successful learning situation by improving in their metacognitive awareness. The researcher used CHAT to describe the division of labour in this research as junior scientists (grade 11 Physical Science

learners) and the principal scientists (the Physical Science teachers and the more able learners) socially interacting (see section 3.1). Acclaiming social interaction as a recommended solution was directed by ZPD, eight phases in metacognitive skills training for Physical Science learners and the “learning pit” (see sections 6.2.3.1 and 6.2.3.2).

CHAT views the grade 11 Physical Science learners and the Physical Science teachers as being the subject (see section 3.1). They are believed to be key participants in promoting metacognitive awareness. CHAT regards tools as cognitive tasks that allow learners to: interact with the scientific content during problem solving, meta-activities to practise metacognitive knowledge and regulation, scaffold tools guiding the learners’ efforts, and instructional tools to provide a clear description of the scientific content (see section 3.1). The use of effective cognitive tasks, meta-activities, and scaffold tools to effectively improve metacognition will be discussed in sections 6.2.3.1. to 6.2.3.3. The instructional tool is the Physical Science curriculum document which could assist in the promotion of metacognition will be discussed in section 6.2.2.3.

The rules or schemas of CHAT include conflicting cultural rules versus the rules of science found in the NCS of the Physical Science (see section 3.1). The literature review on socio-cultural embedment within metacognition (see section 3.4) and BACEIS (see section 3.5) points to a highly significant relationship between culture, scientific attitudes, and the metacognitive awareness of the learners. However, the research suggested that the role of culture was not as substantial as had been expected according to noted theories; but, the data gathered were nevertheless significant (see section 5.4.4). Analysis of the curriculum documents (see section 5.3.1.7 and 5.3.1.8) found they contained no guidance for promoting indigenous knowledge within the Physical Science curriculum. More importantly, the triangulation of data suggested that the time allocated to complete such a rigorous Physical Science curriculum was gravely concerning (5.4.1 and 5.4.8). Discussions on the workable solutions follow.

6.2.3.1 Promoting metacognition in the teaching and learning process

Generally, science teachers engage in problem-solving activities which solidify the hegemony of the prescribed curriculum. As discussed in section 5.3.4.7, teachers used the chalk-and-talk method to reinforce the paradigm of the learned curriculum. However, anomalies can occur if this approach dominates the teaching and learning situation focused on fostering metacognition. The teachers need to modify their practises in order to instil higher ordered thinking successfully in their learners. This part uses strategies which steers away from the more teacher-centred approach to learning and veers toward active learning (see section 4.5.5).

The integration of results in sections 5.4.2.; 5.4.3., and 5.4.7. revealed that the learners and teachers have an over inflated view of their metacognitive awareness. Their perception of their meta-skills does not align itself with the learners' examination results and the observed findings (see section 5.3.4.). The ultimate goal in promoting metacognitive awareness could be viewed as the learner effectively using metacognitive knowledge and regulatory skills independently during problem solving. Merging the Vygotskian theory of social interaction and the non-Vygotskian approach through discussions, models, and explicit instructions could guide the learning to successful independent problem solving (see section 2.9.2. and 2.10). This was found to be lacking in Physical Science classrooms. Effective fostering of metacognitive skills is achieved by social construction of meta-skills in the ZPD, explicitly using problem-solving models encompassing metacognitive knowledge and regulation and encouraging independent problem solving (see section 2.10.).

Metacognition is dependent on both content and context (Lesh & Doerr, 2013:293) and there is a need for metacognition in different domains (Zohar & Dori, 2012:2). Having a specific model for Physical Science is appropriate for a domain specific study in metacognition. Section 2.10.1. highlights the eight phases in metacognitive skills training for Physical Science learners' model (eight-phase model) which embeds the meta-skills within its system. This model gives explicit metacognitive instructions to create opportunities for the learners to socially construct metacognitive skills in their ZPD (Vygotskian) with a view to working independently

at a later stage (non-Vygotskian). This model encourages metacognitive planning through setting goals during problem solving, monitoring progress, and the evaluation of strategies used (see section 2.10.1.). Metacognitive knowledge is also promoted when the learners use declarative, procedural and conditional skills to solve problems.

Metacognition is best enabled when learners have some control during the problem-solving process (see section 2.9.2.) Learners are encouraged to derive the best strategies for problem solving in phase 7 and phase 8 of the model (see section 2.10.1.). This ensures learner involvement by having input into the selection of strategies.

The results of the analysis from the lesson observations showed that teachers did not provide learning intentions and success criteria to the learners (see section 5.3.4). This could be improved if the teachers were to use Marzano's six levels of educational objectives model, which promotes the use of success criteria and learning intentions to encourage higher ordered thinking (see section 2.10.5.). The learning intentions and success criteria can be given during phase 1 of the eight-phase model. During this phase the learner plans. The learning intentions and success criteria allow the learners to plan how to achieve success, and to monitor and evaluate the process of learning in order to lead to the learning goals (see section 2.11.4.). This promotes metacognitive regulation.

Metacognitive regulatory skills and metacognitive knowledge can be further promoted within the eight-phase model by utilising the Regulatory Checklist and the SEM (see 2.10.3.). The Regulatory Checklist and the SEM should be displayed in the classroom and referred to during the problem-solving process. The SEM can be used in phases 3 to 6 of the eight-phase model. Metacognitive knowledge is used to solve problems socially (Vygotskian) or independently (non-Vygotskian) during those phases. The regulatory check list should be used during phases 1 and 2 for planning, phases 3 to 6 for monitoring progress, and phases 7 and 8 to evaluate effectiveness of the problem-solving process.

Formative assessment was identified as being key in assessing progress of the meta-activities within the eight-phase model (see section 2.10.2). Much research promotes the importance of formative assessments as crucial in raising attainment. Furthermore, formative assessment in terms of feedback has a large positive impact on attainment, according to Hattie's research (see section 2.11.4). The learning triangle model could be used by teachers to utilise formative assessment, whilst promoting metacognitive skills (see section 2.10.2). Formative assessment allows the learners to monitor and evaluate their progress, which is metacognitive by nature. Formative assessment could be used during the phases 3 to 6 of the eight-phase model.

Further to considering effective feedback, considering outcomes with higher effect size than 0.6 would have a high impact in improving Physical Science results in South Africa and foster metacognitive awareness (see 2.11.4.). Self-reported grades, Piagetian programmes, classroom discussions, teacher credibility, teacher-student relationship, study skills, metacognitive skills, teaching strategies, and not labelling learners are the outcomes with effect sizes higher than 0.6 (see 2.11.4.). Metacognitive skills and teaching strategies are not discussed as separate entities but as a broader and collective part of this study.

Self-reported grades promote metacognitive evaluation when learners write down their predicted grade before taking the assessment. This allows the learners to evaluate their learning and take ownership of their learning (see section 2.11.4). As discussed in section 5.2.4. high quality assessment enables high quality knowledge through rewarding the competence of the learner in Physical Science through real-world context and indigenous knowledge, as well as assessing metacognitive skills (Novack et.al. 2005:1). The focus of the Physical Science assessments in the school is mainly on the content and needs to integrate indigenous knowledge into the assessment. Table 6.1. below was created using the strategies of the Regulatory Checklist (see section 2.10.3.) and the visible learning (see section 2.11.).

Table 6.1. Metacognitive part of Physical Science assessment

Predicted grade before the test_____
Predicted grade after the test_____
Do you think you have reached your goal? Explain.

What strategies worked?

What strategies did not work?

What would you do differently the next time?

What is your next goal and how will you achieve it?

This table could be attached to the assessment worksheet to reward metacognition. Instead of a score, learners are motivated to complete the table because it could form the basis of teacher and learner discussions of the assessment and could be the focus of the learner-centred parents evening. The learner-centred parent evening is where the learners take the lead during the discussions with the teachers and parents.

Classroom discussions is an approach linked to Vygotsky's (1978) constructivist theory, ZPD (see sections 2.3.2 and 2.5), and active learning (see section 5.3.1.2). Collectively, these approaches promote metacognition through social interaction, as discussed in section 2.9.2. The more able learner socially interacts with less able learners to develop meta-skills through discussions. The less able learners often

enough acquire the ability to work independently. Classroom discussions could be done during phases 3 to 6 of the eight-phase model.

Study skills are rooted in the theory of metacognition (see section 2.11.4). SEM and a regulatory checklist are effective meta-tasks to promote metacognitive knowledge and metacognitive regulation whilst studying problem solving. Memory tricks; effective cramming; planning; gathering information; and problem-solving strategies are metacognitive by nature and is central in promoting effective study skills (see section 5.3.2.4). These skills could be explicitly taught during the teaching and learning process within the eight-phase model. The eight-phase model should be used when the learners are studying at home. This could be done socially with peers and adults, or independently.

Piagetian teaching programmes, teacher-student relationships, and not labelling students are outcomes which lie in the motivational dimension of metacognition. These outcomes will be discussed in the next part of this chapter.

Using the eight-phase model as often as possible during the Physical Science lessons will encourage the learners to practise these meta-skills in a constructivist environment. The teachers need to plan their lessons using these models to explicitly instruct the learners through the problem-solving process and encouraging the learners to persevere through their ZPD. The teachers could plan independent problem-solving activities as an effective way of promoting metacognitive skills for the more able learners (see section 2.10.).

The eight-phase model discussed thus far is incomplete because it does not include the motivational and the cultural dimensions of metacognition. The model discussed thus far will be extended to the discussions in section 6.2.3.2. in order to include the motivational dimension of metacognition, in the form of growth mindset. The cultural factor and the variable of time will be discussed in section 6.2.3.3.

6.2.3.2 Encouraging growth mindset to promote metacognition

The analyses in sections 5.2.2.3; 5.2.2.5, and 5.3.3.2 suggest that a large percentage of learners have fixed mindsets when it comes to the challenges they face in the study of Physical Science. Three-quarters (75.3%) of learners felt that science was not easy (see sections 5.2.2.3. and 5.4.8). Learners with a fixed mindset believe their situation in science will not improve (see section 2.10.4.). The emotions of fixed mindset and growth mindset are similar to the motivational and affective factors stated by the American Psychological Association in section 2.4. of the study. These factors deal holistically with the real-world context of learning. The motivational and affective factors of the learners' mindset influence the learner's higher-ordered thinking abilities. Teachers need to promote a growth mindset parallel to promoting metacognition, as discussed in section 6.2.3.1.

The BACEIS model highlights the multidimensional part of metacognition and suggests that regulating one's motivation to solve science problems increases learners' eagerness to use metacognitive and cognitive strategies in problem solving (see section 3.6.). Regulating learners' approach during problem solving increases learners' eagerness to use metacognitive and cognitive strategies (see section 3.6.). Learners should be encouraged to take risks during their learning process and not be afraid of failure; be tenacious; not give up when they experience difficulties and have confidence in their ability. This aligns with the work of Boekaerts and Corno's (2005:199) in their volitional learning model, discussed in section 2.10.4., where the focus is on promoting academic tenacity to improve attainment. Section 2.10.4. promotes the learning pit model to promote academic tenacity in terms of growth mindset. Dweck's (2006:10-11) studies show that learners with a growth mindset showed a substantial rise in attainment.

As discussed in 6.2.3.1. metacognition is content and context dependent and, in this study, it is focussed on Physical Science. Having a learning pit model for Physical Science could be effective in promoting growth mindset during problem solving. Figure 6.1. below is a merger of the eight-phase model for Physical Science learners (see section 2.10.1.) and the learning pit (see section 2.10.4). The two models were merged to keep the key components in promoting metacognition in the Physical

Science (see section 6.2.3.1.) as well as addressing the motivational dimension of metacognition.

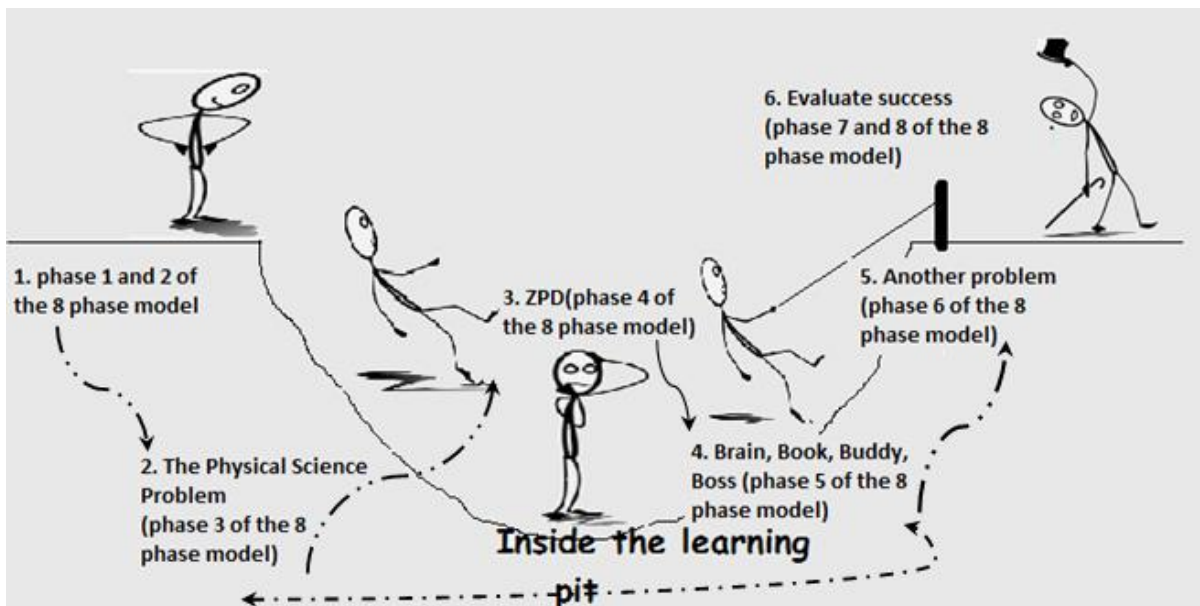


Figure 6.1: Merged model of the eight-phase model and the learning pit.

The first part of the merged version of the eight-phase model and the learning pit represents the phases 1 and 2 of the eight-phase model. The learners are given the opportunity to think about and discuss potential strategies to solve the Physical Science problem. This encourages metacognitive planning. The second part of the learning pit is when the Physical Science problem is given and the learners fall into the pit. The learner feels emotions of confusion and struggle. This is where effective learning begins and is phase 3 of the eight-phase model. The teacher should make the learners aware that the emotions of struggle is natural and should not deter the learner from striving to “escape” from the learning pit.

The third point in the learning pit is the ZPD which represents phase 4 of the eight-phase model. The fourth part of the learning pit is where the learner seeks guidance whilst in the ZPD. The brain, book, buddy, and boss strategy (see section 2.10.1.) should be encouraged here. This represents phase 5 of the eight-phase model. The fifth part of the learning pit represents phase 6 of the eight-phase model where the learner stays in the learning pit solving more problems. Parts three, four, and five of the learning pit are repeated until the learner is confident about solving the problem independently. The learner moves from the Vygotskian to the non-Vygotskian stage which is the aim of the cognitive and metacognitive activity (see section 6.2.1.1.)

Once the learner is capable of solving problems independently, the sixth part of the learning pit is reached. The learner gets out of the pit and evaluates the learning experience. Phases 7 and 8 of the eight-phase model are reached where the learner models the cognitive and meta-strategies which work effectively during problem solving. Repeating this process as often as possible encourages the learners to practise these meta-skills in a constructivist environment which ultimately leads to independent learning. The teachers need to plan their lessons using these models to explicitly instruct the learners through the problem-solving process and encouraging the learners to persevere through their ZPD.

Further to the learning pit, the motivational elements which have a great impact on attainment are the Piagetian teaching programmes, teacher-student relationship, and not labelling students (see section 2.11.4). Together with the merged learning pit and the eight-phase model, these outcomes are seen to effectively promote metacognitive awareness. The Piagetian teaching programmes envision the learner developing thinking skills and knowledge through involvements, social interaction, and enthusiasm which are within the cognitive level of the learners. Developmental influences are the Piagetian effects in learning, whereby the instruction and the tasks for the activity are at the appropriate progressive level of the learner (see section 2.5.1.). Teachers need to ensure the activities given are at the right academic level, because learners become demotivated if they are doing a task that is above or below their academic level.

The teacher-student relationship is integral in building a positive and productive relationship with learners (see section 2.11.4.). An effective attitude for teachers to achieve this relationship is to be caring, yet have high expectations of learners. Teachers need to build this relation through interaction with the learners in guiding them through the learning pit. Guiding and motivating the learners through their struggle within the learning pit build strong relationships between the teachers and learners.

Furthermore, to ensure the learners remain motivated, the teacher must ensure that learners should not be labelled as being poor or weak in Physical Science. The teacher must always consider that learners are born with personal abilities that can be modified to improve their learning (see section 2.4).

The teachers improve motivational levels whilst the learner is in the learning pit by praising and rewarding progress through positive behaviour management. Meta-activities require a great deal of mental efforts which many learners do not want to pursue (see section 1.1.2.). Rewarding the meta-activities through praise and an effective positive reward system could be imperative in motivating learners to invest their time and effort to such cognitively demanding tasks. Rewarding learners inspire academic tenacity. Rewards may be in form of merits earned. This could materialise in awarding certificates for accumulating a targeted number of merits and also a promise of writing a good report for the learner at the end of term. This could be motivated into a meta-activity when the learners are planning their goals. During parents evening the learners' achievements are discussed. This encourages a supportive home culture of learning which according to the BACEIS model improve cognition and metacognition of the learner (see section 3.6.).

Teacher training programmes focusing on the promotion of metacognitive awareness utilising these models might be the most powerful and promising path to follow. Furthermore, ensuring the teachers acquire the crucial skills and characteristics to promote metacognition effectively as discussed in section 3.2. will be key. Training by science advisers, training in curriculum development programmes in schools, and training provided by tertiary institutes should be ongoing in trying to promote metacognition. Science advisers should have regular cluster meetings in the form of workshops, presentations, and meetings with heads of departments, to ensure that it is ongoing. Teacher training institutes should play an important role in this process. Furthermore, in the school, peer observations and class visits by teachers and management could help promote the metacognitive awareness to raise learners' results in Physical Science.

6.2.3.3 Effective curriculum design to raise attainment in Physical Science

The initial analysis of the Physical Science curriculum showed that the curriculum was balanced, supported metacognition, and promoted indigenous knowledge (see section 5.3.1). However, on further analysis, it revealed that there was not much guidance given to the implementation of indigenous knowledge in the curriculum (see section 5.3.1.8). Despite having a balanced curriculum design (see section 5.3.1.6), every teacher interviewed mentioned that there was not enough time during teaching hours to complete the curriculum effectively (see section 5.3.3.2). These factors were discussed in greater detail in the triangulation of data in 5.4.1. and 5.4.4. The workable solutions discussed in 6.2.1.1 and 6.2.1.2. could not optimally increase attainment if the curriculum does not support indigenous culture, moreover, if teachers do not have sufficient teaching time to complete the curriculum effectively. Section 1.1.2. discusses the importance of time and effort required to effectively achieve metacognitive awareness. Meta-activities require a great deal of mental efforts and high motivation (see section 1.1.2.)

The major impact indigenous knowledge and culture have on metacognition has often been mentioned in this research (see section 1.1.2.; 1.3; and Chapter 3). Ensuring that indigenous knowledge is implemented effectively in the Physical Science curriculum promote metacognitive awareness because this fosters the motivational dimension of metacognition. The South African CAPS document promotes indigenous knowledge by stating the appreciation of science of the indigenous knowledge of our forefathers, because modern scientists seek traditional scientific knowledge to use, preserve, and acknowledge (see section 4.1.1.) However, the Physical Science curriculum has just one example of where indigenous knowledge could be integrated: “The concept of friction” (see DBE, 2011:62). More opportunities and guidance provided within the curriculum would promote indigenous knowledge and indigenous culture more effectively during the teaching and learning process. This would lead to more learners being motivated to relate their culture and traditional values to the science being taught.

Indigenous Physical Science learners in South Africa could experience “cultural border-crossing” when they switch from their cultural way of thinking into the type of

thinking expected in the Physical Science classroom (see section 3.4.). This could cause a conflict in the thinking process of the learner. Including indigenous knowledge within the Physical Science classroom lessen the cognitive conflict attributed to cultural border-crossing. An effective way to resolve this conflict is to consider the holistic view where learners accept the notion of the cultural construct of multiple worlds, and resolve the conflicts within the compartmentalisation of those cultural worlds to achieve metacognitive awareness within the science classroom (see section 3.4.).

Furthermore, 35% of the learners would prefer Physical Science to be taught in isiZulu. However, it is worthwhile to mention that English First Language learners and Afrikaans First Language learners have the option of writing the Physical Science examination in their mother tongue. The researcher feels that it is beneficial if indigenous learners have the same option. Many non-Western countries provide science examinations in their native languages. The solutions to this issue require a separate research altogether.

Results from this study concluded that teachers believed that a content-driven Physical Science curriculum prevented them from completing the curriculum effectively (5.4.1 and 5.4.8). Work by numerous researchers such as Erickson (2007:40-50); Hallet & Chapman (2017:400-402); McLaughlin & Nolet (2005:6-7); McTighe & Wiggins (2005:1-9); Olsen (1995:130-134) and Inyang-Abia & Umoren (1995:80-82), promotes the idea of less focus on covering content, and more on mastery of conceptual understanding and development of higher-order thinking skills in a curriculum design. Davies (2017) researched in the UK on “mastery and greater depth in the national curriculum” to promote higher-order thinking skills.

One of the key features in Davies’ research is “re-visit” (Davies, 2017). “Revisit” refers to that part of learning, after a break, where the learner revisits a previously learnt concept to test conceptual understanding and skills within the concept (Davies, 2017). The curriculum allows learners to revisit key concepts to master the essential higher-order thinking skills. To revisit is to reflect on what one has learnt previously, to monitor one’s progress, and evaluate one’s level of conceptual

understanding (see sections 2.3 and 2.5). The “revisit” concept promotes metacognitive regulation and is a metacognitive activity. This is unlike the selected sample of the South African Physical Science classes, where teachers do not have time to revisit key concepts. The “revisit” aspect of curriculum design needs to be included in the South African curriculum, to provide Physical Science learners with opportunities to revisit work and to reflect on its difficulty.

England, Wales, Northern Ireland, Singapore, South Korea, and Finland have all successfully implemented a “mastery and focus on conceptual understanding curriculum” to develop higher-order thinking skills (Hammond, 2014:14-16). Singapore, South Korea, and Finland have successful curriculum designs that can be measured using the 2016 TIMSS rankings (Anderson, 2016). The TIMSS 2016 rankings for a science show that Singapore and South Korea were internationally ranked first and second respectively, while, Finland, which has dominated the international ranking for years, has now dropped from third to seventh in recent times (Anderson, 2016). This could be a motivating factor in modifying the South African curriculum, which has too much content to cover in such a short time (see section 5.3.3.2).

The South African Physical Science curriculum could be adapted to focus on key skills instead of vast content by using the mastery approach to curriculum design. Studying content on such a wide variety of topics as in the Physical Science curriculum only touches on lower- to mid-order thinking levels of Bloom’s revised taxonomy (see section 2.6). Decreasing the amount of content gives the teachers sufficient time to deliver the curriculum effectively, as well as giving time to revisit and focus on higher-order thinking skills. The reduced content along with options of non-compulsory Physical Science topics within the curriculum could be used to drive higher-order thinking, with the emphasis on scientific enquiry and scientific research methods. These skills are essential for post-school study in Physical Science and would lead South Africa towards producing more world-class scientists.

Important skills in Physical Science such as manipulating equations, analysing graphs, scientific enquiry, and research methodology are transferable skills which

are not content specific. Modifying the South African Physical Science curriculum by focusing on the mastery of higher-order thinking skills, instead of remembering and understanding the vast knowledge of Physical Science, is essential in effectively raising attainment.

Curriculum experts should work in conjunction with Physical Science teachers and learners, the major stakeholders, to modify the Physical Science curriculum to focus on mastery of conceptual understanding, include detail on indigenous knowledge in the teaching and learning process, and to add the “revisit” concept to the curriculum. This would give expert curriculum designers more insight into the teaching and learning situation in Physical Science classes in South Africa and qualify them to make the necessary changes.

6.3 Recommendations for future research

There is a need to replicate this study by using a broader sample of Physical Science teachers. Only seven teachers were used in this study. Replicating this study using more teachers could further validate this research or add further evidence of the state of metacognition in South African Physical Science classrooms.

The researcher did not investigate the significant issues of improving staff morale among the Physical Science teachers, or the motivation of learners in choosing Physical Science, or learners pursuing careers in science (see section 5.4.8). The researcher felt that these important issues might overshadow the aim of the study. However, the matter of improving staff morale among the Physical Science teachers and the motivation of learners in choosing Physical Science is a huge concern and lends itself to important research that is fundamental to improving the teaching and learning situation in South African Physical Science classrooms.

Physical Science teachers might feel that a positive reward system and studying physics in isiZulu could have a greater impact on attainment levels in Physical Science, despite Hattie’s work rating these factors as low-effect sizes. More research

is required on the effects of a positive reward system on the intrinsic motivation of Physical Science learners and on the impact of attainment in studying Physical Science in isiZulu. A parallel study could be conducted on learners studying physics whose first language is not isiZulu.

Hattie's (2012:169-192) mind frames for teachers, which facilitate teacher-based research, are:

- primary evaluation of the effect of teaching methods on learners' education and achievement;
- demonstrating that the product of learning depends on what the teacher does or does not do;
- the teacher being the instrument of change;
- the teacher's focus on learning rather than on teaching.

This gives teachers an opportunity to perform small- to large-scale research, using the evidence-based study to continue or modify their teaching practises. These findings could be discussed in cluster meetings to draw a more definitive conclusion by comparing results from other schools. This could well lead to more valid teaching practises in community-based schools, where little or no credible educational research has been undertaken.

Part 6.2.1.3 of this research gives rise to further research into a Physical Science curriculum design that includes elements to raise attainment and focus on the conceptual understanding and skills essential to Physical Science. It invites integration of re-visit in a curriculum design that allows natural learning to take place within the constraints of the allocated teaching time. This research could be aimed at curriculum designers and scholars of science education. It is essential to include Physical Science advisers, heads of departments in science, teachers of Physical Science, and learners of Physical Science in the research.

Invaluable research on the implementation of visible learning techniques and the fostering of an ethos of growth-mindset in South African Physical Science should be undertaken by forward-thinking researchers. This could well be the key to unlocking the great potential trapped within the Physical Science classrooms of South Africa.

Notably, the recommended research should perhaps not be restricted to Physical Science and South Africa but lend itself also to other subjects and countries.

6.4 Limitations of this study

Intrinsic to any research is a certain volume of error from various sources, which may result in a limitation of the research (Gassner, 2006:97). The researcher, in line with research standards, acknowledged what may be measured as a limitation to this research.

Data obtained from the MAI (see section 5.2.1.) and MAIT (see section 5.2.3.) did not align with the observed data, the data from the interview or the analysis of the half-yearly results (see sections 5.4.2). This might have been because the responses to MAI and MAIT were void of human emotions and behaviour, thereby inhibiting the data-gathering of societal and holistic phenomena for the research (see 4.4.9). This could have resulted in over inflated responses of the participants due to self-presentation (see 4.4.9.). Furthermore, the MAI and the MAIT might have been subjective and misleading if the Physical Science learners and the teachers had jointly felt positive about certain points of the survey. In a real-world scenario, however, this might not have been true. Due to self-presentation it was possible that participants felt they may be victimised by responding in a certain way, which might have led to inaccurate responses due to social pressures (McLeod, 2014). There is no way of knowing how truthful the participants were during the surveys.

During the classroom observations, the researcher disturbed the usual day-to-day setting of the classroom atmosphere, and the anxiety and awkwardness of certain respondents were observed throughout the interview process. It is acknowledged that, while it may be possible to restrict observer bias, it is not possible to remove it (Chambers et al., 2007:75).

Participants could have modified their behaviour when being observed similar to results found in Hawthorne's study (see section 4.5.8). Although the researcher tried to remain discreet; the classroom setting seemed rather artificial. Learners appeared well behaved and well-mannered at all times. Learners spoke softly, and

poor discipline seemed non-existent. The whole setting during the interaction with learners seemed too good to be true. These elements might have caused inaccurate data for the interviews and classroom observations. Furthermore, observing the Physical Science classroom in its natural setting limited the researcher's opportunity to observe how the behaviour of learners transform under changing conditions (Green et al., 2006:211). The researcher guaranteed the participants that the interviews would be confidential (see section 4.5.6); however, during the interview, the researcher was aware that his presence might have caused respondents to give answers intended to impress, and therefore sometimes deviated from what occurred or what they felt.

The limited number of teaching participants could also have affected the accuracy of the data (Green et al., 2006:211). Although the research was aimed at indigenous learners from KwaZulu-Natal with similar cultural and financial backgrounds, it was not possible to control that variable. Learners with diminished working memory; learners coming from low-income homes, poor teaching methods, lack of motivation, poor self-esteem, and poor learning environment might have limited the accuracy of the data of metacognition during the investigation (see section 4.5.8).

6.5 Concluding remark

This research aimed to investigate the state of metacognition in selected South African Physical Science classrooms to discover and formulate workable teaching and learning strategies to improve learners' metacognitive skills, by which they might improve their Physical Science results nationally. Immense and irrefutable research completed by numerous researchers over the last 40 years has pointed to the conclusion that improved metacognitive abilities lead to raised academic levels. Most importantly, the implementation of metacognitive awareness needs to be integrated within the teaching and learning process in the Physical Science classroom. The analysis of the data collected in the mixed methods research concluded that there are opportunities for work to be done in the improvement of the state of metacognition in South African Physical Science classrooms.

Teachers were seen to be the driving force of the process. To foster metacognition effectively, teachers should have high metacognition, have a broad understanding of the nature and structure of Physical Science and be able to converse with the learners on the cognitive and metacognitive activities. The Physical Science teachers studied had a broad understanding of the Physical Science curriculum and informally and tacitly promoted metacognitive awareness. However they lacked essential skills in fostering metacognition effectively. Teacher training programs focusing on the promotion of metacognitive awareness ensuring that teachers master the skills to be effective in promoting metacognitive could be the most powerful and promising way forward.

Inferred solutions to effectively develop and enhance the metacognitive awareness within Physical Science classrooms in South Africa were guided by theory which is both current and widely followed by scholars in the field of metacognition. The eight-phase model was merged with the learning pit to incorporate the multidimensional components of metacognition including metacognitive knowledge, metacognitive regulation and motivation. Within the merged model, visible learning interventions, formative assessment strategies, and six levels of educational objectives were integrated to explicitly promote metacognition. Using the merged model, metacognitive awareness is effectively fostered through social constructivism (Vygotskian approach), explicit instruction using models, and independent problem solving (non-Vygotskian).

The factors of time, effort, and rewarding metacognitive skills were perceived as being problematic with the South African Physical Science classroom. The inferred solution was to promote a skills-based curriculum with the intention of revisiting key areas to attain mastery, whilst assessing and rewarding the efforts of the learners in using metacognitive strategies. Formative assessment strategies through learner led discussions with teachers and parents were highlighted, and summative assessment strategies of including metacognitive worksheets within the test were promoted. This strategy could motivate teachers, learners and parents to take the metacognition process seriously. Indigenous knowledge should be integrated effectively within the

curriculum to promote an inclusive Physical Science curriculum to foster respect, cultural awareness, dignity, and antiracist education.

It is further anticipated that the conclusions and suggestions presented in this study will benefit teachers, learners, educational establishments, educational researchers, and curriculum designers, in their bid to effectively raise attainment in South African Physical Science.

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APPENDICES

Appendix 1 Lesson observation protocol from Bonney (2009:57) and Smith et al. (2013:622)

Observation Protocol focusing on Metacognition in the Physics Classroom

District _____ School _____
Teacher _____ Grade Level _____
Subject area: Physics Lesson Topic _____
Observer _____ Date _____ Duration of observation (min.) _____
Portion of the class period observed: <input type="checkbox"/> All or most <input type="checkbox"/> Over half <input type="checkbox"/> Less than half

1. Is the lesson topic connected to the content focus of the Physics Curriculum? Yes No
2. Is the lesson from instructional materials received from The Department of Education? Yes No Not Applicable

During the lesson, take notes describing noteworthy aspects of the lesson and then complete this portion of the instrument. Each of the items should be rated 'globally'; the descriptors are possible indicators, not a required 'check-off' list.

		Not Observed	1	2	3	4	Characterizes
3. Teacher encourage learners to develop a plan before approaching the learning task? (Focus: Developing a Plan)	N/O						

Teacher:

Learning objectives presented to the learners
Link starter to prior knowledge
Direct learners towards where the thought process should take them

Students:

Show understanding of objectives
Use concepts from previous lessons in discussions
Question the direction and relevance of the lesson

4. Teacher encouraged learners to monitor their progress (Focus: Metacognition – students' thinking about their own thinking)		N/O	1	2	3	4	
--	--	-----	---	---	---	---	--

Teacher:

Encouraged students to explain their understanding of concepts
Encouraged students to explain in own words both what and how they learned
Routinely asked for student input and questions

Students:

Discussed what they understood from the class and how they learned it
Identified anything unclear to them

5. Teacher encouraged evaluation of the learners progresses (Focus: Reflection of the learning process)		N/O	1	2	3	4	
--	--	-----	---	---	---	---	--

Teacher:

Check whether objectives have been met
Inquired about learners understanding
Asked whether anything should be repeated

Students:

Showed how well they have obtained the objectives
Thought about how they can apply the knowledge gained and reflected on what they didn't understand
What could of gone differently to improve learning?

6. Teacher provided opportunities for learners to model metacognition skills (Focus: Modeling Metacognition thought process)		N/O	1	2	3	4	
---	--	-----	---	---	---	---	--

Teacher:

Models think aloud thought process
Emphasise/ highlight on key points
Models prewriting strategies such as brainstorming etc.
Teach the importance of using mindmaps, etc.
Use strategies such as mnemonics, analogies etc.
Models problem solving techniques and advise on study skills

Students:

Highlight important points
Plan what to do if concepts not understood
Ask questions during the lessons
Plan before solving problems
Use drawing, concept maps, mnemonics etc
Brainstorm, use models to solve problems



Time/ min	Instrument	Indicator	Description
0-5			
5-10			
10-15			
15-20			
20-25			
25-30			
35-40			
40-45			
45-50			
50-60			



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NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Appendix 2 MAI for learners adapted from Schraw and Dennison (1994:472-474)



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Metacognitive Awareness Inventory (MAI)

Instructions

There are no “right” or “wrong” answers to the following questions. We are simply interested in your feelings about a number of issues related to science and science learning.

- Indicate the extent to which you agree or disagree with each the following statements.
- Place a check tick
- Tick **only one** answer for each question.
- – If you “Strongly disagree” with a statement, then you should tick:

Strongly disagree	Disagree	Agree	Strongly agree
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

	Strongly disagree	Disagree	Agree	Strongly agree
1. I ask myself periodically if I am meeting my goals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. I consider several alternatives to a problem before I answer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. I try to use strategies that have worked in the past	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. I pace myself while learning in order to have enough time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. I understand my intellectual strengths and weaknesses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. I think about what I really need to learn before I begin a task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. I know how well I did once I finish a test	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. I set specific goals before I begin a task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. I slow down when I encounter important information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. I know what kind of information is most important to learn	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. I ask myself if I have considered all options when solving a problem	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. I am good at organizing information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. I consciously focus my attention on important information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. I have a specific purpose for each strategy I use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. I learn best when I know something about the topic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. I know what the teacher expects me to learn	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. I am good at remembering information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. I use different learning strategies depending on the situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. I ask myself if there was an easier way to do things after I finish a task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. I have control over how well I learn	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21. I periodically review to help me understand important relationships	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22. I ask myself questions about the material before I begin.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23. I think of several ways to solve a problem and choose the best one	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24. I summarize what I've learned after I finish	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25. I ask others for help when I don't understand something	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26. I can motivate myself to learn when I need to	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Metacognitive Awareness Inventory (MAI)

	Strongly disagree	Disagree	Agree	Strongly agree
27. I am aware of what strategies I use when I study	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28. I find myself analyzing the usefulness of strategies while I study	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
29. I use my intellectual strengths to compensate for my weaknesses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
30. I focus on the meaning and significance of new information.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
31. I create my own examples to make information more meaningful	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
32. I am a good judge of how well I understand something	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33. I find myself using helpful learning strategies automatically	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
34. I find myself pausing regularly to check my comprehension	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
35. I know when each strategy I use will be most effective	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
36. I ask myself how well I accomplish my goals once I'm finished	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
37. I draw pictures or diagrams to help me understand while learning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
38. I ask myself if I have considered all options after I solve a problem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
39. I try to translate new information into my own words	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
40. I change strategies when I fail to understand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
41. I use the organizational structure of the text to help me learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
42. I read instructions carefully before I begin a task	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
43. I ask myself if what I'm reading is related to what I already know	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
44. I re-evaluate my assumptions when I get confused	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
45. I organize my time to best accomplish my goals	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
46. I learn more when I am interested in the topic	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
47. I try to break studying down into smaller steps	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
48. I focus on overall meaning rather than specifics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
49. I ask myself questions about how well I am doing while I am learning something new	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
50. I ask myself if I learned as much as I could have once I finish a task	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
51. I stop and go back over new information that is not clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
52. I stop and reread when I get confused	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Schraw, G. & Dennison, R.S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19*, 460-475.

THANK YOU FOR COMPLETING THIS SURVEY

Appendix 3 Science Attitude Questionnaire (SAQ) adapted from BrainU (2010) and studies by Summers (2012:92-93)



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Faculty of Education

Science Attitude Questionnaire

Instructions

There are no “right” or “wrong” answers to the following questions. We are simply interested in your feelings about a number of issues related to science and science learning.

- Indicate the extent to which you agree or disagree with each the following statements.
- Place a check tick
- Tick **only one** answer for each question.
- – If you “Strongly disagree” with a statement, then you should tick:

Strongly disagree	Disagree	Agree	Strongly agree
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Agree	Strongly agree
1. I enjoy science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Learning science is not important for my future success	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. We do a lot of interesting activities in science class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Most people should understand science because it affects their lives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I will study science if I get into a university	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. I am sure I can do well on science tests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Scientific discoveries do more harm than good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. I usually give up when I do not understand a science concept	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Science is one of the most interesting school subjects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Teachers encourage me to understand concepts in science classes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Science classes will help prepare me for university	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. Science is easy for me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. My science teachers are very good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I will not pursue a science-related career in the future	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I like to watch TV programs about science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I cannot understand science even if I try hard	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17. Science is useful in solving everyday life problems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18. I will become a scientist in the future	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. I look forward to science activities in class	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. A job as a scientist would be boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. I like to learn more about science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. I really enjoy science lessons	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. I will continue studying science after I leave school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. My family encourages my interest in science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. I am confident that I can understand science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26. We live in a better world because of science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27. I would enjoy working in a science-related career	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28. I will miss studying science when I leave school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Science Attitude Questionnaire

	Strongly disagree	Disagree	Agree	Strongly agree
29. My friends like science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
30. Knowing science can help me make better choices about my health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
31. My family encourages me to have a science-related career.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
32. I really like science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33. If I could choose, I would not take any more science in school	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
34. Knowledge of science helps me protect the environment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
35. It helps me to learn science in the same language I use at home	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
36. Scientific work is only useful to scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
37. Science will help me understand the world around me	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
38. My friends do well in science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
39. If I work hard enough, I can learn difficult science concepts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
40. I will take additional science courses in the future	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
41. Science lessons are a waste of time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
42. Scientists do not have enough time for fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
43. People with science-related careers have a normal family life	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
44. I do not like science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
45. My science teachers motivate me to learn science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
46. The science we learn respects my culture	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
47. In science we learn about scientists from different cultures	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
48. School science encourages people from my community to become scientists	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
49. My country's history discourages me choosing science as a course to study	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
50. There is a lot of black South African scientists that I look up to	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
51. Science that I learn in school will help prepare me for university	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
52. Science feels difficult when we learn things that is different from our culture`	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
53. My beliefs are different from the views we learn in science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
54. Science can be difficult because it uses words that I know but it has a different meaning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Adapted from Summers, R.G. 2012. Development and validation of an instrument to assess precollege Arabic speaking students' attitudes toward science.

THANK YOU FOR COMPLETING THIS SURVEY

Appendix 4 Metacognitive Awareness Inventory for Teachers (MAIT) adapted from Tanner (2012) and Balcikanli (2011:1331)



Private Bag X6001, Potchefstroom, South Africa 2520
Faculty of Education

Metacognitive Awareness Inventory for Teachers (MAIT) and Metacognition Teaching Strategies

Instructions

There are no “right” or “wrong” answers to the following questions. We are simply interested in your feelings about a number of issues related to science and science learning.

- Indicate the extent to which you agree or disagree with each the following statements.
- Place a check tick in the circle.
- Tick **only one** answer for each question.
- – If you “Strongly disagree” with a statement, then you should tick:

Strongly disagree	Disagree	Agree	Strongly agree
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly disagree	Disagree	Agree	Strongly agree
1. I am aware of the strengths and weaknesses in my teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I try to use teaching techniques that worked in the past.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. I use my strengths to compensate for my weaknesses in my teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I pace myself while teaching in order to have enough time.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I ask myself periodically if I meet my teaching goals while I am teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. I ask myself how well I have accomplished my teaching goals once I am finished.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. I know what skills are most important in order to be a good teacher.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. I have a specific reason for choosing each teaching technique I use in class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. I can motivate myself to teach when I really need to teach.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. I set my specific teaching goals before I start teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I find myself assessing how useful my teaching techniques are while I am teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I ask myself if I could have used different techniques after each teaching experience.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I have control over how well I teach.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I am aware of what teaching techniques I use while I am teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I use different teaching techniques depending on the situation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I ask myself about the teaching techniques that I am going to use.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
17. I check regularly to what extent my students comprehend the topic while I am teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
18. After teaching a point, I ask myself if I'd teach it more effectively next time.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
19. I know what I am expected to teach.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
20. I use helpful teaching techniques automatically.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
21. I know when each teaching technique I use will be most effective.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. I organise my time to best accomplish my teaching goals.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. I ask myself questions about how well I am doing while I am teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



Metacognitive Awareness Inventory for Teachers (MAIT) and Metacognition Teaching Strategies

	Strongly disagree	Disagree	Agree	Strongly agree
24. I ask myself if I have considered all possible techniques after teaching a point.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. I teach learners that the ability to learn is not a fixed quantity.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26. I teach learners how to set and plan to meet goals.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27. I encourage the learners to think about key points as they listen and take notes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28. I encourage learners to answer self-assessment questions after all activities.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
29. I state the objectives of the lesson clearly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
30. During activities I encourage learners to ask themselves how they are doing, whether they are on the right track, what information is important, what they do if they don't understand.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
31. At the end of each lesson I gauge whether the lesson objectives have been met.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
32. I encourage learners to ask themselves how well they did, what did they learn, is there anything they didn't understand, can they apply this thinking to other problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33. During problem solving I think aloud and model my thought process during problem solving strategies.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
34. I teach the learners time management skills and study techniques.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
35. I encourage learners to use organisers such as mind maps, Venn diagrams and KWL charts.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
36. During reading activities learners are constantly encouraged to ask questions and ask themselves whether they understand what is read.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
37. During writing activities I model prewriting strategies, promote brainstorming and thinking before completing the task.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
38. I teach learners to use mnemonics and other useful strategies to make learning easier.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
39. I encourage learners to think, understand and apply what has been taught to problem solve and not to memorise and regurgitate information.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
40. I encourage learners to be independent learners and promote original ideas.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Adapted from Balcikanli, C. 2011. Metacognitive Awareness Inventory for Teachers. (In Electronic Journal of Research in Educational Psychology, 9(3): 1309-1332

THANK YOU FOR COMPLETING THIS SURVEY

Appendix 5 Letter to higher authority



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

District Circuit Officer
PHOENIX CIRCUIT
Mt Edgecombe
1 Spire Street
Stonebridge
4068
Durban

Re: The Limitation in Metacognition of South African Indigenous Learners Studying Physical Science

Dear Sir/Madam

My name is Ronesh Rajcoomar and I am a Doctoral student at the North-West University. I wish to conduct my research in schools in the Phoenix Circuit.

Studies done so far shows that the results achieved by physical science learners in South Africa are in a poor state. Intensive studies conducted by many authors suggest that metacognition is the key in defining successful learning. Therefore the aim of the research is to investigate the situation of metacognition in the physical science classroom in South Africa and devise workable teaching and learning strategies to improve the learners' metacognition skills. This research will analyse the teaching and learning situation from the perspective South African indigenous physical science learners. Theory suggests that if metacognition skills improve, the physical science attainment would improve.

Data for the research will in form of:

- open-ended interviews with learners, teachers and administrators;
- analysing curriculum documents, learners test, learners written exercises, learners test scores and note books;
- a metacognition awareness inventory questionnaire for learners;
- conducting classroom observations;
- a scientific attitude questionnaire for teachers and learners.

If permission is granted, I would like you to know that:

- Participants may respond or not to any inquiry without prejudice.
- Participants may withdraw from the process at any time.
- Participants names will not be used in the study, but rather a pseudonym will designate remarks.
- Participants will have the opportunity to review the written transcript of interviews and to delete any portion they feel does not reflect the veracity of the interview process.
- The documentation regarding interviews and observations will be kept in a secure place by me until they are no longer needed and will be shared with no one other than my supervisors.
- The material generated in the interviews will become part of a written project that satisfies the requirement of my masters dissertation and/or other publications deriving from this research. The nature of these

publications would most likely be, but may not be limited to, scholarly research destined for an academic audience.

- I do not expect to benefit monetarily from this research in any direct way.
- Given the nature of my subject, I cannot foresee any unusual risks to the participants.

I would like to thank you for your consideration of my request. If you choose to grant permission in the above described research, please sign one copy of this form and return it to me.

Yours sincerely

Ronesh Rajcoomar

Email: ronesh.rajcoomar@gmail.com
Mobile: 00994515917493

I understand the conditions of this study and wish to grant permission as described above.

NAME: _____ SIGNATURE: _____ DATE: _____

Appendix 6 Informed consent form to the principal of the school



Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

Informed consent form for the principal of the school Doctoral Study through North-West University

Informed Consent form for teachers and administration team involved in the implementation of the Physical Science curriculum in _____ Secondary School. The title of the research project is **"The Limitation in Metacognition of South African Indigenous Learners Studying Physical Science"**.

Name of Principal Investigator- **Mr Ronesh Rajcoomar**

Name of Organization- **North-West University**

This Informed Consent Form has two parts:

1. Information Sheet (to share information about the research with you)
2. Certificate of Consent (for signatures if you agree to take part)

You will be given a copy of the full Informed Consent Form

PART I: Information Sheet

Introduction

My name is Ronesh Rajcoomar and I am a Doctoral student at the North-West University. I am inviting your school to participate in the research that I am conducting. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. There may be some words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me.

Purpose of the research

Studies done so far shows that the results achieved by physical science learners in South Africa are in a poor state. Intensive studies conducted by many authors suggest that metacognition is the key in defining successful learning. Therefore, the aim of the research is to investigate the situation of metacognition in the physical science classroom in South Africa and devise workable teaching and learning strategies to improve the learners' metacognition skills. This research will analyse the teaching and learning situation from the perspective South African indigenous physical science learners. Theory suggests that if metacognition skills improve, the physical science attainment would improve.

Type of Research Intervention

This research will involve:

Data for the research will in form of:

- open-ended interviews with learners, teachers, and administrators;
- analysing curriculum documents, learners test, learners written exercises, learners test scores and note books;
- a metacognition awareness inventory questionnaire for learners;
- conducting classroom observations;
- a scientific attitude questionnaire for teachers and learners.

Participant selection

We are inviting physical science teachers, physical science learners and members of the administration to take part in this research.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may withdraw at any time from the research. If you require more information please feel free to ask any time.

Procedures and Protocol

The researcher will arrive on the days and time arranged by you the principal of the school. The researcher will conduct interviews, observe lessons, and conduct surveys arranged by you the principal of the school.

B. Description of the Process

Duration

The research takes place over during the whole duration agreed by you the principal of the school. During that time, it will be necessary the staff and learners are made fully aware of the researcher's intentions and not feel intimidated.

Benefits

There may not be any direct benefit for you or your school during the research but your school's participation is likely to help us find the answer to the research question. There may not be any benefit to the society at this stage of the research, but in the future, it may offer some solution to improving the physical science results in South Africa.

Reimbursements

Your will not be given any other money to take part in this research.

Confidentiality

The researcher will not be sharing the identity of those participating in the research. The information that the researcher collects from this research project will be kept confidential. Information about you that will be collected during the research will be put away and no-one but the researcher and the university's supervisor may be able to see it. Any information about you will have a number on it instead of your name. Only the researcher will know what your number is.

Sharing the Results

The knowledge that we get from doing this research will be shared with you through emails and telephonic conversations before it is made widely available to the public. Confidential information will not be shared. The researcher will inform you via email or telephonic conversation. The material generated in the interviews will become part of a written project that satisfies the requirement of research and/or other publications deriving from this research. The nature of these publications would most likely be, but may not be limited to, scholarly research destined for an academic audience.

Right to Refuse or Withdraw

You do not have to take part in this research if you do not wish to do so. You may also stop participating in the research at any time you choose. It is your choice and all of your rights will still be respected.

Who to Contact

If you have any questions you may ask the researcher now or later, even after the study has started. If you wish to ask questions later, you may contact the researcher:

Mobile: 00994515917439

Email: ronesh.rajcoomar@gmail.com

PART II: Certificate of Consent

Please indicate your approval of this permission by signing the letter where indicated below and returning it to me as soon as possible. By signing this letter, you are confirming that you own the copyright to the above describe material.

Thank you for your assistance.

Yours sincerely,

Ronesh Rajcoomar

Name of school:

Signature of principal _____

School Stamp

Appendix 7 Interview schedule for learners



Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

Interview Schedule for learners

1. Opening

A. (Establish Rapport) [shake hands] My name is Ronesh Rajcoomar and I am doing my PhD research through the North-West University.

B. (Purpose) I would like to ask you some questions about:

- your learning situation in physical science;
- understanding the thinking strategies, you use in your lesson;
- studying western-science in a South African classroom.

C. (Motivation) I aim to use this information in finding out to what extent effective thinking is taking place in the physical science classroom in South Africa. In addition, how does it affect the progress of the learners.

D. (Time Line) The interview should take approximately 20-30minutes. Are you available to respond to some questions at this time?

(Transition: Let me begin by asking you some questions about the teaching and learning situation focusing on problem solving and culture)

2. Body

Part 1: Metacognitive awareness

Question one: List the steps you take before and during solving a problem.

Question two: What do you think about after you hav solved a problem?

Question three: What would you do if you felt you have not understood the lesson?

Question four: How do you prepare yourself for a test or exam?

(Transition to the next topic: Can we now talk about Culture in the Physical Science Curriculum?)

Part 2: Culture within the Physical Science Curriculum

Question five: To what extent does the physical science curriculum respect your culture?

Question six: Would you be more inspired if there were more African values and culture in the physical science curriculum?

Question seven: What changes do you think is needed in the physical science course in order to encourage more learners to excel and be more motivated in physical science in the future?

(Transition: Well, it has been a pleasure interviewing you. Let me briefly summarise the information that I have recorded during our interview.)

3. Closing

- A. (**Summarise**) Your views on
- B. (**Maintain Rapport**) I appreciate the time you took for this interview. Do you have anything further to add regarding this research?
- C. (**Action to be taken**) I should have all the information I need. Would it be all right to contact you if I have any more questions? Thanks again. You have added a lot of value to this research.

Appendix 8 Interview schedule for teachers



Private Bag X8001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

Interview Schedule for teachers

1. Opening

A. (Establish Rapport) [shake hands] My name is Ronesh Rajcoomar and I am doing my PhD research through the North-West University.

B. (Purpose) I would like to ask you some questions about:

- your teaching situation in physical science;
- understanding the thinking strategies, you use in your lesson;
- studying western-science in a South African classroom.

C. (Motivation) I aim to use this information in finding out to what extent effective thinking is taking place in the physical science classroom in South Africa. In addition, how does it affect the progress of the learners.

D. (Time Line) The interview should take approximately 20-30minutes. Are you available to respond to some questions at this time?

(Transition: Let me begin by asking you some questions about the teaching and learning situation focusing on problem solving and culture)

2. Body

Part 1: Metacognitive awareness

Question one: What training have you been given in promoting and teaching metacognitive skills?

Question two: Please provide details on how the physical science curriculum encourages thinking skills that would develop world class scientists?

(Transition to the next topic: Can we now talk about Culture in the Physical Science Curriculum?)

Part 2: Culture within the Physical Science Curriculum

Question three: To what extent does the physical science curriculum respect the cultural views of the indigenous learners?

Question four: Describe any signs of resentment or demotivation shown by the learners in studying a western science?

Question five: Elaborate on any conflict in cultural views displayed by the learners in the physical science classrooms?

Question six: To what extent have you been trained in promoting indigenous culture in physical science?

Question five: To what extent does the physical science curriculum respect your culture?

Question six: Would you be more inspired if there were more African values and culture in the physical science curriculum?

Question seven: Please give your views on what is working and what is not working in science?

(Transition: Well, it has been a pleasure interviewing you. Let me briefly summarise the information that I have recorded during our interview.)

3. Closing

- A. **(Summarise)** Your views on
- B. **(Maintain Rapport)** I appreciate the time you took for this interview. Do you have anything further to add regarding this research?
- C. **(Action to be taken)** I should have all the information I need. Would it be all right to contact you if I have any more questions? Thanks again. You have added a lot of value to this research.

Appendix 9 Informed consent form for learners of the school

INFORMED CONSENT FORM FOR LEARNERS



Tel: 018 299-1111/2222

Web: <http://www.nwu.ac.za>

Re: The Limitation in Metacognition of South African Indigenous Learners Studying Physical Science

Dear Parent/Guardian

My name is Ronesh Rajcoomar and I am a Doctoral student at the North-West University. The results achieved by Physical Science learners in South Africa are in a poor state. The research that I am doing is to find effective strategies to be implemented by teachers and learners to improve these results so that we can create more world-class scientists.

I have planned to observe to Physical Science lessons that your child is in. I may also interview your child. Your child will also be asked to fill questionnaires that is crucial to the research. No one will be named in the report.

The head teacher of the school is interested in and willing to cooperate with my research and has identified classes that will be observed.

If you are willing to agree to your son or daughter taking part, I would be very grateful if you could sign the attached form and return it to school. If you would like to know more about the project, I would be very happy to chat with you. If you wish to do this, please feel free to contact either the head teacher at the school or me (my details are below).

Many thanks for taking the time to read this letter and for your help.

Yours sincerely

Ronesh Rajcoomar

. Please feel free to contact me at any time:

1. e-mail address – ronesh.rajcoomar@gmail.com
2. mobile- 0823688924

I wish my child to take part in the project.

Signed.....

Parent/Guardian

Please print your name _____

Please return this form to school as soon as possible

Appendix 10 Informed consent form for the teachers of the school



NORTH-WEST UNIVERSITY[®]
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
POTCHEFSTROOM CAMPUS

Private Bag X6001, Potchefstroom
South Africa 2520
Tel: 018 299-1111/2222
Web: <http://www.nwu.ac.za>

Faculty of Education

INFORMED CONSENT FORM FOR TEACHER INTERVIEWS

Thank you for agreeing to participate in this study, which will take place from _____ . This form details the purpose of this study, a description of the involvement required and your rights as a participant.

Name of Principal Investigator- **Mr Ronesh Rajcoomar**

Name of Organisation- **North-West University**

Purpose of the research

Studies done so far shows the results achieved by Physical Science learners in South Africa are in a poor state. Intensive studies conducted by many authors suggest that metacognition is the key in defining successful learning. Therefore, the aim of the research is to investigate the situation of metacognition in the Physical Science classroom in South Africa and promote workable teaching and learning strategies to improve learners' metacognition skills. This research will analyse the teaching and learning situation from the perspective South African indigenous Physical Science learners. Theory suggests that if metacognition skills improve, the Physical Science attainment would improve.

The methods that will be used to meet this purpose include:

- One-on-one interviews
- Mini discussion groups of two or three participants

You are encouraged to ask questions or raise concerns at any time about the nature of the study

or the methods I am using. Please contact me at anytime at the:

- e-mail address – ronesh.rajcoomar@gmail.com
- mobile- 00994515917493

Our discussion will be transcribed to help me accurately capture your insights in your own words. The documentation will only be studied with me for the purpose of this study. If you feel uncomfortable with the proceedings you may stop at any time.

You also have the right to withdraw from the study at any time. In the event you choose to withdraw from the study all information you provide will be destroyed and omitted from the final paper.

Insights gathered by you and other participants will be used in writing a qualitative research report, which will be read by my supervisor. Though direct quotes from you may be used in the paper, your name and other identifying information will be kept anonymous.

By signing this consent form I certify that I _____ agree to
(Print full name here)
the terms of this agreement.

(Signature) (Date)

Appendix 11 Ethics Approval Certificate



NORTH-WEST UNIVERSITY
YUNIBESITHI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom,
South Africa, 2520

Tel: (018) 299-4900

Faks: (018) 299-4910

Web: <http://www.nwu.ac.za>

Institutional Research Ethics Regulatory Committee

Tel: +27 18 299 4849

Email: Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF STUDY

Based on approval by the Ethics Committee of the Faculty of Education Sciences (ESREC) on 20/01/2017 after being reviewed at the meeting held on 29/10/2015, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your study as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Metacognition within physical science classrooms in two KwaZulu-Natal districts.																															
Study Leader/Supervisor:	Prof B Breed																														
Project team:	R Rajcoomar & Dr N Morabe																														
Ethics number:	<table border="1"><tr><td>N</td><td>W</td><td>U</td><td>-</td><td>0</td><td>0</td><td>4</td><td>4</td><td>8</td><td>-</td><td>1</td><td>5</td><td>-</td><td>A</td><td>2</td></tr><tr><td colspan="3">Institution</td><td colspan="5">Study Number</td><td colspan="2">Year</td><td colspan="5">Status</td></tr></table> <small>Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation</small>	N	W	U	-	0	0	4	4	8	-	1	5	-	A	2	Institution			Study Number					Year		Status				
N	W	U	-	0	0	4	4	8	-	1	5	-	A	2																	
Institution			Study Number					Year		Status																					
Application Type:	N/A																														
Commencement date:	2015-10-29																														
Expiry date:	2017-12-31																														
Risk:	<table border="1"><tr><td>N/A</td></tr></table>	N/A																													
N/A																															

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the ESREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the ESREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The study leader (principle investigator) must report in the prescribed format to the NWU-IRERC via ESREC:
 - annually (or as otherwise requested) on the progress of the study, and upon completion of the project
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
 - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the proposal as stipulated in the application form. Would any changes to the proposal be deemed necessary during the course of the study, the study leader must apply for approval of these changes at the ESREC. Would there be deviated from the study proposal without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via ESREC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-IRERC and ESREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the study;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the ESREC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.
- ESREC can be contacted for further information or any report templates via Erna.Conradie@nwu.ac.za or 018 299 4656

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC or ESREC for any further enquiries or requests for assistance.

Yours sincerely

Prof LA Du Plessis
Digitally signed by
Prof LA Du Plessis
Date: 2017.01.27
08:46:49 +02'00'

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

Appendix 12 Editing Certificate

HILTON RATCLIFFE, WORDSMITH cell 082 650 8313
Email hilton@hiltonratcliffe.com website www.hiltonratcliffe.com

EDITING CERTIFICATE

I hereby confirm that I have proof-read, formatted, and edited the style, layout, references, and language of the

**Thesis submitted for the degree *Doctor Philosophiae* in
Natural Science Education at the Potchefstroom Campus
of the North-West University**

by

Ronesh Rajcoomar

entitled

**METACOGNITION WITHIN PHYSICAL SCIENCES
CLASSROOMS IN TWO KWAZULU-NATAL DISTRICTS**

(337 pages, 78,600 words)

Note: The edited work described here may not be identical to that submitted. The author, at its sole discretion, has the prerogative to accept, delete, or change amendments made by the editor before submission.

Signed:



Date: 30 December 2017

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