A METACOGNITIVE LEARNING ENVIRONMENT FOR PHYSICAL SCIENCE CLASSROOMS

by

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DECLARATION

I, Heidi Hanekom, declare that “A Metacognitive Learning environment for Physical Science classrooms” is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

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Date: 19 January 2017

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DECLARATION BY LANGUAGE EDITOR

I, Gert VdM Hanekom, hereby declare that I edited this manuscript to the best of my knowledge, experience and ability as a qualified editor of academic English texts.

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Date: 18 January 2017

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SUMMARY

In order to address the problem of poor Physical Sciences performances in the Northern Cape, metacognitive awareness was identified as being the impetus that could stimulate Physical Sciences learning and improve performances in the subject. A metacognitive learning environment was identified as being a possible factor that could improve learners' metacognitive awareness. The aim of the research was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. This was done by first investigating the knowledge and skills learners need to master in Physical Sciences. Metacognition was identified as playing a role in acquiring knowledge and skills in Physical Sciences. The need for metacognitive awareness in Physical Sciences learning was highlighted by analysing how Physical Sciences learning takes places. Existing research into the components of metacognition was reviewed and when the components were analysed with reference to Physical Sciences learning, the importance of metacognitive awareness in effective Physical Sciences learning was established. The metacognitive learning environment was identified as a factor that could improve learners' metacognitive awareness and existing research into metacognitive learning environments were reviewed and applied to Physical Sciences classrooms. Learners' metacognitive awareness in Physical Sciences classrooms in the Northern Cape was investigated as well as the difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools. The characteristics of Northern Cape learning environments that are structured for Physical Sciences were identified and the difference between Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools was explored. A positive correlation between learners' metacognitive awareness in Physical Sciences and their Physical Sciences learning environments was confirmed. It was found, however, that the Physical Sciences learning environments did not always provide learners with the opportunity to develop their metacognitive awareness. Recommendations were made as to how the learning environments could be structured to allow for metacognitive awareness development in Physical Sciences.

OPSOMMING

Ten einde die probleem van swak leerderuitslae in Fisiese Wetenskappe in die Noord-Kaap aan te spreek, is metakognitiewe bewussyn geïdentifiseer as die hoofdryfveer wat leer in Fisiese Wetenskappe kan stimuleer en uitslae in die vak kan verbeter. ŉ Metakognitiewe leeromgewing is as moontlike faktor wat leerders se metakognitiewe bewussuyn kan verbeter geïdentifiseer. Die doel van die navorsing was om te bepaal tot watter mate Fisiese Wetenskappe-leeromgewings in die Noord-Kaap aan leerders die geleentheid gebied het om metakognitiewe bewussyn te ontwikkel. Dit is gedoen deur, eerstens, die kennis en vaardighede wat leerders benodig om Fisiese Wetenskappe te bemeester te ondersoek. Metakognisie is geïdentifiseer as ŉ faktor in die verkryging van kennis en vaardighede in Fisiese Wetenskappe. Die behoefte vir metakognitiewe bewussyn in Fisiese Wetenskappe-leer is uitgelig deur hoe leer in Fisiese Wetenskappe plaasvind te analiseer. Bestaande navorsing oor die komponente van metakognisie is daarna ondersoek en by die analise van die komponente met verwysing na Fisiese Wetenskappe-leer is die belangrikheid van metakognitiewe bewussyn vir doeltreffende Fisiese Wetenskappe-leer vasgestel. Die metakognitiewe leeromgewing is daarna geïdentifiseer as ŉ faktor wat leerders se metakognitiewe bewussyn kan verbeter en bestaande navorsing oor metakognitiewe leeromgewings is ondersoek en toegepas op Fisiese Wetenskappe-klaskamers. Leerders se metakognitiewe bewussyn in Fisiese Wetenskappe-klaskamers in die Noord-Kaap is ondersoek asook die verskil tussen leerders se metakognitiewe bewyssyn in Dinaledi-skole en nie-Dinaledi skole. Die eienskappe van Noord-Kaapse leeromgewings wat gestruktureer is vir Fisiese Wetenskappe is geïdentifiseer en die verskil tussen Fisiese Wetenskappe-leeromgewings by Dinaledi-skole en nie-Dinaledi skole is verken. ‘n Positiewe korrelasie tussen leerders se metakognitiewe bewussyn in Fisiese Wetenskappe en hul Fisiese Wetenskappe-leeromgewings is bevestig. Dit is bevind dat die Fisiese Wetenskappe leeromgewings nie altyd aan leerders die geleentheid gegun het om hul metakognitiewe bewussyn te ontwikkel nie. Voorstelle is ontwikkel oor hoe die leeromgewings gestruktureer kan word om metakognitiewe bewussynsontwikkeling in Fisiese Wetenskappe te bevorder.

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ORIENTATION

1.1 INTRODUCTION

International measures showed that South African learners were performing poorly in the Sciences in comparison with their counterparts in many other countries. The performance of the South African learners was ranked the lowest in Mathematics and Science[1] of the countries that participated in the International Association for Evaluation and Educational Achievement's Trends in Mathematics and Sciences Study (TIMSS) in 2001 and 2003. The Programme for International Student Assessment (PISA) confirmed the poor performances in Science (and Mathematics) among learners from different countries (OECD, 2010:159). From all the countries that participated, one in five learners only functioned at a very basic level in the Sciences classroom. These learners would have great difficulty to think scientifically in a world that demands that of them, both in the workplace and as active citizens (OECD, 2010:160). Ensuing from the results gathered from the TIMSS report, South Africa's average Science achievement for Grade 9 was significantly lower than that of the other 48 participating countries with 75% of the South African learners who partook in the study not even reaching the low international benchmark (Martin, Mullis, Foy & Stanco 2012:115). What is alarming is that only 1% of South African learners scored at the level of the advanced international benchmark (Martin *et al.,* 2012: 115). These results show that only a very small percentage of South African learners are able to conceptualise complex and abstract concepts that are crucial to excel in the Physical Sciences[2] (Martin *et al.,* 2012:111). Consequently, improved Sciences education should be both a national and provincial priority in South Africa.

Poor performance in Physical Sciences is a national problem. Statistics provided by the Department of Basic Education (DBE) revealed the following results concerning the pass rates for Grade 12 Physical Sciences for South Africa and the Northern Cape over previous years:

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[1] Science in this context refers to Natural Sciences

[2] Although the title refers to "Physical Science" the term "Physical Sciences" will be used in this study. The title of the study was registered in 2011. In 2011 the NCS was still enacted in schools and the subject was named "Physical Science". From 2012 up to present, CAPS have been enacted in schools and the subject is now named "Physical Sciences".

Table 1.1: Comparison between Physical Sciences results for Grade 12 learners nationally and in the Northern Cape

YEARS	2009	2010	2011	2012	2013	2014	2015
	Percentages of learners who achieved 30% or more in Physical Sciences						
National	36.8	47.8	53.4	61.3	67.4	61.5	58.6
Northern Cape	33.4	45.6	44.0	60.1	61.5	60.4	54.3
	Percentage of learners who failed Physical Sciences						
National	73.2	52.2	56.4	38.7	32.6	38.5	41.4
Northern Cape	76.6	55.4	56.0	39.1	38.5	39.6	45.7

(DBE, 2011a:62; DBE, 2014:79; DBE, 2015:62)

With regards to the National pass rate of Physical Sciences, more learners failed Physical Sciences than those who passed for the period 2009 - 2011. From 2009 to 2012 however, the Physical Sciences pass rate increased steadily until 2012, when more learners passed Physical Sciences than those who failed. From 2012 to 2015 the Physical Sciences pass rate stayed above 50%. The Physical Sciences pass rate trend for the Northern Cape Province followed the National trend, although it was always below the national average. During the 2011 National Senior Certificate Examination, the Northern Cape had the lowest pass rate for Physical Sciences in the country (DBE, 2011a:62).

Ten years ago it was already envisaged by the then-called Department of Education (2006:10) that learners who took Physical Sciences should be able to solve problems, answer questions and think critically within the Physical Sciences context. Currently the DBE aspires to develop Physical Sciences learners who possess the necessary knowledge and skills to construct and apply scientific knowledge to perform higher-order thinking skills, problem solving skills, and reflective skills (DBE, 2011:8).

While studying the pass rate from 2009 to 2011, the question arose whether Physical Sciences learners in the Northern Cape were able to demonstrate the outcomes as set out by the National Curriculum Statement of the Department of Education in 2006 and consequently, higher-order cognitive skills. From 2012 to 2013 there was an improvement, although it should be noted that the pass rate was indicative of learners who passed with a 30% which was the minimum requirement (and still is). In 2014 the Curriculum and Assessment Policy was implemented in Grade 12 and learners would have to perform according to the aims as set out by the Department of Basic Education. From 2013 to 2015 the Physical Sciences pass rate has steadily decreased both nationally and in the Northern

Cape. Once again the question could be asked whether the learners were able to reach the learning goals set for them by the DBE.

1.2 PROBLEM STATEMENT

Successful Physical Sciences learners should be able to attain the learning goals of Physical Sciences – being able to apply critical and reflective thinking to solve problems, and demonstrate higher order thinking skills when constructing and applying Physical Sciences knowledge (DBE, 2011:8). Poor performances in Physical Sciences could indicate that learners were unable to manage their learning process to attain the learning goals presented to them. Schraw and Dennison (1994:460) labelled the ability to plan, monitor and evaluate learning and strategy use as metacognition. Schraw (1998:114) reiterated and described metacognition as follows:

> "…*knowledge of cognition that refers to what individuals know about their own cognition and cognition in general…[and] regulation of cognition refers to a set of activities to help students control their learning."*

Developing learners' metacognitive skills holds many advantages for learning. The development of metacognitive skills necessary for learners to manage and control complex cognitive processes should improve their learning (Serra & Metcalfe, 2009:278). Metacognition could be seen as the impetus that will stimulate learning and address higher-order thinking skills that learners should demonstrate. Thomas (2003:176) advocated the idea that if learners' metacognition could be improved, the demonstration of learning outcomes should also improve. This specifically relates to Physical Sciences since the learning outcomes refer to critical and reflective thinking, both of which are dependent on metacognitive skills.

Schraw (1998:18) and Thomas (2003:176) alluded to the fact that metacognition could be improved through the practice and modelling of metacognitive strategies in the classroom. In the Physical Sciences classroom learners should not only be taught content and skills relating to Physical Sciences, but they should also be given opportunities to develop their metacognitive knowledge and skills in order to reach their learning goals. Improving learners' metacognition should therefore be a priority in the Physical Sciences classroom.

In order for learners to develop their metacognition in Physical Sciences, a suitable learning environment should be created. Schraw (1998:121) mentioned that metacognitive skills do not exist in a vacuum. In order to improve and develop learners' metacognitive skills, a learning environment should be created that supports metacognitive development. Thus, if the proposed outcome is to improve learners' metacognitive skills, the extent to which this outcome will be achieved is determined by the learning environment. It could be concluded that the learning environment plays an important role in the development and improvement of learners' metacognition. The learning environment should have certain characteristics that support metacognitive development and promote the use of metacognitive skills and knowledge in order to achieve learning outcomes in Physical Sciences.

Thomas (2003:180) suggested that since metacognitive learning environments are underpinned by the theory of social constructivism, the roles of discourse, language and social interaction are very important. Learners should be able to communicate with the teacher, with each other, and also engage in self-dialogue, as mentioned by Thomas and McRobbie (2001:223). Thomas (2003:181) also mentioned that metacognitive-orientated classrooms should foster autonomous and self-regulated learning. Therefore, it is important that learners also voice their opinions in the classroom, and for teachers to involve learners in the planning process of their own learning. Communication will only be possible if a language of learning has been acquired by both teacher and learners, to make it possible for them to discuss cognitive aspects of the learning experience (Thomas & McRobbie, 2001:223). Thomas (2003:183 – 184) also noted that, in a metacognitive orientated learning environment, learners should be aware of metacognitive demands. Once again, a shared language of learning is crucial for learners to understand commands and describe to what extent they adhere to these demands. Lastly, Thomas (2003:184) referred to the motivational and emotional aspects of a learning environment and the importance of emotional encouragement and support from the teacher.

Unfortunately, as McRobbie and Thomas (2001:210) also noted, the traditional Sciences classroom environments are often not conducive for higher order learning. There is also concern about the extent to which learners understand the subject in these traditional classrooms. The question could be asked whether these unfavourable learning environments could be a contributing factor to the low metacognitive usage among Physical Sciences learners. When the latest pass rate for Physical Sciences is considered (see Table 1.1), it is clear that there is a problem with learners demonstrating the outcomes of the subject. If metacognitive awareness is necessary to be successful in a subject such as Physical Sciences and learners are not exposed to an environment that will enhance their metacognitive awareness, they could perform poorly in Physical Sciences.

To address the problem of learners' poor results in the subjects Physical Sciences, as well as Mathematics, the Department of Education implemented the Dinaledi School Project to improve the teaching and learning of Physical Sciences and Mathematics (Department of Education, 2009:8). Schools that were selected to take part in the project were provided with additional resources and support. The resources and support included additional teachers to be employed to teach Mathematics and Physical Sciences (Department of Education, 2009:9). In addition, the Department of Education provided training to Mathematics and Physical Sciences teachers, as well as Heads of Departments for Mathematics and Physical Sciences (Department of Education, 2009:8). Laboratory infrastructure and equipment were also provided to Dinaledi schools to promote practical work (Department of Education, 2009:9). The Dinaledi School project aimed to improve the Physical Sciences and Mathematics pass rates by creating a favourable learning environment where learners could engage with the subjects. A distinction can therefore be made between two Physical Sciences learning environments – learning environments in schools who receive additional resources and support (Dinaledi schools) and learning environments in schools who do not receive additional resources and support (non-Dinaledi schools). The question could, however, be asked whether the Physical Sciences classrooms from the Dinaledi Schools would be more conducive to higher order learning and metacognitive awareness than Physical Sciences classrooms from non-Dinaledi schools, as proposed by Thomas and McRobbie in the previous paragraph.

The aforementioned discussion suggests that the performance for Physical Sciences in the Northern Cape could be improved by developing learners' metacognition in a classroom that fosters the development thereof. The problem envisaged was to determine whether the Physical Sciences classrooms in the Northern Cape afforded learners the opportunity to develop their metacognitive awareness, which gave rise to the primary research question:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

To fully explore the primary research question, the following secondary research questions needed to be answered:

- What knowledge and skills do learners need to master in Physical Sciences?
- What role does metacognition play in Physical Sciences learning?
- What are the different components of metacognition?
- What are the characteristics of a metacognitive learning environment for the Physical Sciences?
- To what extent do learners demonstrate metacognitive awareness in the Physical Sciences classrooms in the Northern Cape?

- What are the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape?
- Is there a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools?
- Is there a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools?

1.3 AIM AND OBJECTIVES

The aim of this study is to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. The following objectives guided the research in an effort to realize this aim:

- Investigate the knowledge and skills that learners need to master in Physical Sciences.
- Highlight the role that metacognition plays in Physical Sciences learning.
- Review the existing research into the different components of metacognition.
- Review the existing research into metacognitive learning environments for Physical Sciences classrooms.
- Investigate learners' metacognitive awareness in Physical Sciences classrooms in the Northern Cape.
- Identify the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape.
- Investigate whether there is a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools.
- Investigate whether there is a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools.
- Provide recommendations based on the findings of this research that could enhance learners' performance in Physical Sciences.

1.4 RESEARCH METHODOLOGY

The research methodology guides the layout, progression and outcome of an investigation. This sections comprises the following subsections: the research paradigm, the research design, and the validation of the quantitative data.

1.4.1 Research Paradigm

Predictions regarding the Physical Sciences learning environment, as well as learners' metacognitive awareness, are made from previous observations, such as those in the TIMMS and PISA reports, and previous research on metacognition and learning environments, as well as results of the National Senior Certificate Examination. This research aimed to investigate the Physical Sciences classrooms and learners' perceived metacognitive awareness from an objective point of view.

Babbie (2010:35) asserted that positivism is grounded objective reality. In this study the underlying paradigm was positivist in nature. In the search to answer the research questions both a literature study and an empirical study were conducted.

1.4.2 Research design

To find the answers to the research questions both a literature study and an empirical study was conducted.

1.4.2.1 Literature study

The literature study was conducted by studying and analysing different literature resources to provide possible answers to the first four research questions. The literature study is divided here into two sections. The first section focuses primarily on Physical Sciences learning and aspires to provide insight into the knowledge and skills needed to master Physical Sciences. The second section focuses on how learning takes place in Physical Sciences and the role that metacognition plays in Physical Sciences learning. The development of metacognition as well as current theories concerning metacognition was explored. The different components of metacognition, as well as the extent to which the current curriculum allows for learners to develop the necessary metacognitive knowledge and skills, were also investigated. Lastly, a discussion on the characteristics of a metacognitive learning environment, as well as its implications for Physical Sciences classrooms, is presented.

1.4.2.2 Empirical study

A quantitative research method was employed to investigate the phenomena. Maree and Pietersen (2010c:145) defined quantitative research as:

> *"…a process that is systematic and objective in its ways of using numerical data from only a selected subgroup of the population to generalise the findings to the universe that is being studied."*

The empirical data obtained was analysed using quantitative methods to determine to what extent the learning environments in Physical Sciences classrooms in the Northern Cape afforded learners the opportunity to develop metacognitive awareness.

To answer the last four research questions posed, numerical data were needed. For this purpose a standardised questionnaire was used as an instrument to collect empirical data that allowed the researcher to identify characteristics of metacognitive learning environments in Physical Sciences classrooms and learners' metacognitive awareness in the subject. The findings could contribute to clarifying the extent to which learners currently demonstrate metacognition, as well as the true nature of the Physical Sciences learning environments in the Northern Cape. The difference between Physical Sciences learning environments in Dinaledi and non-Dinaledi schools was also investigated as well as the metacognitive awareness of learners' in Dinaledi and non-Dinaledi schools. A survey design was utilised to explore the last four research questions for this study, and to describe the current state of Physical Sciences learning environments, as well as learners' metacognition (Mouton, 2002:152).

1.4.3 Validation of the quantitative data

1.4.3.1 Reliability

A pilot study was conducted to determine the reliability of the questionnaires in the South African context. The Cronbach's alpha coefficient was used in the statistical analyses to determine the internal reliability, and to observe the extent of the correlation between the items within the construct (Pietersen & Maree, 2010a:216). The Cronbach's alpha coefficient calculation supported the internal reliability of the questionnaire, therefore the questionnaire was used to collect data for the study.

1.4.3.2 Validity

According to Pietersen and Maree (2010a:216 – 217) an instrument will be valid if it measures what it is supposed to measure. Pietersen and Maree (2010a:217) distinguished between four different types of validity, namely face validity, content validity, construct validity, and criterion validity. In this study face, content and construct validity were used to determine the validity of the questionnaires.

1.5 DATA COLLECTION

1.5.1 Population

The population was Grade 10 and 11 learners from the Northern Cape who were enrolled for Physical Sciences as a subject. The research sites were high schools in the Northern Cape that present Physical Sciences as a subject.

1.5.2 Sample

In order to collect as much data as possible from participants from different schools, convenience sampling (Maree & Pietersen, 2010b:176) was used and 14 schools in and around Kimberley in the Frances Baard district were asked to take part in the investigation. In the sample Dinaledi schools and non-Dinaledi schools were included. Data from 816 respondents were collected.

1.5.3 Data collection procedures

After the schools making up the sample were identified and permission was granted from the Department of Basic Education, principals, parents and learners for the research to be conducted, the questionnaires were administered to the learners by the researcher. The data were collected over a two week period during the fourth term of 2012. The study was completed in 2016 and submitted to the UFS at the end of January 2017 for assessment purposes.

1.6 DATA ANALYSIS

The data were analysed by means of analytical and inferential statistics. Calculating the mean score of the different constructs, as well as the standard deviation. Findings are presented in a descriptive fashion by means of mean scores and standard deviations. In order to determine whether a practical significant difference exists between the mean scores (for learning environments and metacognitive awareness) of Dinaledi and non-Dinaledi schools, effect sizes were calculated.

The correlation between the Physical Sciences learning environment and learners' metacognitive awareness was investigated by formulating two hypotheses, namely a null hypotheses (H_0) and an alternative hypotheses (H_A).

- H_0: $\rho=0$: There is no significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment
- H_A: $\rho > 0$: There is a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment

In order to test these hypotheses, the Pearson Correlation coefficient and the p-value were calculated, as advocated by Pietersen and Maree (2010c:234 – 237).

1.7 ETHICAL CONSIDERATIONS

Before the research was conducted, ethical clearance and permission to perform the study were obtained from different role players. The Ethics Board of the Faculty of Education issued the ethical clearance certificate (UFS – EDU-2012-0020) for research to be conducted for the study on 23 May 2012 (Appendix A: Ethical Clearance Letter). A letter was sent to the Department of Education to ask for permission to conduct research (Appendix C: Letter to Department of Education for permission to conduct research). The Northern Cape Department of Education Chief Director: Districts, Mr Esau, granted permission for the research to be conducted at high schools in the Northern Cape (Appendix B: Letter to Northern Cape Department of Education for permission to conduct research at high schools in Northern Cape). After identifying schools that would form part of the sample, letters were sent to the principals of these schools to obtain permission to conduct research at their schools (Appendix D: Letter to Principals for permission to conduct research at school). Once permission was obtained to conduct research at the school, letters of permission to administer questionnaires to learners were sent home to the learner's parents to sign and send back to school (Appendix E: Letter of permission from parents to administer questionnaire to their children). Lastly, on the day when the questionnaires were administered, each learner signed a letter acknowledging that they were willing to take part in the research and that they gave permission for the questionnaire to be administered to them (Appendix F: Letter to learners for permission to administer questionnaires to them). As stated in Chapter 4, all ethical considerations related to research participants' potential benefits and hazards, recruitment procedures, informed consent, voluntary participation, confidentiality, anonymity, data protection, and trustworthiness of findings were explained and observed during fieldwork. The data collected would only be used for the purpose of the study and not be made publically accessible in any other way.

1.8 DELIMITATION

The study focused on the relative metacognitive awareness of Physical Sciences learners. The researched explored the possibility of developing a metacognitive learning environment to improve learners' metacognitive awareness for improved teaching and learning in Physical Sciences.

When the field work of the study was conducted, the NCS (implemented in 2006) had been enacted for Grade 11 Physical Sciences, while the CAPS (implemented from 2012) had been enacted for Grade 10 Physical Sciences. Since the CAPS forms part of the current curriculum implemented in South Africa, the CAPS document is referred to in the study and not the NCS document.

This study was conducted within the discipline of Education, specifically Curriculum Studies. In summary the focus of the study was on Physical Sciences learning environments that enhance metacognition.

1.9 DEFINITION OF TERMS

1.9.1 Physical Sciences

Physical Sciences is the subject in which the research was conducted. This comprises both chemistry and physics. The subject Physical Sciences is defined in the CAPS (DBE, 2011:8) as the investigation, explanation and prediction of physical and chemical phenomena through scientific inquiry and by applying scientific models and theories to understand how the physical environment works, so that human beings could benefit from it.

1.9.2 Metacognition

Schraw (1998:114) proposed that metacognition could be divided into two categories, namely knowledge of cognition, and regulation of cognition. Knowledge of cognition refers to a learners' knowledge about his or her own skills and cognitive abilities, how to complete a certain task and when to use certain skills and knowledge. Schraw describes regulation of cognition as the actions learners take to manage their learning. Learners should plan their learning, manage information, monitor learning and strategy use, check and correct understanding if necessary, and evaluate their learning and the effectiveness of strategy use (Schraw & Dennison, 1994:461). Metacognitive awareness allows learners to apply their metacognition better – it allows them to plan, sequence and monitor their learning in a way that improves their performance (Schraw & Dennison, 1994:460).

1.9.3 Metacognitive learning environment

The metacognitive learning environment refers to the environment in which learners should be able to develop and utilise their metacognitive skills. These classrooms should stimulate metacognitive learning and improve learners' metacognitive orientation. Thomas (2003:177) stated that metacognitive-orientated classrooms should foster metacognitive development. For this study, the learning environment was the Physical Sciences classrooms in the Northern Cape. The learning environment was studied to find to what extent it displayed characteristics of a metacognitive learning environment.

1.9.4 Curriculum and Assessment Policy Document (CAPS)

The Curriculum and Assessment Policy document replaced the NCS document. The whole curriculum was not adapted at once across all grades, and the CAPS document was introduced in stages. In 2012, for the Further Education and Training (FET) phase, the NCS was enacted for Grade 11 and 12 while Grade 10 learners were studying the CAPS. Like its predecessor, the CAPS document informs the teaching and learning methods that should be used in the Physical Sciences classroom in order for learners to master the necessary knowledge, skills and attitudes. At the time of this study, the CAPS was the curriculum that was being followed in South African schools.

1.10 LAYOUT OF THE STUDY

The dissertation consists of six chapters. The first chapter discusses the problem of learners in the Northern Cape performing poorly in Physical Sciences. The research aim and research questions have already been stated, as well as a brief overview of the study.

Two literature chapters are included, namely Chapter 2 and Chapter 3. Chapter 2 is a literature review providing a discussion and explanation of the framework of the knowledge and skills which Physical Sciences learners need to master. A summary of the chapter concludes Chapter 2.

Chapter 3 reviews the learning process in Physical Sciences, and highlights the importance of metacognition. The different components of metacognition, knowledge of cognition and regulation of cognition, are reviewed and analysed. The characteristics of a Physical

Sciences learning environment that enhances learners ‘metacognition are also explored. A summary of the main points discussed in the chapter concludes Chapter 3.

Chapter 4 provides the research methodology of the study. This includes a discussion of the research paradigm, the research design, the population and sampling methods, the data collection instrument, and the data analysis procedures, data validity, and data reliability. Ethical considerations, as well as data collection are reported on. A summary of the chapter concludes the discussion of the Chapter 4.

In Chapter 5 an analysis and interpretation of the results from the study are presented in order to provide possible answers to the research questions that seek to be answered through empirical research. The results aid in clarifying the characteristics of Physical Sciences classrooms, as well as the state of learners’ metacognitive awareness. An interpretation of the relationship between learners’ metacognitive awareness and the learning environment are also presented in this chapter. Chapter 5 is concluded with a summary.

The final chapter, Chapter 6, focuses on the findings, conclusions and recommendations that were drawn from the study. Concluding remarks are presented at the end of Chapter 6.

1.11 SUMMARY

In this chapter the problems regarding poor Physical Sciences performances in the Northern Cape were highlighted. It was suggested that poor performances in Physical Sciences could indicate that learners were unable to manage their learning process to attain the learning goals presented to them. The ability to plan, monitor and evaluate learning, and strategy use was labelled as metacognition. It was alluded to that if learners’ metacognition could be improved, the demonstration of learning outcomes would also improve. Metacognitive awareness was identified as a possible factor that could have an influence on Physical Sciences learning and performances in the subject. The learning environment was implied as an important factor in the development and improvement of learners’ metacognitive awareness. The problem that was envisaged was to determine whether the Physical Sciences classrooms in the Northern Cape afforded learners the opportunity to develop their metacognitive awareness. The problem gave rise to the primary research question:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

Secondary research questions were also formulated, guiding the researcher to fully explore the primary research question and to reach the aim of the study:

> *To determine to what extent the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness.*

Both a literature study and empirical research were conducted find answers to the research questions. Based on the positivist paradigm, it was decided that quantitative research methods would be employed to conduct the empirical research. Grade 10 and 11 learners presenting Physical Sciences as a subject from schools in the Northern Cape were identified as the population. Convenience sampling was used and questionnaires were used to collect data from participants in the sample regarding their metacognitive awareness and Physical Sciences learning environment.

In the following chapter the nature of Physical Sciences will be explored so as to identify the role that metacognition plays in Physical Sciences learning.

CHAPTER 2
THE NATURE OF PHYSICAL SCIENCES

2.1 INTRODUCTION

The aim of this study was to determine to what extent learning Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. Before analysing metacognition or learning environments, it is necessary to understand what the subject, Physical Sciences, entails. Chapter 2 is concerned with finding an answer to the following secondary research question:

What knowledge and skills do learners need to master in Physical Sciences?

In order to answer this question, the nature and structure of Physical Sciences are explored first. Once the nature and structure of Physical Sciences are established, Anderson and Krathwohl's revised taxonomy is applied to classify knowledge types and cognitive processes in Physical Sciences. A framework for Physical Sciences is then constructed to delineate the knowledge and skills that learners need to master in Physical Sciences.

2.2 THE NATURE AND STRUCTURE OF PHYSICAL SCIENCES

To determine what knowledge and skills learners need to master in Physical Sciences, the nature and structure of the subject needs to be studied first. Maarschalk and McFarlane (1988:41) stated that Physical Sciences together with Biological Sciences and Earth Sciences are part of a broader body of Sciences namely Natural Sciences. Physical Sciences in turn consists of two disciplines, namely Physics and Chemistry. Van Aswegen, Fraser, Nortje, Slabbert and Kaske (1993:2) described this in the following manner:

> *"Physics is concerned with the properties and nature of matter in general, various forms of energy and the mutual interaction of energy and matter. Chemistry is a study of the composition of substances and their combination and change under various conditions."*

To conceptualise the nature of Physical Sciences it is important to also take into consideration the nature of Natural Sciences. Van Aswegen *et al.* (1993:4 – 6) stated that Natural Sciences consists of two components, namely the substantive and the syntactical structure. While the substantive structure is concerned with the content (or body of knowledge), the syntactical structure is concerned with the processes (or skills). The structure of Natural Sciences, and Physical Sciences, are therefore two-dimensional in nature.

The CAPS for Physical Sciences defines Physical Sciences as the investigation of physical and chemical phenomena through scientific inquiry, as well as the application of scientific models, theories and laws in order to explain and predict events in the physical environment (DBE, 2011:8). The two dimensions as proposed by Van Aswegen *et al.* (1993:4 – 8) are clearly evident in this definition of Physical Sciences, as both the knowledge and skills of Physical Sciences are addressed in this definition. Studying the substantive and syntactical structure of Natural Sciences as proposed by Van Aswegen *et al.* (1993:4 – 8) will serve as the starting point to investigate the knowledge and skills needed to master Physical Sciences.

2.2.1 The substantive structure

Dreckmeyr (1994:13), as well as Van Aswegen *et al.* (1993:4) stated that the content of Natural Sciences refers to the body of knowledge which is the substantive structure of the subject. Dreckmeyr (1994:13) pointed out that for Physical Sciences the substantive structure refers to knowledge about the kinematic and physical aspects of natural objects or phenomena. The CAPS (DBE, 2011:8) document lists the construction and application of scientific and technological knowledge as one of the specific aims of Physical Sciences. The CAPS therefore also promotes the substantive structure as an important aspect of Physical Sciences that has to be mastered by the learners.

Van Aswegen *et al.* (1993:4) differentiated between different types of knowledge, namely facts, concepts and generalisations within the substantive structure. These components of the substantive structure are discussed next.

2.2.1.1 Facts

Facts are the most basic forms of knowledge according to Gunter, Estes and Schwab (1995:43), who report that facts are singular in “occurrence” and have “no predicative value”. Van Aswegen *et al.* (1993:5) defined facts as fragments of information that could be employed to develop concepts and generalisations. Examples of facts in Physical Sciences could include terminology such as names of processes and elements, names of scientists, and names of laws, theories or rules.

In Grade 10 Physical Sciences learners should know the names and symbols of different elements. Learners need to know these facts, because they use them later on to name chemical compounds and write chemical formulae.

Although facts are the most basic forms of knowledge, Van Aswegen *et al* (1993:5) pointed out that facts serve as starting points for the development of concepts and, later, generalisations. Although facts themselves are meaningless on their own, when they are used by the learner they become an important part of a learner's knowledge about the subject. As in the example above, learners would not be able to name chemical compounds if they do not know the names of elements.

Facts are the most basic component of the substantive structure of Physical Sciences. However, they are also precursors to concepts and therefore it is important that learners memorise certain necessary facts.

2.2.1.2 Concepts

Once facts have been established and memorised, learners could use knowledge of multiple facts to form concepts. Gunter *et al.* (1995:43) stated that concepts are the result of classifying facts according to similarities. Van Aswegen *et al.* (1993:5) also defined a concept as an individual's attempt to categorise and label events and objects and consider concepts to be fundamental to the structure of the subject.

As mentioned in 2.2.1.1 facts are meaningless on their own but when they are condensed into concepts they are manageable forms of knowledge (Van Aswegen *et al.,* 1993:5).

In Physical Sciences facts are also condensed into concepts. For example, learners are required to know the valency of elements in order to be able to write chemical formulas. After studying the periodic table learners should know that the group number is equal to the valence electrons and that valency is related to the group number. Instead of memorising the valency of every element it is easier to understand the concept of groups on the periodic table and how the group number is related to the valency. By learning the concept and not the masses of facts, learners should not only save time but also eliminate the likelihood of making a mistake by forgetting the valency for a certain element. Furthermore, when learners learn the concept of valency instead of the valency for each element as a separate entity, it should help them to understand other related concepts such as chemical bonding.

Physical Sciences learners should first memorise the facts but are later also required to draw Lewis dot diagrams to show covalent and ionic bonds. As learners progress there is a gradual shift from the facts (valency, valence electrons, energy levels, orbitals) to the formation of concepts (chemical bonding).

Learners should conceptualise facts properly since concepts are used to form generalisations. Without a firm understanding of the necessary concepts in Physical Sciences, learners will not be able to make sensible generalisations.

2.2.1.3 Generalisations

Van Aswegen *et al.* (1993:5) described generalisations as conceptual frameworks where the relationship between facts and concepts are described. Dreckmeyr (1994:16) referred to theories in Physical Sciences as the connections between facts and concepts. Theories and generalisations could therefore be seen to have the same meaning in this context where both are used to describe the establishment of connections between facts and concepts.

Generalisations, or theories, are predictive, as Gunter *et al.* (1995:43) pointed out. Dreckmeyr (1994:16) argued that Physical Sciences theories are used to explain aspects of the physical world. Since the nature of Physical Sciences is concerned with predicting events in nature, theories and generalisations play an important role in the subject.

When a learner knows that elements in the same group has the same valency, they should find a link between valency (the facts) and the group numbers (the concepts). The link (generalisation or theory) should then be made that the group number gives an indication of the valency, as well as the number of valence electrons. Learners could then also generalise that atoms will share, gain or lose electrons in order the get the electron structure of a noble gas which has a filled energy levels.

Physical Sciences theories and generalisations are not rigid, dynamic. Dreckmeyr (1994:17) commented on the dynamic nature of scientific knowledge as scientific theories that are constantly being revised and replaced as more insight is gained into the physical world. Van Aswegen *et al.* (1993:5) postulated that new observations and experiences could enlighten the structure of the subject and therefore theories and generalisations could change to accommodate new understandings of our physical world. Both authors agree that scientific theories and generalisations are not to be presented as final and always true. The learner should realise that in the Physical Sciences new observations could lead to new theories or generalisations.

A good example of the dynamic nature of Physical Sciences is the various atomic models from Democritus who said that the smallest particles will be labelled “atomos” to the current model which depicts atoms with a core and a cloud of electrons surrounding it in quantised energy levels. Generalisations could change due to the tentative nature of Physical Sciences (Dreckmeyr, 1994:17) but it is still an important component of the structure of Physical Sciences. Learners should know that Sciences is dynamic and that generalisations and theories are not set in stone and could change as new research comes to light.

Knowledge in Physical Sciences could be obtained through one of two processes – the inductive approach (see 2.2.4.1) or the deductive approach (see 2.2.4.2) (Dreckmeyr, 1994:13). Dreckmeyr (1994:13 – 14) described the inductive approach as proceeding from the specific to the general and vice versa for the deductive approach. While the inductive approach requires from learners to formulate a generalisation from specific observations, the deductive approach requires that learners apply a generalisation to explain observations. Both approaches require learners to investigate natural phenomena and to apply necessary skills in order to formulate or test generalisations. It is therefore necessary to explore the skills that learners need to engage in the process of constructing knowledge.

2.2.2 The Syntactical structure

As established above, learners need certain skills in order to construct and explain Physical Sciences knowledge. Van Aswegen *et al.* (1993:6) described the syntactical structure as the processes used to obtain knowledge.

The syntactical structure, as proposed by Van Aswegen *et al.* (1993:6 – 7) consists of six skills:

- Sensorimotor skills – receiving information through the senses and performing basic motor skills.
- Cognitive skills – an activity of the mind that could be guided by one or more sensorimotor skills.
- Techniques – Using cognitive skills and motor skills to manipulate an instrument, apparatus or machine as an extension of the human body.
- Observation – involving all the senses to make relevant observations in and about the natural world and which could include using techniques to do so.
- A scientific language system – terminology and visual presentations such as graphs, equations and diagrams to internalise observations and to communicate these to the wider society.
- Discovery – includes sensorimotor skills, cognitive skills, techniques, observations and scientific language to perform the scientific investigations to discover and confirm knowledge.

The CAPS (DBE, 2011:8) emphasises that the purpose of Physical Sciences is to equip learners with the following investigative skills:

- classifying,
- communicating,
- measuring,
- designing an investigation,
- drawing and evaluating conclusions,
- formulating models,
- hypothesising,
- identifying and controlling variables,
- inferring,
- observing,
- comparing,
- interpreting,
- predicting,
- problem-solving, and
- reflective skills.

The skills listed by the CAPS (2011:8) correlate with the skills implied in the syntactical structure, as proposed by Van Aswegen *et al.* (1993) above. The skills also feature in the scientific method as proposed by Dreckmeyr (1994:13) to be the method used in Physical Sciences to acquire knowledge. The scientific method includes identification and formulation of the problem, formulating a hypothesis, as well as collecting data by means of an investigation or experiments and making conclusions (Dreckmeyr, 1994:13 – 14). The Scientific method is therefore a culmination of skills and is an integral component in the syntactical structure – the process of acquiring knowledge – of Physical Sciences.

The syntactical structure of Physical Sciences could be analysed by referring to the six skills as defined by Van Aswegen *et al.* (1993:6 – 7).

2.2.2.1 Sensorimotor skills

Van Aswegen *et al.* (1993:6) defined sensorimotor skills as the primary reception of impressions and basic motor skills. In Physical Sciences learners use their sensorimotor skills when they are using any of their senses – sight, smell, touch, taste and hearing – to form an impression of the world around them. They should see that magnesium burns with a bright white flame, they should smell that acids have a sour smell, they should feel that the temperature of water decreases as ammonium nitrate is added due to the endothermic reaction taking place, they should taste that pure water is tasteless and they should hear sounds with different frequencies. Basic motor skills could be described as the precise movement of muscles, usually in the hands and fingers, to perform a specific task (Anon, 2013) In Physical Sciences basic motor skills could include tasks such as pouring a liquid from one flask to the next, adjusting the gas supply to the Bunsen burner, using a spatula to collect crystals, or connecting components of an electric circuit with crocodile clips.

Sensorimotor skills are very basic skills and are usually combined with other skills such as cognitive skills to perform more complex tasks.

2.2.2.2 Cognitive skills

Cognitive skills are activities of the mind that could be accompanied by sensorimotor skills, although this is not always the case (Van Aswegen, 1993:6). In Physical Sciences cognitive skills also refer to when learners are constructing knowledge or applying knowledge to give explanations. As an example, learners have to differentiate between endothermic and exothermic reactions. A learner could be provided with two beakers – in the one beaker a magnesium strip is added to hydrochloric acid while ammonium hydroxide is added to water in another beaker. The learner then has to complete the following activities in order to differentiate between exothermic and endothermic reactions:

- Adding the reagents together in the two beakers requires basic motor skills.
- Using the sense of touch to feel the temperatures of both beakers.
- Noting the difference in temperature as one reaction will increases in temperature while the other will decrease in temperature

In this case, the cognitive skill of differentiating between endothermic and exothermic reactions was accompanied by the sensory skills like feeling and looking as well as basic motor skills.

2.2.2.3 Techniques

Techniques are described as the technical manipulation of an instrument, apparatus or machine, which requires cognitive skills as well as sensorimotor skills (Van Aswegen *et al.*, 1993:6). In order to differentiate between the endothermic and exothermic reaction in the example given in the previous paragraph, a learner might have to use a thermometer to determine the temperature of the contents in each beaker. The technique of using a thermometer to accomplish the task of differentiate between two reactions requires the following actions:

- Using the thermometer requires basic motor skills.
- The thermometer acts as an extension of the sense of touch, giving exact temperatures instead of merely being able to differentiate between “warm” and “cold”.
- Noting the difference between the two thermometer readings – the reading for the exothermic reaction should be more than the reading for the endothermic reaction.

2.2.2.4 Observation

Mannoia (as quoted in Van Aswegen *et al.*, 1993:6) emphasised the role of observation in the construction of scientific knowledge. The author referred to senses and made the following statement; “Scientific knowledge is about the sensible world, originates in the sense experience and is ultimately tested against the standard of the senses”.

This creates the impression that observation is the starting point for scientific knowledge and also plays a crucial role in the final culmination of events that lead to new scientific knowledge.

In Physical Sciences, scientific investigations also start with an observation. A hypothesis cannot be formulated without having first observed the phenomenon that is being studied. No matter how abstract the problem might be, observation forms part of the scientific method of investigation.

In Physical Sciences, learners are asked to make observations in order to enable them to think about a problem or to introduce them to a new content. To illustrate Newton’s First Law the teacher might prompt the learners to think about what happens when they are travelling in a car and the breaks are applied. The learners should then recall previously observations made in real life in order to answer the question. When learners are introduced to the concept of transverse pulses and waves, the teacher could use a slinky or heavy rope to generate a pulse or wave. In order for learners to make observations, the teacher could focus the learners’ attention on the movement of the slinky and the movement of the pulse as well as the rest position and the maximum displacement from the rest position. In both of the examples given above, observations are prerequisite to new knowledge and the new knowledge cannot be consolidated without the use of observations. Furthermore, the learners’ comprehension of the theory, law or generalisation could be assessed by asking the learner to explain an observation.

When conducting scientific investigations or experiments, learners are also required to make observations in order to identify the problem. From the problem statement, as well as the observation, a hypothesis is formulated. The learner should plan and conduct an investigation to test the hypothesis. During the investigation data are collected. Data are also collected by means of observation, whether it is a measurement or observing a colour change or noting whether a substance dissolves or not. To make an observation is therefore an important skill in Physical Sciences, not only for the development of new knowledge within the subject, but also for learners who have to process the content of the subject. After an observation has been made, the insight gained from the observation has to be processed and internalised. In order to do this, the learners should be able to communicate their findings by means of a scientific language system.

2.2.2.5 Scientific language system

Van Aswegen *et al.* (1993:7) classified a scientific language system as a crucial component of the syntactical structure. When an observation is made, the individual first provides personal meaning to the observation to form a concept and then conform it to the subject norm using scientific language (Van Aswegen *et al.,* 1993:7*)*. In this way a scientific language system is developed that has meaning to the learner.

A learner might view the wave created in the slinky and say to themselves, “The slower waves the waves are bigger than the faster waves”. The learner therefore formulates a concept in their own words to describe what they observed. When the words *frequency* and *wavelength* are introduced, the learner should reformulate the concept in scientific language as, “the less the frequency of a wave, the greater the wavelength will be”, and later, “if the velocity of the wave stays constant, the frequency of the wave is inversely proportional to the wavelength of the wave.”

Van Aswegen *et al.* (1993:7) elaborated that the subject language of Natural Sciences does not only contain terminology, but also other aspects such as visual representations, for example sketches and diagrams, as well as mathematical representations such as graphs. In Physical Sciences terminology, visual as well as mathematical representations form part of the subject language. For the example above, a mathematical representation might be $v = f \times \lambda$.

2.2.2.6 Discovery skills

Van Aswegen *et al.* (1993:7) referred to discovery skills as a collection of skills that enables scientists and learners alike to investigate scientific problems and to ultimately generate new scientific knowledge. Dreckmeyr (1994:13) summarised these competencies under the label “the process of natural Sciences”.

Dreckmeyr (1994:13 – 15) distinguished between two alternative approaches, namely the scientific method, and Maarschalk’s heuristic approach. The scientific method, as Van Aswegen *et al.* (1993:7) also pointed out, is not a set method but rather consists of competencies such as identification and formulation of a problem statement and hypotheses, planning and carrying out an investigation to collect data, as well as interpreting data and drawing conclusions.

Dreckmeyr (1994:13) supplied a very clear layout of the scientific method and differentiated between two approaches that form part of the scientific method, namely the inductive approach and the deductive approach.

Dreckmeyr (1994:14) indicated that the inductive approach of the scientific method is initiated when a problem is identified and stated and a hypothesis generated. Dreckmeyr (1994:14) also pointed out that the problem could arise from an observation, discussion or thought but that the hypotheses will be based on observation. An investigation is then designed and data are collected by means of experimentation. When enough data have been collected, the hypotheses could then be either supported, rejected or modified. Since this approach strives to establish general rules from specific data the process could be described as inductive.

The hypotheses could, however, also be falsified. Maarschalk and McFarlane (1988:64) referred to Popper’s falsification where a hypothesis is postulated vaguely. Instead of trying to prove the hypothesis, a conscious attempt is made to try and falsify the hypotheses by exposing weaknesses and, if possible, to prove it to be false. If the hypothesis is falsified, the process does lend itself to deduction, since it moves from the general rule to specific details. Dreckmeyr (1994:14) noted that if during an investigation a rule is tested the researcher is working inductively. When the researcher is aiming to falsify the hypotheses, specific details should be tested or examined to prove the general rule to be false. The researcher also makes use of deductive approaches when the data are processed and the findings summarised (Dreckmeyr, 1994:14) in order to make inferences or provide explanations or make predictions.

The scientific method, although not set in stone, utilises both inductive and deductive approaches in order to generate hypotheses, testing them and using the data to generate a scientific law or rule which could explain certain observations. However, the scientific method as described above is not the only way in which learners and researchers think and gain new knowledge in Physical Sciences. Maarschalk and McFarlane (1988:65) postulated that all people work on a method of “finding through seeking”. Three distinguishable phases could be identified in this method of thinking in Physical Sciences, namely wondering about the problem, seeking a solution, and finding a solution. During the first two phases the problem is identified and a hypothesis is formulated (Maarschalk & McFarlane, 1988:65), which is then tested by deductive and inductive approaches. Eventually, during the finding phase, insight should be gained as a result of a positive test or solution to the problem (Maarschalk & McFarlane, 1998:65). This way of tackling problems in Physical Sciences does not only help learners and future scientists to tackle theoretical problems but also real problems in the world that they live in. Ultimately, the problem-solving skills mentioned above are essential in order for learners to become contributing citizens.

2.2.3 The way of thinking that leads to a better understanding of nature

Dreckmeyr (1994:23) concluded that Physical Sciences education should lead to a better understanding of the natural aspects of reality and that it helps learners to understand and fulfil their tasks in the world. The CAPS document states that the Nation Curriculum Statement serves the purpose to equip learners for self-fulfilment as well as meaningful participation in society (DBE, 2011:3). Physical Sciences assists in equipping learners with skills to make meaningful contributions to society, since it prepares learners for citizenship by fostering an understanding of and appreciation for how the physical environment works so that they could benefit from it and care for it (DBE, 2011:8).

2.2.4 Acquiring knowledge through syntactical and substantive approaches

As discussed above knowledge could be acquired through either the syntactical or substantive approaches. It was also discussed (see 2.2.2.6) that knowledge could be acquired through either inductive or deductive methods. The example below clearly illustrates how both inductive and deductive reasoning features in the construction and application of Physical Sciences knowledge (facts, concepts and generalisations) through the use of skills (sensorimotor skills, cognitive skills, techniques, observation skills, language skills and scientific approach).

2.2.4.1 Inductive reasoning – syntactical to substantive

When learners are first confronted with the concept of static and kinetic friction in Grade 11, an experiment could be set up to prove that, when a non-constant force is applied to an object, the static friction increases until it reaches a maximum value and that as soon as the object starts moving, the friction decreases. The knowledge is constructed using the inductive approach.

Using skills from the syntactical structure, learners could complete an experiment to construct knowledge about friction. Learners could plan an investigation using the scientific approach where they formulate a hypothesis, plan and conduct an investigation and collect data to prove or disprove their hypothesis. One way to conduct the experiment could be to attach a Newton scale to a wooden block and then pull it over a flat surface. Using Newton scales to collect data requires a certain technique. Learners could take readings on the Newton scale just before the object starts moving, and while it is moving, and then compare the two readings. This requires that learners use sensorimotor, cognitive, as well as observation skills. While completing the experiment, learners should note that the frictional force increases until it reaches a maximum value, and then the object starts moving. Learners could investigate the phenomenon further by changing certain variables, such as using blocks with different surface areas, different masses, as well as different surfaces, and compare these readings. Using scientific language, learners should also communicate their findings about static and kinetic friction. Working inductively, the learners would have collected data in order to make a generalisation or conclusion about static and kinetic friction. They could therefore progress from specific examples to formulate a general rule.

The first generalisation would be that static friction reaches a maximum value just before the object starts moving and that the kinetic friction will be constant but less than the static friction. The second generalisation will be that the only two variables influence the friction between two surfaces namely the Normal Force and the Coefficient of static or kinetic friction.

2.2.4.2 Deductive reasoning – substantive to syntactical

After learners have established the generalisations they could use deductive reasoning to determine the value of the co-efficient of maximum static or kinetic friction by using the formulae for maximum static friction or kinetic friction. They could then use a general rule to determine specific values. They could also apply the formulas as well as the generalisations to solve problems regarding friction. A common problem could be the minimum coefficient of kinetic friction that a surface such as a tiled floor should have in order for it to be safe to walk on without slipping. Learners should then apply their knowledge of kinetic and static friction and conduct an experiment to find the specific co-efficient of kinetic friction that tiles need to make them safe to install in houses and shopping centres. Learners could then apply knowledge from the substantive structure to conduct an experiment where they use skills from the syntactical structure to find a specific value.

From the two examples above it is clear that both structures – the syntactical and the substantive – are important in the development of knowledge in Physical Sciences, just as deductive and inductive reasoning are both equally important in the process of the construction of Physical Sciences knowledge. The syntactical and substantive structure are intertwined – knowledge cannot be separated from skills in Physical Sciences. In the same way inductive and deductive reasoning are both important in the construction of Physical Sciences knowledge and the application of Physical Sciences knowledge.

2.3 KNOWLEDGE AND COGNITIVE SKILLS IN PHYSICAL SCIENCES

The substantive and syntactical structure of Physical Sciences comprises a body of knowledge and cognitive, as well as practical skills. Although they are separate structures, the interconnectedness between the two structures were clearly identified in 2.2. The substantive and syntactical structure serves as a starting point for investigating the knowledge and skills that are necessary to master Physical Sciences. In order to define what learners should know and be able to demonstrate in the subject, objectives should be identified. In this regard, Krathwohl (2002:212) stated that a taxonomy classifies what learners are intended to learn as a result of instruction. In Physical Sciences a taxonomy of knowledge and cognitive skills could also be used to guide teachers in planning and facilitating instruction, learning and assessment, and to assist learners in learning and assessment. The CAPS document (DBE, 2011:152) includes a Physical Sciences assessment taxonomy (derived from Bloom's taxonomy of the cognitive domain) as a "possible hierarchy of cognitive levels" to give learners the opportunity to perform at various levels and for teachers to assess at different levels. The taxonomy only refers to cognitive processes and not knowledge types or practical skills, or the interplay between knowledge, cognitive processes, and practical skills.

Anderson and Krathwohl (2001:28) revised Bloom's taxonomy of the cognitive domain to include both knowledge types and the cognitive processes that are necessary to yield a two-dimensional taxonomy. Anderson and Krathwohl's taxonomy could therefore be consulted in order to construct a framework of the knowledge and cognitive skills that should be mastered in Physical Sciences, in more detail than has been done in 2.2.1 and 2.2.2. For the purpose of this chapter, Anderson and Krathwohl (2001) was consulted as the primary source. More recent sources were also referred to such a Bass, Contant and Carin (2009), Ahmad (2011) and McMillan (2011), but these sources also refer to Anderson and Krathwohl (2001) as their primary source. The researcher therefore mainly refers to the work of Anderson and Krathwohl (2001) to further investigate the knowledge and skills that need to be mastered in Physical Sciences.

2.3.1 Anderson and Krathwohl's revised taxonomy

As already mentioned above, the revised taxonomy by Anderson and Krathwohl has two dimensions – knowledge types and cognitive processes. The table below summarises the two domains clearly.

Table 2.1: Summary of knowledge types and cognitive processes

Knowledge Type	**Explanation**
Factual Knowledge	Basic elements
Conceptual Knowledge	Interrelationships between basic elements
Procedural Knowledge	Methods of inquiry, criteria for using skills, algorithms, techniques, and methods
Metacognitive Knowledge	Knowledge of cognition on general and awareness and knowledge of one's own cognition
Cognitive Category	**Explanation**
Remember	Retrieve relevant knowledge from long-term memory.
Understand	Construct meaning from information.
Apply	Carry out procedure in given context.
Analyse	Break up content into existing parts and determine relationship between parts and overall structure.
Evaluate	Make judgement based on criteria and standards.
Create	Reorganise or put elements together to form a new, coherent and functional whole.

(Anderson & Krathwohl, 2001: 29&31)

The knowledge types are mentioned in the substantive structure (see 2.2.1) but the knowledge types described by Anderson and Krathwohl are more detailed and extensive than what has been presented up to now. The cognitive processes are also referred to in the Assessment Taxonomy in the CAPS document (DBE, 2011: 152). The syntactical structure of Physical Sciences makes reference to these cognitive skills (see 2.2.2).

The Revised Taxonomy, as proposed by Anderson and Krathwohl, is discussed below in the context of Physical Sciences to investigate the knowledge and cognitive skills that learners need to master Physical Sciences.

2.3.2 The Knowledge Dimension

2.3.2.1 Factual knowledge

Anderson and Krathwohl (2001:27&29) defined factual knowledge as knowledge of terminology and specific details, as well as "....knowledge of discrete, isolated content elements..." McMillan (2011: 43) agreed that factual knowledge encompasses basic elements about a discipline. Bass, Contant and Carin (2009:13) defined a fact in Sciences as a statement about an observation that has been repeatedly confirmed. Even though facts are regarded as lower-level declarative knowledge (McMillan, 2011:45) learners use facts to communicate, organise and understand a specific discipline (Anderson & Krathwohl, 2001:45). It is therefore important that learners have the correct scientific vocabulary and have knowledge of these most basic elements that make up the subject.

2.3.2.1.1 Knowledge of terminology

Terminology refers to verbal and nonverbal labels and symbols (McMillan, 2011:43). Without these labels and symbols, learners and experts will not be able to think, comprehend or communicate in the subject (Anderson & Krathwohl, 2001:45). Physical Sciences learners should also adopt Physical Sciences terminology so that they can think and reason within the subject and communicate Physical Sciences knowledge to others.

In Physical Sciences, learners are expected to have knowledge of the following terms when dealing with forces, as an example; normal force, gravitational force, kinetic frictional force, static frictional force, tension, and applied force. Without knowledge of these forces, learners will not be able to understand and interpret mechanics problems. The terminology forms the basis of the understanding of the subject, Physical Sciences.

2.3.2.1.2 Knowledge of details and facts

Apart from mastering the terminology of the subject, Physical Sciences learners should also be aware of and master the specific details and facts of the subject. Anderson and Krathwohl (2001:47) defined details and facts as discrete, isolated elements of knowledge such as dates, times, people, places and the like that describe the field of a subject.

In Physical Sciences there are mention of dates, times, people and places, but there is a greater emphasis on facts and details about the natural world. The table below shows an example of specific details and facts which could be found in Physical Sciences.

Table 2.2: Summary of forces

Terminology	**Type of force**	**Direction of the force**	**Magnitude of force**	**Formula**
Normal force	Contact force	Perpendicular to surface	Equal to the perpendicular force an object exerts on a surface	$N = mgcos\theta$
Friction force	Contact force	Opposite to direction of motion or intended motion	Equal to the product of the normal force and the coefficient of friction	$f_k = \mu_k . N$ $f_{s\,max} = \mu_{s\,max} . N$
Gravitational force	Non-contact force	Towards the centre of the earth / solar body	Equal to the product of the mass of an object and the gravitational acceleration	$F = mg$

2.3.2.2 Conceptual knowledge

Anderson and Krathwohl (2001:48) distinguished conceptual knowledge from factual knowledge by labelling it as a more complex and organised knowledge form. McMillan (2011:45) also argued that knowledge of concepts is at a higher level than knowledge of facts and highlights that a critical distinction should be made between the learning and assessment of memorisation and association of facts as opposed to the generalised understanding and usage of facts. Anderson and Krathwohl (2001:42) supported the notion of deep learning and suggested that learners should have a deep understanding of what they are learning and should be able to apply knowledge to solve problems within the subject and to understand everyday situations. Unlike surface learning, deep learning does not imply mere memorisation of fact and procedures, but rather an understanding of what is being learnt

(Gynnild, Holstad & Myrhaug, 2008:148 – 149). Conceptual knowledge therefore plays a very important role in achieving the understanding of Physical Sciences, rather than merely repeating details and facts.

Bass *et al.* (2009:13) defined Sciences concepts as abstract ideas derived from experiences that reflect the larger idea of Sciences. Anderson and Krathwohl (2001:48) elaborated that conceptual knowledge include schemas, models and theories that represent the knowledge an individual has about how particular subject matter is organised and divided this knowledge type into three subtypes, namely knowledge of classification and categories, knowledge of principles and generalisations, as well as knowledge of theories, models and structures.

2.3.2.2.1 Knowledge of classifications and categories

Anderson and Krathwohl (2001:49) stated that knowledge of classifications and categories supply connecting links between specific details and elements. Bass *et al.* (2011:13) confirmed that concepts enable learners to interconnect past experiences so that they could better understand new experiences. Anderson and Krathwohl (2001:49) emphasised that for learning end development to take place, learners should classify newly discovered knowledge into appropriate categories to keep their body of knowledge organised. In order for learners to properly conceptualise knowledge in Physical Sciences, proper classifications and categorisations should be made. Teachers should also be aware of the possibility of misclassification and be alert when dealing with knowledge of classifications and categories in order to address the matter.

When dealing with the topic of forces learners should be able to distinguish between vectors and scalars and contact and noncontact forces to name a few examples. Learners should also be able to label quantities such as mass, weight, velocity, acceleration, time, distance, and displacement as either vectors or scalars. Furthermore, learners have to identify whether friction, gravity, tension, and push and pull forces are non-contact or contact forces. To complicate matters, friction could also be classified as a dissipative force which causes a system to lose energy when motion takes place. Friction itself could also be categorised as either static friction or kinetic friction, depending on whether the object that experiences friction is stationary or in motion.

Learners could construct concepts when they categorise and classify facts and details and these concepts could then be used to construct principles and generalisations (Anderson and Krathwohl, 2001:51).

2.3.2.2.2 Knowledge of principles and generalisations

Principles and generalisations are a crucial part of Physical Sciences, as it helps learners and experts to study phenomena in the subject and to solve problems in the discipline (Anderson & Krathwohl, 2001:51). Anderson and Krathwohl (2001:51) further elaborated that principles and generalisations bring together large numbers of facts, classifications and categories. Bass *et al.* (2009:15) supported this statement by defining principles as ideas about relationships among concepts. The authors also reasoned that principles are formed from investigations and generalised through inductive reasoning. Inductive reasoning (see 2.2.4.1) plays an important role in the learning of Physical Sciences, since the syntactical structure of Physical Sciences is based on inductive thought that flows from observation. Generalisation is therefore an important skill in Physical Sciences.

Generalisation in terms of Newton's Second Law could be seen when learners are studying the relationship between the mass of an object, the net force acting upon it as well as the resulting acceleration. They should discover that a heavier object has a smaller acceleration when the same net force is applied to it than a lighter object. They should also discover that the greater the net force, the more the object will accelerate if the mass is kept constant. From this experiment learners could deduce the generalisation that the resultant force is directly proportional to acceleration and indirectly proportional to the mass of the object.

Learners should be able to identify patterns through observation and make meaningful conclusions or generalisations from these observations so that meaningful learning could take place. Anderson and Krathwohl (2001:51) stated that when students know principles and generalisations they have a way of organising and relating content which contributes to a better insight in the subject. In Physical Sciences, once learners have formed knowledge of certain principles and generalisations they could organise new knowledge and explain new observations since they could relate new information to their current knowledge structure. The different knowledge types are interconnected – facts are categorised and classified to form concepts and concepts are applied to formulate generalisations and principles which learners could use to relate new information to what they already know. In Physical Sciences, once learners have formed knowledge of principles and generalisations they could use that knowledge to formulate theories to explain what they observe in the natural world around them.

2.3.2.2.3 Knowledge of theories, models and structures

This subtype of knowledge provides a clear and systematic view of a complex phenomenon, since it includes the knowledge of the interconnectedness of principles and generalisations

(Anderson and Krathwohl, 2001:51 – 52). Learners could either learn existing theories or they formulate their own theories. In order to understand or formulate theories, learners should bind principles and generalisations together in a meaningful way – they should understand the interrelationship between principles and generalisations.

Bass *et al.* (2009:14) mentioned two definitions for theories. The first refers to theories as an explanation of an aspect of the physical world that has undergone testing, such as the kinetic molecular theory. Secondly, the authors made mention of theories (or hypotheses) which learners formulate as part of their learning processes, as they make observations, in order to make sense of their experiences. Once more, this illustrates the interrelationship between the substantive and the syntactical nature of Physical Sciences where learners are encouraged to investigate physical phenomena, make observations, and formulate a temporary theory which they then have to test inductively and apply deductively.

In Physical Sciences learners should use their knowledge of principles and generalisations to formulate theorems. Learners should be granted the opportunity to formulate their own temporary theories about physical phenomena by organising facts, concepts and generalisations. They should then also be encouraged to test their theory or hypothesis. Most experiments are structured in such a way that it proves an existing theory to be true. The theory is, however, new to the learners so they are constructing the knowledge for themselves for the first time. Learners are guided to generate a possible theory to explain the relationship between variables such as type of surface, surface area, mass, normal force, and kinetic friction. Learners should reason inductively to construct the theory and they use the syntactical structure to construct knowledge in the substantive structure.

Once theories have been established, leaners should be encouraged to apply them in order to solve problems. This includes the deductive nature of Physical Sciences, since learners could also acquire knowledge by applying facts, concepts, generalisations, and theories from the substantive structure to perform certain activities from the syntactical structure. Learners could therefore learn about the theory and then be asked to apply it to a problem. As an example, Newton’s Laws, as well as energy principles, should be applied in the process of formulating and fully understanding the work energy theorem. The work energy theorem states that the work done on an object by the net force is equal to the change in kinetic energy of the object. In order to use this theory, learners should apply principles of mechanics to draw accurate force diagrams of the forces acting in on the object and formulate possible ways to calculate the resultant force acting in on the object, as well as the resultant work done on the object. Learners could then use the work energy theorem to calculate variables such as mass or velocity, displacement, angle of inclination of a plane, friction, height of the slope, change in kinetic energy, acceleration, and applied force. Not only could the work-energy theorem be used to do calculations based on set up questions, but it could also be used to determine unknown variables during experiments to collect meaningful data in order to determine coefficients of friction for example.

Bass *et al.* (2009:14) also highlighted the importance of models as aids that teachers could use to make it easier for learners to understand abstract concepts. The atomic model could help learners to visualise the atom and therefore have a better understanding of the concept of the core, orbitals, and energy diagrams.

The knowledge of theories, models and structures should be used by learners to understand Physical Sciences and also to solve complicated problems. Theories, models and structures provide a possible way to reason about observations made in the natural world.

2.3.2.3 Procedural knowledge

It is not enough for learners to have factual and conceptual knowledge, they should also possess procedural knowledge so that they know how to apply that knowledge (Anderson & Krathwohl, 2001:52). In Physical Sciences learners need to apply factual and conceptual knowledge to make inferences, explain observations, and solve problems. Mc Millan (2011:46) defined procedural knowledge as the “knowledge of how to do something” by applying the necessary strategies, procedures and skills. Anderson and Krathwohl (2001:52) differentiated between knowledge of skills and algorithms, techniques and methods (how to use knowledge), and knowledge of criteria (when and where to use knowledge.)

2.3.2.3.1 Knowledge of subject-specific skills and algorithms

Anderson and Krathwohl (2001:53) argued that procedural knowledge could be expressed as a series or sequence of steps. The authors elaborated that while some steps should be taken in a fixed order to get to the result, other problems might require careful thought about what step is to be taken next. However, the end result for this type of knowledge is usually fixed (Anderson & Krathwohl, 2001:53).

In Physical Sciences learners are faced with problems which may have multiple ways of arriving at the same solution. The following problem could, for example, be posed to learners:

Consider the following crate with mass 10 kg, which is being pulled from rest across a rough surface with a cable parallel to the surface. The tension, T, in the cable is equal to 100 N. The coefficient of kinetic friction for the surface is $\mu_k = 0{,}2$. If the crate undergoes a displacement of 5 m, calculate the velocity of the crate after 5 m.

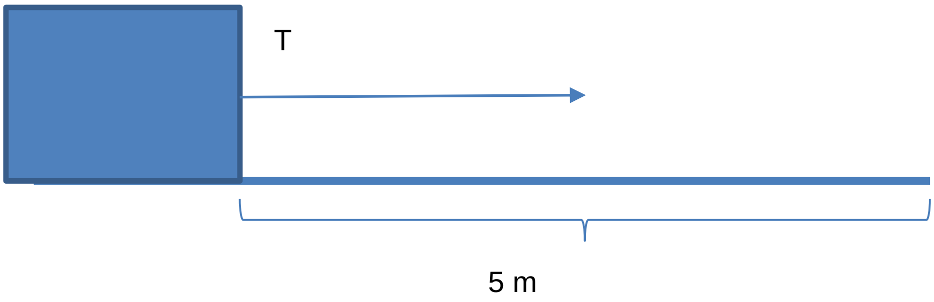

Figure 2.1: A crate moving along a rough surface

A possible way to solve this problem would be to use the following equation of motion to find the final velocity:

$$v_f^2 = v_i^2 + 2a\Delta x$$

Where:

- v_f = the final velocity of the crate after 5 m;
- v_i = the initial velocity, which is 0 m.s^{-1}, since the crate is moving from rest ;
- Δx = 5 m; and
- a = the acceleration of the crate.

The equation has two unknown variables, namely final velocity and acceleration. In order to find the final velocity the learner should first find the acceleration of the crate by applying Newton's Second Law, $F_{net} = ma$.

To calculate the acceleration, the learner needs to calculate the net force. The learner should know that the net force acting in on an object is equal to the sum of the forces acting in on the object. The learner should also know that forces are vectors, so the direction of the forces should also be taken into account.

The two forces acting in on the crate are the friction force and the tension in the cable. The tension is given as 100 N but the friction has to be calculated using the formula, $f_k = \mu_k.N$.

Once the learner has calculated the frictional force, the net force can be calculated, then the acceleration can be calculated and lastly the final velocity can be calculated.

The example above illustrates how the learner would have to apply knowledge of algorithms and skills to use a series of steps in the correct sequence to calculate the final answer. If the learner used a different approach, maybe applying knowledge of the non-conservation of mechanical energy or the work-energy theorem, the answer for the final velocity should still be the same. The question is therefore not open-ended, since it has a fixed end result, but multiple processes could be followed to arrive at the same answer. Some problems might not have fixed end results and then learners need to apply subject-specific techniques and methods to find the solutions. A different type of knowledge should then be applied, namely knowledge of techniques and methods.

2.3.2.3.2 Knowledge of subject-specific techniques and methods

A distinction could be made between skills and algorithms used in Physical Sciences, and techniques and methods used in Physical Sciences. Although the two knowledge domains are different, the knowledge of skills and algorithms have been obtained by experts through thought and problem solving, while techniques and methods reflect how experts think and solve problems in the subject field (Anderson & Krathwohl, 2001:54)

A learner could be asked to design an investigation to determine the coefficient of kinetic friction of a surface of their choice. Due to the nature of the problem, the solution is open-ended. Neither the type of surface nor the algorithms or skills that should be used to find the coefficient is prescribed or familiar. Learners should apply their knowledge of methods and techniques that are commonly used in Physical Sciences to solve the problem. Learners should have knowledge of the Scientific method of investigation. If they follow this pattern of thought, they should first describe the aim of their investigation, then identify the variables that they need to investigate and use a method that they could employ to collect data. Once the data have been collected and recorded, they should analyse it to calculate the coefficient of kinetic friction. It is also important that they then reflect on their investigation to evaluate the effectiveness of their method, as well as the accuracy of their data and calculations.

Since the focus is on knowledge of methods and techniques, each learner might present different solutions and answers to the problem. Learners might all apply the same factual and conceptual knowledge, but the procedural knowledge that they apply might differ in terms of the methods and techniques that they use to collect data and calculate the coefficient of kinetic friction.

From the example above it should be clear that knowledge of methods and techniques are important procedural knowledge forms which has to be addressed in Physical Sciences classrooms, since these will enable learners to solve new problems in unfamiliar contexts in creative and innovating ways.

Procedural knowledge should enable learners to select the appropriate procedures when solving a problem in the Physical Sciences. If it is a familiar problem in a familiar context then the learner could apply knowledge of skills and algorithms to find the solution. If it is a new problem in an unfamiliar context then the learners should be able to apply methods and techniques similar to those that experts would use to solve the problem.

2.3.2.3.3 Knowledge of criteria and appropriate procedures

It is not enough for learners to know about subject-specific procedures – be it knowledge skills and algorithms to solve known problems or knowledge of methods and techniques to solve new problems. They should also know when and how to apply which procedures (Anderson & Krathwohl, 2001:54). To help learners make the decision, they should be aware of the criteria which will be the conditions under which procedures are to be applied (Anderson & Krathwohl, 2001:55).

In the Physical Sciences classroom, the Law of conservation of mechanical energy only applies when no external forces act in on the object in question. The only force acting in on the object could be gravity. Learners have to analyse the problem before solving it. In order to use the law of conservation of mechanical energy principle to solve the problem, certain criteria need to be adhered to – there has to be no force other than gravity acting in on the object. If other forces are involved, learners should take them into account as non-conservative forces and do the calculation so that mechanical energy is not conserved.

When learners activate knowledge of criteria to determine the effectiveness of a procedure, they are actually reflecting on both their learning process and their thought processes. For learners to effectively activate and apply their procedural knowledge they should be reflective learners who are aware of their though processes. This phenomenon – thinking about one's own thinking – was defined as metacognition. From the above discussion on the different knowledge types it should be clear that metacognition is necessary to guide learners in their acquisition and application of the different knowledge forms.

2.3.2.4 Metacognitive knowledge

Anderson and Krathwohl viewed metacognitive knowledge as being about both cognition in general and knowledge about one's own cognition (2001:55). From their explanation of metacognitive knowledge it is clear metacognitive knowledge does not relate to a specific subject, as factual, conceptual or procedural knowledge does, but rather refers to generic knowledge and strategies that could be used to assist learners in learning any subject. Metacognitive knowledge does not replace learners' factual, conceptual and procedural knowledge, but it could assist learners in better acquiring and applying their knowledge. Anderson and Krathwohl (2001:56 – 59) highlighted that metacognitive knowledge includes knowledge of strategies to plan, organise, monitor, and regulate cognition; knowledge of when and why to use certain subject-specific skills, algorithms and techniques; as well as knowledge of one's own strengths and weaknesses related to learning.

From Anderson and Krathwohl’s description, it is clear that metacognition is not merely a form of knowledge, but also involves using certain strategies. In chapter 3 metacognition is discussed in more detail, referring to the knowledge and strategies mentioned here.

Up to now, only the different knowledge types in Physical Sciences were discussed. How the knowledge should be applied and the thought processes that accompany the application of knowledge lead to the cognitive process dimension (see Table 2.1). The different cognitive skills that learners should master and demonstrate in Physical Sciences are discussed next.

2.3.3 Cognitive Process Dimension

The CAPS document advocates that teachers use a hierarchy of cognitive levels so that learners could achieve at different levels and be assessed at different levels (DBE, 2011:152). This suggests that in order to assist learners in meaningful learning of Physical Sciences, teachers should utilise different types of assessment tasks. The cognitive levels advocated in the CAPS document are based on Bloom’s Taxonomy for the cognitive domain. Krathwohl (2002:213) stated that Bloom’s original taxonomy for the cognitive domain consisted of six carefully formulated major categories, namely knowledge, comprehension, application, analysis, synthesis, and evaluation. The Revised Taxonomy also consists of six categories that have been renamed in order to make their objectives clearer and less complicated (Krathwohl, 2002:215), namely remember, understand, apply, analyse, evaluate, and create. Each cognitive category is subdivided into cognitive processes that characterise that particular category.

Anderson and Krathwohl’s cognitive categories could also be further divided into higher and lower order cognitive categories. McMillan (2011: 46) distinguished between “simple cognitive acts”, where learners merely remember, understand and apply, and “higher-level cognition”, where learners are expected to analyse, evaluate and create. McMillan (2011:48) described “evaluation” as critical thinking or problem solving skills and “creating” as inquiry, where information and critical thinking are synthesised to produce new knowledge. When considering these definitions, it is clear that higher-level cognition refers to cognitive categories where learners are required to mentally manipulate information, while simple cognitive acts refer to simply making sense out of the information (McMillan, 2011:46). The focus in the Physical Sciences classroom should therefore be on first mastering the simple cognitive categories, and then using the knowledge gained to stimulate higher order thinking such as analysing a problem, evaluating possible solutions, and constructing a possible solution. Table 2.3 below distinguishes between lower order thinking and higher order thinking.

Table 2.3: Lower order and higher order thinking skills

	Lower order thinking skills			**Higher order thinking skills**		
Cognitive category	Remember	Understand	Apply	Analyse	Evaluate	Create

McMillan (2011:45 – 46) stated that leaners could gain knowledge in the classroom but ultimately it is what they do with that knowledge in the classroom that stimulates and develops higher order thinking or not. In order to clearly explain what learners should do with the knowledge that they gain in the Physical Sciences classroom, it is important to examine and interpret each cognitive category in terms of Physical Sciences content.

2.3.3.1 Remember

Being able to remember refers to lowest category of the cognitive domain (Ahmad, 2011:36). Anderson and Krathwohl (2001:67) defined the cognitive process of remembering as being able to retrieve relevant knowledge from long term memory. Two cognitive processes could be identified in this category, namely recognising and recalling (Ahmad, 2011:36; Anderson & Krathwohl, 2001: 67).

As already discussed under the nature and structure of Physical Sciences (see 2.2), when learners are asked to learn factual knowledge such as terminology, details and facts, they should memorise these details. For the purpose of this section, the topic of chemical bonding is used to explain the cognitive process domain. When studying chemical bonding, learners are prompted to remember definitions of “ionic compounds”, “molecules”, “covalent bonds”, “metallic bonds”, “valence electrons”, “electronegativity”, “Van der Waals forces” and “Coulomb forces”.

If learners are asked to define the term “valence electrons” or “ionic compound” they should remember a specific fact or detail. This type of question is regarded as a level one question according to the CAPS document. In order to answer this type of question learners should be able to access factual knowledge in their long term memory, such as knowledge of terminology and details. According to McMillan (2011:45) this type of question is represented by rote memory and requires the memorisation and recall of declarative knowledge. The knowledge required to answer this question is factual (see 2.3.2.1). Although basic, if learners cannot recall what valence electrons are, they will not be able to answer more complicated questions later on.

The simplest cognitive process is remembering factual knowledge. To understand is the next cognitive process that learners have to master.

2.3.3.2 Understand

After learners have memorised knowledge, they should develop understanding or comprehension of the knowledge (Ahmad, 2011:36). According to Ahmad (2011:36) learners demonstrate understanding through actions such as interpreting, translating, and extrapolating. In the Physical Sciences classroom, learners should also be given the opportunity to demonstrate their ability to understand the subject matter during learning experiences and exercises, but also during assessment tasks. According to the CAPS document (DBE, 2011:153), questions that require learners to understand the subject matter, are ranked as level 2 questions. In order for learners to demonstrate that they understand the subject matter, they should be able to interpret and translate what has been learnt (DBE, 2011:153). Anderson and Krathwohl (2001:67) also emphasised the importance of meaning making during the understanding process and that learners should be able to communicate what they have learnt. McMillan (2011:45) argued that learners should be able to understand declarative knowledge such as concepts, ideas and generalizations, and also points out that there should be differentiation between memorising and repeating facts, and understanding concepts and generalisations during teaching and assessment.

In Physical Sciences learners should prove that they understand the concepts and generalisations of the subject by demonstrating the following actions referred to by Anderson and Krathwohl (2001:67), and by the CAPS document (DBE, 2011:153); they should interpret, exemplify, classify, summarise, infer, compare and explain. It is essential that learners are prompted to demonstrate these activities in class as well as during assessment tasks.

2.3.3.2.1 Interpret

Anderson and Krathwohl (2001:70) defined interpreting as the skill to convert information from one form to another, for example, numbers to words. In Physical Sciences, a learner might be presented with the following Bohr model of Magnesium:

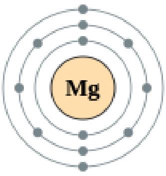

Figure 2.2: The Bohr model of Magnesium

(Source: https://commons.wikimedia.org/wiki/Electron_shell_-_no_label)

If a learner is asked to identify the number of valance electrons present in the atom, the learner should interpret the diagram and convert information into words or numbers. The valance electrons will be the two electrons in the outer shell, encircled in red inFigure 2.3.

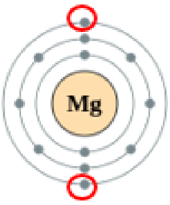

Figure 2.3: The Bohr model of Magnesium indicating two valence electrons

2.3.3.2.2 Exemplifying

Exemplifying occurs when learners provide a specific example of a concept or principle (Anderson & Krathwohl, 2001:71). In Physical Sciences a learner might be asked to demonstrate their understanding of the term “ionic compound” by providing an example of an ionic compound. In order to provide the correct example, the learner has to recall the meaning of the term “ionic compound” but also understand its meaning and know about the characteristics of an ionic compound in order to give an example of an ionic compound.

2.3.3.2.3 Classifying

Learners should not only be able to give examples of a concept, they should also be able to classify certain details as part of a certain concept. Anderson and Krathwohl (2001:72) described this cognitive skill as being able to place something in a specific category. In the Physical Sciences classroom learners should know whether a bond is covalent, ionic or metallic. They should demonstrate their knowledge of this concept by recognising the underlying details and by understanding the definitions.

The following exercise could be done in class to prompt learners to classify. Learners are supplied with a substance, magnesium oxide, and have to classify it as a covalent, ionic or metallic bond by referring to details of the compound, and the definitions of covalent, ionic and metallic bonds.

STEP 1: the learner has to identify the details of the compound:

1. The compound consists of magnesium and oxygen
2. The electronegativity difference between magnesium and oxygen ≈ 2.3

STEP 2: The learner has to compare the details with the definitions provided for covalent, ionic and metallic substances.

Table 2.4: Types of bonds

TYPE OF BOND		COVALENT	IONIC	METALLIC
DEFINITION	1. Particles	Atoms	Ions	Delocalised electrons and cations rests
	2. Electronegativity difference	$< 2,1$	$\geq 2,1$	

When comparing electronegativity difference from the calculation in step 1 with the electronegativity difference in STEP 2 it is clear that the substance must contain covalent bonds.

2.3.3.2.4 Summarising

In order to prove that learners understand a concept, they could also be asked to summarise major points. Learners should be able to condense information so that only the general theme is represented (Anderson & Krathwohl, 2001:73). A learner could be asked to summarise the characteristics of an ionic compound. By prompting the learner to summarise the characteristics of ionic bonding, the learner should be able to recall factual as well as conceptual knowledge of ionic compounds. If the learner does not understand the concept, it will be very difficult for the learner to summarise the characteristics of ionic compounds so that only the main facts and concepts are presented.

2.3.3.2.5 Inferring

When learners understand a concept, they could also demonstrate it by making conclusions or making predictions. As Anderson and Krathwohl (2001:73) indicated, inferring occurs when a learner identifies a pattern. By prompting learners to infer, they are given the opportunity to demonstrate their understanding. A learner could be asked to study the following table presenting information on the boiling points of ionic compounds and molecules and draw a conclusion about the boiling points of ionic compounds and molecules:

Table 2.5: Boiling Points of compounds

Type of bond	Formula of compound	Boiling point (°C)
IONIC BOND	MgO	3600
	$NaC\ell$	1465
	$A\ell C\ell_3$	423
	Fe_2O_3	1565
COVALENT BOND	H_2O	100
	NH_3	-33
	HI	-35
	CO	-191

The above values were obtained from (http://www.gcseSciences.com/imeltcomplz.htm).

From the table, the learners could infer that in general ionic compounds should have a higher boiling point than molecules. In order to infer, learners should interpret the information and identify the pattern. Using the same question, learners could now be asked to draw comparisons and to explain what they observe.

2.3.3.2.6 Comparing

Learners could demonstrate understanding of a concept further by comparing different objects or processes and looking for similarities and differences (Anderson & Krathwohl, 2001:75). In order to compare different objects or processes, learners should understand their workings and characteristics. When considering the question about boiling points above, learners could then be asked to compare ionic compounds to molecules. Learners might compare the ionic compounds and discuss how they are different by referring to particles, intermolecular force, phase at room temperature, and difference in boiling points. When learners are asked to compare these two type of compounds, they should focus on the similarities and differences between ionic compounds and molecules. In order to compare, learners should access factual and conceptual knowledge about chemical bonding, intermolecular forces and phases of matter.

2.3.3.2.7 Explaining

Still referring to

Table 2.5, learners could now be asked to explain why ionic compounds have higher boiling points than substances made up of molecules. Prompting learners to explain a certain observation or occurrence could assist learners in understanding the subject as they have to reword learnt concepts in their own words and internalise the information. Anderson and Krathwohl (2001:75) stated that in the Natural Sciences learners' explanations should be derived from formal theory and that their explanations should take the form of a "cause-and-effect" model.

In order to explain why ionic compounds have higher boiling points than molecules, learners should refer to the different intermolecular forces present in ionic compounds and molecular compounds, and also their relative strengths. Learners should then refer to the fact that in order for a substance to boil (go from the liquid to the gaseous phase) the particles need to gain enough kinetic energy to overcome the intermolecular forces keeping them together. Learners might then draw from the inferences and comparisons that they have already made and apply a "cause-and-effect" model.

The *cause* for the difference in boiling points will be the different intermolecular forces. Ionic compounds have stronger intermolecular forces (Coulomb forces) than molecular compounds, which have weaker intermolecular forces (van der Waals forces).

The *effect* will be that more energy will be needed to overcome the Coulomb forces than the van der Waals forces, and therefore the ionic compounds will have higher boiling points.

The example above illustrates the importance to prompt learners to demonstrate their understanding by interpreting, exemplifying, classifying, summarising, inferring, comparing and explaining. Once learners have constructed a solid understanding of important conceptual knowledge, they could apply the knowledge to solve more complex problems.

2.3.3.3 Apply

After learners have acquired knowledge and understood it, they could begin to apply the knowledge to solve problems (Ahmad, 2011:36). When learners apply knowledge they should use the knowledge and skills they possess about an object or process in order to perform an action. Anderson and Krathwohl (2001:67) defined this cognitive process as carrying out a procedure in a given context or situation. According to the CAPS (DBE, 2011:153) the situation could be either familiar or new. Anderson and Krathwohl (2001:78 – 79) identified two categories of application, namely executing and implementing. The main difference between executing and implementing is the context. When a learner has to apply knowledge to solve a familiar problem, the learner is executing a task, but when the learner is applying knowledge to solve an unfamiliar task, the learner is implementing.

2.3.3.3.1 Executing

When a learner is executing a task, the task is actually a familiar exercise, so the learner should what procedural knowledge to apply (Anderson & Krathwohl, 2001:77). Anderson and Krathwohl (2001:77) also confirmed that knowledge of skills and algorithms (see 2.3.2.3.1) should be applied when a learner is executing a task, since the problem and context are familiar. The learner should be familiar with the procedures and processes that should be followed to arrive at the answer.

In Physical Sciences, learners could be asked to execute a task when they have to give the Lewis structure of a common compound such as sodium chloride or water. It is possible that they have seen these diagrams before or that the exact same problems have been presented to them before, perhaps during a lesson or homework exercises. The learner cannot rely on memory to answer the question and should still have to apply factual, conceptual and procedural knowledge to solve the problem.

The question would be considerably more difficult if the learner was asked to give the Lewis structure of sulphur trioxide, or dinitrogen tetroxide, or any other example that is unfamiliar. When the learner applies knowledge to solve an unfamiliar problem, implementation takes place.

2.3.3.3.2 Implementing

When the learner is implementing, the task is an unfamiliar problem and the learner should select both the procedural, and conceptual knowledge to be able to apply (Anderson & Krathwohl, 2001:78). Anderson and Krathwohl (2001:78) also noted that implementing should utilise subject-specific knowledge of methods and techniques.

Using the example given above, if a learner is asked to give the Lewis structure of sulphur trioxide or dinitrogen tetroxide, they should combine and apply knowledge of the Lewis theory to draw the correct structures. The Lewis theory is not an algorithm that produces the correct answer each time, but rather a method that could be applied

When learners are faced with problems to solve, it is possible that they might have studied similar examples, but that the context of the problem is such that each task will be unfamiliar. Learners cannot merely carry out the procedure, but should rather use their knowledge and skills in order to come up with a creative procedure to solve the problem.

2.3.3.4 Analyse

According to the CAPS document (DBE, 2011:152) applying and analysing form part of the third cognitive level. Learners analyse when they appreciate the significance of the parts in relation to the whole (DBE, 2011:152). When learners analyse they apply a different form of cognitive ability than when they remember, understand or apply. Mc Millan (2011: 46) referred to learners' ability to analyse as proof of deep understanding and reasoning. Ahmad (2011:36) defined a learner's ability to analyse as breaking up the whole into its constituting parts to understand the relationship between them. Analysing could therefore be differentiated from the previous three cognitive levels, since it requires higher order cognition. When learners analyse they identify different parts of the whole but also recognise the relationship between the different parts. They should therefore be able to analyse a problem, phenomenon or process both holistically and systematically. Analysis could be sub-divided into three different cognitive processes, namely differentiation, organisation and attribution.

2.3.3.4.1 Differentiating

In the Physical Sciences classroom learners should be able to differentiate between important and unimportant or irrelevant information (Anderson & Krathwohl, 2001:80). This skill is referred to as differentiating and is an important cognitive process. When learners are presented with a Physical Sciences problem it is possible that not all the information given is relevant or necessary to solve the problem. Learners should learn to work selectively with information and focus on what is relevant.

Learners could be asked to demonstrate their understanding of ionic compounds by summarising the characteristics of ionic compounds. In a similar question learners could be asked to read a passage on the formation of ionic compounds and describe the process by referring to the most important steps in the process. Anderson and Krathwohl (2001:80) confirmed that when learners are asked to select the main steps in a written description of a process, it could be regarded as analysing and not merely understanding. When learners are summarising, they merely prove that they understand a concept by repeating facts or details in their own words. When a learner has to condense a written description into main ideas or concepts, the learner should analyse the written description, differentiate between relevant and irrelevant information, and only select the important information.

When comparing, the learners should compare ionic compounds to molecules. If the learners were asked to differentiate ionic compounds and molecular compounds in the context of intermolecular forces, they should focus on what is relevant in the context. Comparing the two types of compounds in the context of particles, boiling points and phase at room temperature is no longer relevant and the focus is solely on intermolecular forces. Learners should study the table to notice that, in general, the ionic compounds have higher boiling points than the molecular compounds, which have to indicate stronger intermolecular forces between the ions than between molecules. This could lead to learners differentiating between Coulomb forces and Van der Waals forces in terms of strength.

2.3.3.4.2 Organising

Anderson and Krathwohl (2001:81) described organising as a learner's ability to build "systematic and coherent connections between pieces of information". This allows for learners to structure information in such a way that it is easier to process and to retain the information as knowledge. In the Physical Sciences classroom learners should organise information in order to make it easier to access.

After learners have learnt that there are different factors influencing the strength of intermolecular forces, they could apply this knowledge to organise a given list of substances according to physical properties, such as boiling points. When given the following list of compounds, learners could be asked to rank the compounds in order of decreasing boiling points. Some of the boiling points are not included in the table, so learners should analyse the compounds to determine how they should be arranged.

Table 2.6: Boiling points of organic compounds

Compound	**Boiling point (°C)**
Ethanol	78
Pentanol	?
Pentane	36
Ethane	?
2-methyl-butane	?

In order to rank these compounds from highest to lowest boiling point, learners should apply factual and conceptual knowledge of chemical bonding, intermolecular forces, physical properties, as well as organic chemistry. Learners should first study the table, and differentiate between the compounds listed before they could organise them from highest to lowest boiling point. As Anderson and Krathwohl (2001: 82) stated, organising information usually goes hand in hand with attributing where learners should deconstruct meaning.

2.3.3.4.3 Attributing

As already mentioned, attributing, as defined by Anderson and Krathwohl (2001:82), does not only refer to interpreting the information, but also to deconstructing the meaning of the given information. With reference to the example on the previous page with regard to boiling points, learners could be asked to identify from the list compounds which should be used with utter caution in a lab where there are open flames, and maybe even suggest safety precautions.

When asking learners to identify possible safety hazards with regard to the chemicals listed in the table with their boiling points, learners should be able to determine that some of the compounds will be in the gaseous phase at room temperature, all the compounds listed are flammable, and that they will consequently not be safe to use in a laboratory with open flames. The learner would only be able to answer the question by deconstructing the given information, namely the names of the compounds.

2.3.3.5 Evaluate

Creating and evaluating are on the same level according to the CAPS (DBE, 2011:152), namely level four, the highest cognitive level according to the taxonomy used in CAPS. Ahmad (2011:37) proposed that the ability to evaluate is the most challenging cognitive ability, since it involves all the other cognitive abilities. Anderson and Krathwohl (2001:83) identified two main cognitive processes related to evaluation, namely checking and critiquing, or deconstructing.

2.3.3.5.1 Checking

Anderson and Krathwohl (2001:83) defined checking as testing for internal inconsistencies. When learners are testing a hypothesis during a practical investigation, they are indeed checking to see if their hypothesis could be proved either correct or incorrect.

In Physical Sciences, the data that learners collect should either confirm their hypothesis or falsify it. Their conclusions should be consistent with the data collected, so that when they evaluate their conclusion they are checking to find inconsistencies between the data and the conclusion, if any. In order to do this learners should have an in-depth understanding of the problem that they are studying, as well as the method that they are using to test the hypotheses. In order for learners to check their hypotheses and draw up a conclusion, independent thought is needed, as well as critical thinking skills. Learners should also be able to check their own understanding of the problem results throughout the investigation and this requires metacognitive functioning, since metacognition also refers to learners' ability to think about and manage their own thinking, as well as learning processes.

2.3.3.5.2 Critiquing

Anderson and Krathwohl (2001:84) highlighted that critiquing lies at the core of critical thinking, since a learner should judge the merits of a possible solution. In Physical Sciences learners are confronted with issues regarding the impact of Sciences and technology on life. To encourage learners to develop sensitivity towards environmental and humanitarian issues and the role that Physical Sciences play in those issues, learners should be taught that fertilisers were introduced to solve the problem of possible global food shortages and famine, but that the production and use of fertilisers pose some environmental problems such as eutrophication. The same could be said about motor vehicles that run on petroleum. At first this invention was a marvel but today fossil fuels are considered to be a non-renewable energy source and their combustion also contributes to pollution. It could therefore be reasoned that Sciences and technology contribute to the problem of pollution due to the combustion of petroleum, as is true of many other modern problems. However, learners and individuals who are capable of critiquing will not only be able to identify both the problem and possible solutions, but they should also be able to recognise the value that scientific and technological discoveries add to our everyday lives. In the same way learners should identify possible solutions to problems by the effect that it would have on the environment as well as the quality of life of all humans.

2.3.3.6 Create

The highest cognitive level, as described by Anderson and Krathwohl (2001:84), is a learner's ability to synthesise new knowledge. Anderson and Krathwohl (2001:84) defined this cognitive level as a learner's ability to "organise elements or parts into a structure not clearly present before". Ahmad (2011:37) also provided a definition for this cognitive activity and labelled it "synthesis", which refers to a learner's ability to combine certain parts to create a whole. In order to create new knowledge, learners should combine other cognitive skills such as understanding, applying and organising, but ultimately they should "construct an original product". Anderson and Krathwohl (2001:85 – 86) also identified three phases in the process of creating. Learners should first generate possible solutions to a problem, then plan how to implement the solution, and, finally, execute the task, collect and analyse data, and draw conclusions. This process relates to the scientific approach as discussed in 2.2.2.6. These three phases make up the process of creating. In Physical Sciences, new scientific knowledge is created during this three step process. This new knowledge could then be used to build a new prototype or to describe or predict a phenomenon better. The DBE (2011:8) states that scientific inquiry is promoted in Physical Sciences. New knowledge in Physical Sciences could be created by means of the Scientific method. The three phases, as described by Anderson and Krathwohl (2001:85 – 86), also correspond to the Scientific method of investigation. These three phases – generating, planning and producing – are discussed next in the context of a Physical Sciences learning environment.

2.3.3.6.1 Generating

In Physical Sciences, the first step in creating new knowledge is generating a hypothesis. When learners conduct practical investigations, they should arrive at a hypothesis, which should then be tested. Anderson and Krathwohl (2001:86) confirmed that hypothesising is an alternative term for *generating*. The hypothesis is a possible solution to the problem and if it is properly formulated it should inform the method to be followed for collecting and analysing data, and arriving at a conclusion.

2.3.3.6.2 Planning

Anderson and Krathwohl (2001:87) described the planning process as designing a study to test the hypotheses generated during the first phase of creating new knowledge. In Physical Sciences, when learners are following the scientific method, the hypothesis should be proved incorrect, correct, partially correct with some adaptations, or partially incorrect with some corrections. In order to try and prove the hypotheses, a learner should develop a method of gathering data. As part of the planning, learners should identify the variables as well as a detailed method of how the independent variable will be changed, how the dependant variable will be measured, and how the controlled variable will be kept constant.

2.3.3.6.3 Producing

During the third phase learners should execute the method that they have designed during the planning phase. Anderson and Krathwohl (2001:87) stated that planning may require the coordination of the four types of knowledge, namely factual, conceptual, procedural and metacognitive knowledge. During this phase learners collect the data, organise the data and use the analyses to draw a conclusion of whether or not to accept the hypothesis. Whether the hypotheses is proved correct or incorrect, new knowledge has been created and recorded by the learner.

Ultimately, Physical Sciences is concerned with producing new knowledge. The process of scientific enquiry was advocated by van Aswegen *et al.* (1993:7) as enabling scientists and learners alike to investigate scientific problems and to ultimately generate new scientific knowledge (see 2.2.2.6 and 2.2.4.1). Competent Physical Sciences learners should be able successfully utilise cognitive processes and apply the knowledge types discussed above in order to conduct a scientific investigation to ultimately construct new knowledge.

From the discussions above it should be clear that there is an integration between the knowledge types and cognitive skills. The nature and structure of Physical Sciences also reveals that knowledge and skills are intertwined (see 2.2.4.1 and 2.2.4.2). The objective that this chapter strove to address was to investigate the knowledge and skills that learners need to master in Physical Sciences. To summarise what was discovered during the investigation, a framework for Physical Sciences knowledge and skills is discussed next.

2.4 A FRAMEWORK FOR PHYSICAL SCIENCES KNOWLEDGE AND SKILLS

This framework for Physical Sciences knowledge and skills incorporates the substantive and syntactical structure, as well as the knowledge types and cognitive processes that were discussed in 2.2 and 2.3. The figure below summarises the framework for Physical Sciences knowledge and skills:

FRAMEWORK FOR PHYSICAL SCIENCES KNOWLEDGE AND SKILLS		
PHYSICAL SCIENCES KNOWLEDGE		
Knowledge type	**Knowledge subtype**	**Example**
Factual	Knowledge of terminology	Names of different forces: normal force, frictional force, gravitational force (See 2.3.2.1.1)
	Knowledge of specific detail	Definitions of these forces (See 2.3.2.1.2)
Conceptual	Knowledge of classifications and categories	Classification of physical quantities as vectors or scalars based on characteristics (See 2.3.2.2.1)
	Knowledge of principles and generalisations	Newton's 2nd Law – relationship between mass, resultant force and acceleration (See 2.3.2.2.2)
	Knowledge of theories, models and structures	Knowledge of the work-energy theorem (See 2.3.2.2.3)

Procedural	Knowledge of subject-specific skills and algorithms	Knowledge of skills and algorithms to solve problems regarding forces that require solutions with multiple steps (See 2.3.2.3.1)
	Knowledge of subject specific techniques and methods	Knowledge of designing an investigation to find the coefficient of kinetic friction for a surface (See 2.3.2.3.2)
	Knowledge of criteria for determining when to use appropriate procedures	Knowledge of when to use the theorem of conservation of mechanical energy to solve problems (See2.3.2.3.3)

PHYSICAL SCIENCES SKILLS

Skill type	**Skill subtypes**		**Example**
Sensorimotor	Receiving information through the senses		Touching different beakers with different temperatures (See 2.2.2.1)
	Performing basic motor skills		Pouring solutions from one beaker to another (See 2.2.2.1)
Cognitive	*Cognitive category*	*Cognitive processes*	
	Remember	Recognize	Recognizing covalent bonds, ionic bonds and metallic bonds (See 2.3.3.1)
		Recalling	Recalling information about covalent bonds, ionic bonds and metallic bonds (See 2.3.3.1)
	Understand	Interpreting	Interpret Bohr diagrams of elements (See 2.3.3.2.1)
		Exemplifying	Providing examples of ionic compounds (See 2.3.3.2.2)
		Classifying	Classify a substance as ionic, covalent of metallic (See 2.3.3.2.3)
		Summarising	Summarise Characteristics of an ionic compound (See 2.3.3.2.4)
		Inferring	Make inferences about the boiling points of molecules and ionic compounds (See 2.3.3.2.5)

		Comparing	Compare molecules and ionic compounds by referring to similarities and differences (See 2.3.3.2.6)
		Explaining	Explain differences in boiling points of molecules and ionic compounds (See 2.3.3.2.7)
	Apply	Executing	Use Lewis Theory to supply the Lewis structure of a common molecule, like carbon dioxide (See 2.3.3.3.1)
		Implementing	Use Lewis Theory to supply the Lewis structure of an unknown molecule, like sulphur trioxide (See 2.3.3.3.2)
	Analyse	Differentiating	Differentiate between the strength of the intermolecular forces between ions and molecules (See 2.3.3.4.1)
		Organizing	Organise compounds or molecules in the order of increasing or decreasing boiling points (See 2.3.3.4.2)
		Attributing	Attribute safety hazards to compounds with certain characteristics (See 2.3.3.4.3)
	Evaluate	Checking	Checking to find possible inconsistencies between data and conclusions (See 2.3.3.5.1)
		Critiquing	Judging the merits of a possible solution to pollution due to burning of fossil fuels (See 2.3.3.5.2)
	Create	Generate	Formulating an hypothesis (See 2.3.3.6.1)
		Planning	Design an investigation to prove hypothesis (See 2.3.3.6.2)
		Producing	Execute an investigation to prove hypothesis (See 2.3.3.6.3)
Techniques (See 2.2.2.3)	Using cognitive skills and motor skills to manipulate an instrument		Using an ammeter or voltmeter in an electric circuit
	Using cognitive skill and motor skills to manipulate apparatus		Working with a burette during a titration
	Using cognitive skill and motor skill to manipulate a machine		Using an electronic scale to accurately measure the mass of a reagent

Observation (See 2.2.2.4)	Involving all senses and can include techniques	Sight	Seeing a white flame when magnesium burns in oxygen
		Hearing	Hearing a popping sound when testing for hydrogen
		Touch	Feeling that the temperature of a beaker when hydrochloric acid is reacting with sodium hydroxide
		Smell	Smelling different esters
		Taste	Tasting that acids like vinegar have a sour taste
Scientific Language System (See 2.2.2.5)	Using terminology		Using the correct terminology in a scientific report
	Using visual presentations such as graphs, equations and diagrams		Graph of resultant force vs acceleration Equation based on Newton's Second Law: $F_{res} = m.a$ Diagram of magnetic field around a magnet
Discovery (See 2.2.2.6)	Includes all skills to perform the scientific investigations to discover and confirm knowledge.		Identifying problem
			Formulating hypothesis
			Identifying variables
			Planning experiment
			Executing experiment
			Collecting data
			Analysing data
			Communicating conclusions
			Drawing conclusions
			Identifying problem
			Formulating hypothesis
			Identifying variables
			Planning experiment

Figure 2.4: A Framework for Physical Sciences knowledge and skills

The framework summarises the knowledge and skills that learners need to master in order to be successful in Physical Sciences. There is also interaction between the components; a knowledge type or skill type will never be used in isolation but always in connection with another knowledge or skill type. In order to illustrate the interaction between the parts of the framework, an example is presented below. In order to easily identify the different parts of the framework being accessed, the text in parenthesis refers to knowledge or skills that the learner should use in executing a specific task.

Suppose a learner has to investigate light refraction, for example, the learner should first formulate a hypothesis, identify the variables and plan the experiment. In order to do this the learner should apply the scientific method (knowledge type: Procedural knowledge - knowledge of subject-specific techniques and methods, discovery skills), but also prior knowledge that the learner has about concepts of light and the behaviour of light when it moves through substances denser than air (knowledge type: Conceptual knowledge - knowledge of principles and generalisations). After planning the experiment, the learner should use a light source and a glass prism (apparatus), and a ruler and a protractor (instrument) to measure the angle of incidence and the angle of refraction. The learner should look at the light moving through the prism (sensorimotor skill) to make an observation (using sense of sight). The learner could then draw a sketch of what is observed using sensorimotor skills. The sketch should then be labelled using the correct terminology, such as angle of incidence, angle of refraction, incident ray, refracted ray, and normal (scientific language system: terminology). The learner should then repeat the experiment by letting the light enter the glass prism at a different angle. The learner should record data collected in a table and draw a graph of the angle of incidence vs the angle of refraction (scientific language system: using visual presentations). The graph could then be interpreted (cognitive skill: analyse) and the learner could formulate a conclusion (cognitive skill: create, discovery skills) and try to provide an explanation for what has been observed in order to construct knowledge about the concept of the refraction of light (cognitive skill: Understanding, knowledge type: Conceptual knowledge – knowledge of principles and generalisations).

In this experiment inductive reasoning should be used, as learners will record different angles of incidence and refraction (observe specific examples) and should notice the trend that if the angle of incidence increases, so does the angle of refraction (make abstractions), in order to finally explain that when light moves from an optically less dense to an optically more dense medium, the wavelength and velocity of the light wave decreases, resulting in the light wave refracting towards the normal.

From the example above it is clear that the knowledge and skills in Physical Sciences do not exist in isolation from each other. When learning Physical Sciences, learners constantly have to access different combinations of knowledge and skills. In order to manage this process, learners could apply metacognitive knowledge and skills to help them regulate their learning and execution of learning tasks.

2.5 SUMMARY

This chapter focused on investigating the knowledge and skills that learners need to master in Physical Sciences. The nature and structure of Physical Sciences was identified as being two dimensional, consisting of both the syntactical and the substantive structure (see 2.2.1 and 2.2.2). The substantive structure comprises the body of knowledge, while the syntactical structure comprises the processes or skills needed in the subject Physical Sciences. The nature and structure of the subject Physical Sciences informs the process in which knowledge could be acquired in the subject. Learners could either construct knowledge inductively by using the scientific approach, and/or they could apply knowledge deductively to solve problems. Inductive and deductive reasoning highlights the importance of higher order thinking skills such as applying, analysing, evaluating and creating, which are of utmost importance in the construction and application of Physical Sciences knowledge.

Physical Sciences knowledge and cognitive processes were investigated using the revised taxonomy of Anderson and Krathwohl (see 2.3) to differentiate between the different knowledge types and cognitive processes that learners need to master in Physical Sciences. A framework for Physical Sciences knowledge and skills was constructed using the substantive and syntactical structures as points of departure (see 2.4). The substantive structure includes the factual, conceptual, procedural and metacognitive knowledge types, along with their various subtypes. The syntactical structure includes sensorimotor skills, cognitive skills, observation skills, techniques, a scientific language system, and discovery skills. The main cognitive categories identified as cognitive skills in the substantive structure are remembering, understanding, applying, analysing, evaluating and creating, as well as the various cognitive processes that each category consist of.

From the framework it was clear that in order to effectively master the content and processes represented in the framework, learners need to regulate their learning. The importance of metacognition in Physical Sciences learning has been confirmed and has to be researched further.

CHAPTER 3
MEANINGFUL LEARNING IN PHYSICAL SCIENCES

3.1 INTRODUCTION

In Chapter 2, metacognitive knowledge was identified as a knowledge type that learners have to master in Physical Sciences. Given that it was suggested that metacognition is important for the acquisition of other knowledge types and skills in Physical Sciences, the following two secondary research questions now seek answers:

> *What role does metacognition play in Physical Sciences learning?*
>
> and
>
> *What are the different components of metacognition?*

In order to investigate the role metacognition plays in Physical Sciences learning, cognitive and social constructivist theories were studied and applied to establish how learning takes place in Physical Sciences. Metacognition was identified as an important aspect of learning and the existing research into the different components of metacognition is reviewed in this chapter. Each component of metacognition were analysed with reference to Physical Sciences learning to highlight the role that metacognition plays in Physical Sciences learning. Effective learning is also discussed in this chapter to substantiate the claim that metacognition is imperative to successfully acquire knowledge and skills in Physical Sciences. Once the importance of metacognition was confirmed, possible ways to develop learners' metacognition were identified and are presented here. The metacognitive learning environment emanated as an important key in enhancing metacognitive awareness of learners. This gave rise to a third secondary research question that is addressed in this chapter:

> *What are the characteristics of a metacognitive learning environment for the Physical Sciences?*

The researcher furthermore describes the metacognitive learning environment for the Physical Sciences classrooms as well as the implications that the metacognitive learning environment holds for Physical Sciences learning and teaching within the South African context.

3.2 CONSTRUCTIVISM AND PHYSICAL SCIENCES

It is crucial to examine the way in which learning takes place so that the Physical Sciences learning environment could be structured to support learning. Although there are many viewpoints on how learning takes place, current educational psychology adopts the constructivist perspective as proposed by Piaget, as well as the social constructivist perspective as formulated by Vygotsky (Donald, Lazarus & Moolla, 2014:72 & 77). The structure of knowledge and skills presented in Physical Sciences, as well as the Physical Sciences learning environment should echo the principles of social constructivism in order for all learners to learn effectively.

According to Piaget's theory, children's cognition develops in stages which are linked to their age (Jacobs *et al.*, 2014:68 – 69 and Donald *et al.*, 2014:73 – 76). Killen (2015:38) concluded, however, that children's cognition do not develop in the clearly defined steps as proposed by Piaget. Blake and Pope (2008:61) reported that one of the reasons why some researchers do not agree with Piaget's theory is because he did not include social influences as a factor that could impact on cognitive development. In formulating a model of constructivism in the Physical Sciences classroom, it is necessary to focus on the works of more than one scholar. According to Donald *et al.* (2014:77) Vygotsky's social constructivist theory, or activity theory, provides an alternative view on the topic of cognitive development. Vygotsky proposed that learning takes place through the construction of meanings during social interaction (Donald *et al.*, 2014:77). These two theories are not necessarily conflicting and could be viewed as complimentary. In order to formulate a framework for teaching and learning to happen in a constructive way in the Physical Sciences classroom, the cognitive development theories as proposed by Piaget and Vygotsky were interpreted and analysed as well as applied to Physical Sciences learning environments.

3.2.1 Piaget's cognitive constructivism theory

As already mentioned, Piaget's work focused on the cognitive developmental stages of a child from infancy through to adolescence. Donald *et al.* (2014:72) warned that in order to understand the significance of the stages of cognitive development, it is important to understand how learning takes place. Firstly, it should be noted that Piaget's theory is underpinned by active learning. As Piaget stated (Piaget, 1976:12):

> *"In order to know objects (the external world), the learner must act upon them, and transform them: he must displace, connect, combine, take apart, and reassemble them".*

This statement requires of learners to be actively and autonomously involved in the learning process. Piaget (1976:14) further explained that it is the interaction between the learner and the external world that leads to the construction of knowledge. According to Piaget a child will not learn if he or she is passive during the learning process. This implies that learners learn best when they have an interactive experience with the world around them. Donald *et al.* (2014:76) also stressed this point made by Piaget, emphasising that learners should learn best through active engagement, i.e. when they are actively involved in the learning process, and should be given opportunities to engage in activities such as exploring, experimenting, reflecting, questioning, and solving problems. Pritchard (2009:20) confirmed this idea by stating that learners construct an understanding of the world around them by making sense of the experiences they have. The construction of knowledge therefore requires active engagement between the external world and the learner, which implies that learners should be active, not passive, in their learning experiences. Pelech and Pieper (2010:12) supported this view by concluding that knowledge is the result of active engagements between the environment and the learner. It could be concluded that the cognitive theory, as proposed by Piaget, is grounded in the active engagement between the environment and the learner, which will result in the learner constructing knowledge about the environment.

It has been established that active learning through active engagement with the external world will promote construction of knowledge, according to the cognitive constructivist theory. It is, however, perhaps worthwhile to reflect on how the active engagement between the learner and the external world takes place through Piaget's lens.

Before the process of knowledge construction is described, it is necessary to review the terms Piaget used in describe learning. Piaget (1976:14) differentiated between the learner's perception of reality (schema) and operational activities. Donald *et al.* (2014:73) clarified the latter as logical thoughts or actions. The schema could also be defined as a learners pre-existing cognitive structure (Blake & Pope, 2008: 61). As has already been established, the learner should interact with the external world to construct knowledge about it. Piaget suggested, however, that the learner should engage in the learning process with an existing perception of the external world, which is the cognitive structure. The cognitive structure will be incomplete or incorrect in some instances, so the schema should be adapted and completed. Donald *et al.* (2014:72) referred to "three continuously interacting processes" that were initially conceived by Piaget, namely assimilation, accommodation, and equilibration.

Donald *et al.* (2014:72) defined assimilation as a learner's ability to fit new information into the existing schema. Learners should be able to assimilate the new information by means of cognitive operations such as thinking, reasoning, or other problem solving activities. Once the new information has been processed, it should be assimilated into the schema. This could only happen if the new information is not in conflict with the existing cognitive structure.

Accommodation was described by Donald *et al.* (2014:72) as new information that causes cognitive conflict with the learner's schema. Cognitive conflict was defined by Donald *et al.* (2014: 73) as new knowledge that is in contrast to the current schemata. In order to understand the new information, the learner should first adapt the schema in order to accommodate the new, contradicting knowledge. It is interesting to note that it is the schemata that should be manipulated and adapted, not the new information. The process to accommodate the new knowledge into the schema is called equilibration (Donald *et al.*, 2014:72). Pritchard (2009: 20) described equilibration as the process of establishing a "stable state" where there is no more cognitive conflict. Donald *et al.* (2014:72 – 73) explained that these three processes, namely accommodation, assimilation and equilibration should be continuous and cannot happen in isolation from each other.

Piaget did not only promote active engagement by assimilation and accommodation of new knowledge, but he also proposed the different cognitive developmental stages in children. Since Physical Sciences are only offered from Grade 10 to 12 in South Africa, learners who take Physical Sciences should all be older than 11 years and should therefore be functioning in the formal operational phase, according to Piaget's theory of cognitive development (Donald *et al.*, 2014: 75; Jacobs *et al.*, 2003:68). During this stage, the final developmental stage, learners should be able to think in symbolic or abstract terms (Jacobs *et al.*, 2003:68) and abstract thought should be applied by the learners (Donald *et al.*, 2014:75). Although abstract thought is the trademark skill of this level, research suggest that most learners in this stage still learn best when provided with concrete examples to help them understand abstract concepts (Donald *et al.*, 2014: 76; Jacobs *et al.*, 2003:68).

As already mentioned, Piaget's theory enhances constructive learning and teaching but it does not form the only argument. The activity theory, as posed by Vygotsky, should also be studied, as Vygotsky adds another dimension to the learning phenomenon. It addresses the issues of the impact of social and cultural interaction on learning that was left unanswered by Piaget's theory.

3.2.2 Vygotsky's social constructivist theory

Similar to Piaget, Vygotsky believed that cognitive development took place through active learning and he also focused on the construction process of knowledge. However, Vygotsky had a different view on how the knowledge was constructed. Pelech and Pieper (2010:13) argued that Vygotsky linked social contexts to personal knowledge construction. Vygotsky viewed learning as taking place through social interaction (Donald *et al.*, 2014:77). During these social interactions language is used to communicate meanings (Donald *et al.,* 2014:78). According to Vygotsky, meanings are socially constructed truths about the world and reality that are learnt during social interaction with other people (Donald *et al.*, 2014:77 – 78). Vygotsky therefore placed a lot of emphasis on knowledge as meanings that are socially constructed via mediation from a parent, teacher, or older peer that has mastered the knowledge that has yet to be mastered by the learner (Donald *et al.*, 2014:79). Vygotsky also mentioned that mediation should take place in the zone of proximal development (ZPD), which could best be described as the space where a learner cannot grasp certain meanings yet, but has the potential to do so through proximal social interaction and mediation (Donald *et al.*, 2014:79).

Four important aspects summarised very briefly in the foregoing paragraph now need more attention. They are meanings as social constructs, learning through social interaction by using language, mediated learning, and the zone of proximal development. Each of these four aspects of Vygotsky's theory are now discussed.

Since meanings are contextualised they could vary over historical times and different social contexts (Donald *et al.*, 2014:81). Meanings are the building blocks of knowledge, according to Vygotsky's model and it is important to understand that meanings may vary not only across time periods, but also different social and cultural contexts. This does not mean, however, that meanings should merely be accepted at face value without questioning their validity within a different social context or era. Just as Piaget used assimilation and accommodation to construct knowledge, Donald *et al.* (2014:81) emphasised that, according to social constructivism, meanings and therefore knowledge should constantly be evaluated and undergo reconstruction if necessary. The construction of knowledge is therefore an ongoing process.

Meanings are conveyed through the use of a language system when social interaction takes place. Donald *et al.* (2014:78) distinguished between written, spoken, symbolic, and mathematical language. Pritchard (2009:24) emphasised the importance of language in the construction of knowledge from a social constructivist viewpoint, as it could be considered to be "the vehicle by which ideas are considered, shared and developed". Social interaction refers to a dialogue that should take place between a more knowledgeable other or peers, where individuals contribute their prior knowledge to the dialogue in order to construct new ideas (Pritchard, 2009:24). The dialogue therefore serves as the medium through which meanings are transported. Learners can therefore not learn without being socially interactive and meaning making only happens when a dialogue is taking place. Through social interaction learners might gain new knowledge or they might identify misconceptions in their previous knowledge, which have to be rectified before the new knowledge could be incorporated in their existing schema.

It is, however, of utmost importance that learning is mediated. Vygotsky suggested that a parent, teacher or more knowledgeable peer should act as the mediator and mediate the learning process. Mediation was defined by Donald *et al.* (2014:79) as assisting a learner to acquire the necessary cognitive tools to facilitate the construction of knowledge. This relates closely to Bruner's idea of scaffolding, where the teacher provides temporary support to learners to master new knowledge and skills and then gradually removes support when learners have internalised the knowledge and skills (Jacobs *et al.,* 2014:112). The "cognitive tools" to which Donald *et al.* refer to, were clarified by Daniels (2008:9) as:

> *"…tools which could be used to direct the mind and the behaviour or to bring about changes in other objects".*

Cognitive tools should therefore enable a learner to construct new knowledge about the world by either adapting prior knowledge or by adding new knowledge to existing schema. It is also possible that new knowledge might be metacognitive in nature in order to "direct the mind and behaviour". Donald *et al.* (2014:80) noted that a person interacts with each other and their mediators through mediation, which could take the form of culturally generated tools such as language, art or technology. Donald *et al.* (2014:80) emphasised that, according to Vygotsky, mediation implies guided assistance. Blake and Pope (2014:63) stated that "teachers should be explaining, modelling and using guided practice in the classroom". Although emphasis is placed on guided learning, interaction is still urged from the learners' side, since Vygotsky places strong emphasis on social construction and re-construction of knowledge (Donald *et al.*, 2014:81). New meanings cannot merely be accepted passively by the learners. They should actively interact with the mediator, each other and the new meanings in order to construct new knowledge.

According to social constructivism guided learning and interaction between learners and mediators are key elements in meaning making and knowledge construction. Guided learning and interaction is an integral part of the ZPD as described by Vygotsky. As mentioned earlier, Vygotsky contributed to the development of social constructivism by identifying the cognitive space 'where' learning takes place. Daniels (2008:20) explained that the ZPD was first discussed by Vygotsky in terms of assessment and instruction and refers to the relationship between the learner and mediator.

3.2.3 Metacognition and constructivism

As established from the overview of the theories of Piaget and Vygotsky, effective learning relies on learners' ability to construct their own knowledge about the world – through accommodation and assimilation and through mediation and social interaction. In order to construct knowledge – socially or individually – they need to apply cognitive skills (Donald *et al.,* 2014: 107) as explained in Chapter 2 (see 2.3.3). These cognitive skills include remembering, understanding, applying, analysing, evaluating and creating. In order to learn effectively, these skills need to be applied effectively. Donald *et al.* (2014:107) identified metacognition as an important aspect of learning since learners could use metacognition to be more aware of their thought processes, or cognitive skills, and to actively engage with their thought processes.

In Physical Sciences, learners could use metacognition to know how they apply certain thought processes and how they could improve on them. The role that metacognition plays in Physical Sciences learning needs to be investigated.

3.3 CONCEPTUALISING METACOGNITION

In Physical Sciences, the learner should reflect on the interaction they have with teacher or peers, their understanding of new information, the structure of their schema and detect discrepancies between the schema and new information. If there are differences, the learner should reflect on whether or not the new information is interpreted correctly or whether any misconceptions might have taken place earlier during the learning process and are now embedded in their schema. Reflection is therefore part of the learning process and is central in a constructivist learning environment. Dewey (1910:6) defined reflection as:

> *"Active, persistent and careful consideration of any belief or supposed from of knowledge in the light of the grounds that support it, and the further conclusion to which it tends"*

As stated in 3.2, when learners are confronted with new information through interaction with text or through interaction with teachers and other peers, they should either assimilate or accommodate that information into their schema. In order to decide what action to take, they should constantly reflect on their prior knowledge, the new information as well as any contradictions that might arise between prior knowledge and new information. One might also make use of the term "metacognition" to describe the actions taken by the learners when they reflect on their learning and monitor, regulate and evaluate their understanding of new concepts. Metacognition is not only significant to enhance constructive learning but it is also characteristic of quality learning.

This study focused on metacognitive development in the Physical Sciences classroom. Schraw (1998:116) viewed metacognition as a generic skill while cognitive skills are subject specific. Kaplan, Silver, Lavaque-Manty, and Meizlish (2013:10 –11) also shared this view that metacognition is not subject specific, but rather “domain general”, but warns that individual learners might not apply metacognitive skills in a specific subject, because they have not received instruction and practice in how to apply their metacognitive skills in that subject. Kaplan *et al.* (2013:11) concluded that metacognition is a skill that needs development like all other skills that should be developed in the classroom. Schraw (1998:118) provided four general ways to improve metacognition in the classroom, namely promoting general awareness of metacognition, developing knowledge of cognition, developing regulation of cognition, and developing metacognitive awareness through metacognition-orientated learning environments. It is therefore important to promote metacognition in the Physical Sciences classroom if teachers want learners to apply metacognitive skills to their Physical Sciences learning. The constructs of metacognition are discussed next, as well as the development, use, and awareness of metacognition in the Physical Sciences classroom setting.

3.3.1 Defining metacognition

Although metacognition and cognition are both skills that should be mastered by learners in order to be self-regulated and successful, a clear distinction could be made between the two skills. Garner (as cited in Schraw, 1998:113) stated that while cognitive skills are used to perform a task, metacognition is applied to understand how to perform the task. Many definitions have been provided for metacognition in literature and a few are highlighted here. Georghiades (2004:365) provided a definition for metacognition as “thinking about one’s own thinking”, while Armbruster, Echols and Brown (1983:2) described metacognition quite rightfully as “transcending knowledge”. Schraw and Dennison (1994:460) also gave a comprehensive definition of metacognition:

> *“Metacognition refers to the ability to reflect upon, understand and control one’s learning”*

Metacognitive awareness allows learners to use their metacognition better. Schraw and Dennison (1994:460) reported that metacognitive awareness it allows learners to plan, sequence and monitor their learning in a way that improves performance.

To truly understand the concept of metacognition awareness and the role metacognition plays in fostering independent, active, self-regulated and life-long learners it is important to study the underpinning theories that gave rise to the idea of metacognition as we know it today. Spearman (as quoted in Georghiades, 2004:367) pointed out that Plato was probably one of the first philosophers to distinguish thinking about cognition from other cognitive actions. According to Georghiades (2004:366 – 367) Dewey, Thorndike and Locke acknowledged metacognitive activities, although they did not label it as "metacognition" but rather as "reflection". When a person reflects on his own thinking or cognitive processes that activity could be labelled metacognition. In the same fashion Piaget and Vygotsky also implied the importance of metacognitive activities in learning (Kaplan *et al.*, 2013:8). White, Shimoda and Frederickson (1999:151) noted that, according to Piaget, reflecting on one's own learning is an important characteristic of advanced cognitive development. White, Shimoda and Frederickson (1999:151) also referred to Vygotsky's research, which refers to learners reaching an independent status where they could regulate their own cognitive processes without the help of teachers or other learners. In both instances Piaget and Vygotsky acknowledged the importance of being able to think about and to regulate one's own learning process.

Although all of the above researchers, philosophers and authors made a contribution to understanding and defining the phenomenon of "thinking about thinking", it was John Flavell who first labelled "thinking about thinking" as metacognition in the early 1970's (Kaplan *et al.*, 2013:9). The word metacognition was based on the term "metamemory", which was also coined by Flavell (Georgiades, 2004:365). While the majority of metacognitive research was only focused on metamemory, peoples' knowledge and regulation of their memory – other studies also began to focus on children's cognition of, amongst other things, comprehension and problem solving (Flavell, 2004:275). Schneider (2008; 114) stated that after the first wave of studies focused on metacognition in children and adolescents, the second wave of research focused on 'theory-of-mind' in very young children. Flavell (2004:274) stated that theory-of-mind is an area of cognitive development research that focuses on the development and understanding of the mental world. When theory-of-mind research was conducted on infants and small children, it was found that they were limited in their knowledge and monitoring of cognition (Flavell, 1979:906). This raised questions as to what a child or adolescent might have to learn to eventually become a metacognitive learner (Flavell, 1979:906).

Flavell's attempt to answer this question resulted in a model of metacognition that he called "cognitive monitoring." Flavell's model of cognitive monitoring focuses on four classes of phenomena, namely metacognitive knowledge, metacognitive experiences, goals, and actions (Flavell, 1979:906). Flavell (1979:907) also stated that metacognitive knowledge comprises of three categories, namely knowledge of the person, task, and strategy. The person category refers to everything individuals hold true about their own cognition and the cognition of others (Flavell, 1979:907). The task category refers to the nature, quality and quantity of the information available during a cognitive task, while the strategy category concerns the selection and proper application of strategies that would be effective in attaining learning goals (Flavell, 1979:907). Flavell (1979:908) described metacognitive experiences as “metacognitive knowledge that has entered consciousness” and also explained that metacognitive experiences could impact cognitive goals and activate the use of certain cognitive and metacognitive strategies. According to Kaplan *et al.* (2013:10) Flavell described procedures in which learners would achieve metacognitive knowledge and select strategies, but his construct of metacognition did not indicate whether the metacognitive knowledge achieved was in actual fact correct or whether the strategy selected was the best choice.

In her research on metacognition in the early 1970’s, Ann Brown also acknowledged metacognition as learners’ knowledge, awareness and control of the processes by which they learn (Georghiades, 2004:365). Schraw and Moshman (1995:352) noted that most researchers distinguished between metacognitive knowledge and metacognitive control processes. Brown’s theories regarding metacognition agreed with that of Flavell, since both theories clearly distinguish between metacognitive knowledge and metacognitive control and both theories describe the phenomenon of metacognition as “thinking about thinking”. Brown and Campione (1980:12 – 13) distinguished between knowledge of cognition and regulation of cognition, and acknowledges Flavell’s theory as a metacognitive theory that explicitly refers to the separate, yet co-existing, phenomena that are collectively called metacognition. Accordingly, Armbruster *et al.* (1983:2) identified knowledge about four variables and their interaction that constitute metacognitive knowledge and control and named these variables text (information to be learnt), task (how the information should be applied), strategies (storage and retrieval methods of information), and learner characteristics (motivation, learning strategies, personal attributes). Armbruster *et al.* (1983:3) also admitted that these four variables interact in a complex way during the learning process. Brown (1992:146) later described metacognition as a phenomenon that has “fuzzy boundaries”.

For the purpose of this literature study, the researcher focused on the contributions made by Schraw, but this chapter also discusses how Schraw’s theory of metacognition relates to the theory of other researchers such as Brown and Flavell. Schraw and Dennison (1998:114) mentioned that most researchers agree that there are two distinct categories of metacognition namely *knowledge of cognition* and *regulation of cognition*.

The two categories of metacognition are analysed next. The relevance and application of these different categories of metacognition in Physical Sciences learning are also investigated.

3.3.2 Categories of Metacognition

3.3.2.1 Knowledge of Cognition

Metacognitive knowledge was classified by Armbruster *et al.* (1983:2), Flavell (1979:906), and Schraw (1998:114) as one of the components of metacognition. As already mentioned, Flavell's definition of metacognitive knowledge refers to knowledge or beliefs a person holds that will impact their learning and defines three subcategories, namely person, task and strategy. Schraw (1998:114) claimed that metacognitive knowledge refers to the knowledge learners have about their own cognition, or cognition in a general sense. Both of these definitions refer to metacognitive knowledge as something that the individual 'knows' about their own cognition or factors influencing their cognition.

Schraw (1998:114) labelled metacognitive knowledge as "knowledge of cognition". The author further identified that knowledge of cognition could refer to knowledge of one's own cognition, or cognition in general (Schraw, 1998:114). Schraw (1998:114) identified three forms of knowledge of cognition, namely declarative knowledge, procedural knowledge, and conditional knowledge.

3.3.2.1.1 Procedural Knowledge

Even when learners know how they learn best or solve problems most effectively, they should also have knowledge of the different strategies at their disposal to do so. Schraw (1998:114) emphasised the importance of procedural knowledge, which could be described as "knowledge about doing things" and could refer to either heuristics or strategies. Flavell (1979: 907) also referred to knowledge of cognitive strategies as an important component of metacognitive knowledge, as knowledge of these strategies could assist learners in attaining cognitive goals. Learners could use their procedural knowledge to select and apply appropriate strategies to perform cognitive tasks. It is important to note that procedural knowledge forms part of metacognition, and therefore does not refer to the implementation and execution of these strategies, but rather the knowledge of them. It is important to note that Anderson and Krathwohl (2001:52) included procedural knowledge as a knowledge type that is separate from metacognitive knowledge. The procedural knowledge discussed in section 2.3.2.3 refers to the procedural knowledge specific to the subject Physical Sciences. The procedural knowledge discussed in this section refers to a knowledge about cognition that could be used across all disciplines. Anderson and Krathwohl (2001:56) defined metacognitive procedural knowledge as “strategic knowledge”, which could be described as “general strategies for learning, thinking and problem solving” across subjects, which includes a wide scope of knowledge of strategies including memorisation, elaboration, organisation, planning, monitoring, and regulating cognition, as well as problem solving.

There are a great variety of strategies that could be applied during the learning process and during completion of a cognitive task. Armbruster *et al.* (1983:14) differentiated between “fix-up” strategies and “studying strategies”. While “fix-up” strategies are aimed at correcting comprehension, “study strategies” refer to activities aimed at processing and memorising information.

Schraw, Crippen and Hartley (2006:114) described procedural knowledge as “…a basic repertoire of useful strategies such as note-taking, slowing down for important information, skimming unimportant information, using mnemonics, summarising main ideas, and periodic self-testing”.

According to Schraw and Dennison (1994:472–474) examples of procedural knowledge might include using strategies that have worked in the past, being aware of the strategies used, as well as their purpose, and using helpful learning strategies automatically. In order to be effective metacognitive learners, learners should take cognisance of as many cognitive strategies as possible in order to broaden their procedural knowledge. Schraw (1998:114) stated that learners that are more aware of their metacognition should be able to apply more strategies and be able to apply, select and sequence different strategies more effectively.

In the Physical Sciences context, procedural knowledge should assist learners in performing a task successfully, since they should be able to select a strategy from their repertoire. Without the knowledge of a strategy, a learner will not be able to apply that strategy. To return to the electricity example used to describe declarative knowledge, many strategies are needed to effectively learn about electricity and to solve electricity problems. Except for summarising important information, learners should also know how to incorporate self-testing to ensure that they could also apply knowledge to solve problems. When solving electricity problems, they should also be able to use processes or methods which have worked in the past, such as processes or methods they used when they were doing class work or homework. In Physical Sciences many strategies are needed in order to successfully conceptualise and apply knowledge. Simple strategies such as note taking could assist learners to collect information during demonstrations and experiments. Furthermore, strategies such as summarising main ideas should prevent learners from merely memorising the textbook, but rather assist them to engage in deep learning by interacting with concepts and generalisations.

It is important that a learner identifies the task at hand and then chooses the appropriate combination and order of strategies to complete the task. Learners should therefore be aware of what the cognitive goals or prerequisites of the task are and how the information that should be learnt or used is delivered. Furthermore, they should keep in mind what their cognitive strengths and weaknesses are in choosing a strategy or sequence of strategies to learn, or solve a problem. Metacognitive learners should have access to declarative and procedural knowledge, but should also know how to apply this knowledge. This knowledge of application leads to a new category of metacognitive knowledge, namely conditional knowledge, which discussed next.

3.3.2.1.2 Declarative Knowledge

According to Schraw (1998:114) declarative knowledge refers to the knowledge learners have about themselves and about factors that will influence their performance. Schraw *et al.* (2006:114) reported that knowing these factors could contribute to better planning and compensate for cognitive limitations such as poor memory on the learner's part.

Flavell (1979:907) also referred to declarative knowledge but labelled this type of metacognitive knowledge as the person category. According to Flavell (1979:907) this type of metacognitive knowledge refers to everything an individual could believe about his or her own cognition, as well as the cognition of other people, and cognition in general. Anderson and Krathwohl (2001:59) agreed with the model proposed by Flavell and referred to declarative knowledge as self-knowledge, and highlights that self-knowledge includes knowledge of one's own cognitive strengths and weaknesses, knowledge of the scope of one's knowledge base, as well as beliefs about one's motivation. Linnenbrink and Pintrich (2002:314) stated that learners' engagement and achievement in a subject depends on their thoughts about their learning and motivation. Anderson and Krathwohl (2001:60) warned, however, that learners should have accurate self-knowledge and should know where their cognitive weaknesses lie. Teachers should therefore not present learners with an inflated, but flawed, view of their learning and progress as an attempt to motivate them. This implies honest, constructive and accurate feedback that could bolster learners' self-knowledge.

Armbruster *et al.* (1983:2) also referred to learners' characteristics as one of the variables that will produce or be responsible for learning. Armbruster *et al.* (1983:2 & 20) specifically referred to the ability, motivation and personal attributes (characteristics) of the learner, as well as learners' awareness of those characteristics. Learners should be aware of their own interest and skills, and what they are good at, but also know their weaknesses with regard to studying.

Brown’s explanation of a learner’s knowledge about personal characteristics that will influence learning could be compared to Schraw’s definition of declarative knowledge since both refer to knowledge about one’s own cognition. Favell’s description of self-knowledge also corresponds with that of Schraw, since it places emphasis on the beliefs about one’s own cognition, as well as cognition in general. Learners should be able to identify their own cognitive strengths and weaknesses on the basis of self-knowledge, as well as knowledge about cognition in general. This should ensure that learners could use and manage certain aspects of their cognition, such as memory, optimally.

In order to further define declarative knowledge (and metacognition, as becomes clear later on in this section), the research conducted by Schraw and Dennison was studied, as they devised an instrument to measure metacognitive awareness, called the Metacognitive Awareness Inventory (MAI). The MAI was designed to measure the two main constructs, namely knowledge of cognition and regulation of cognition, as well as the subcomponents under each main construct (Schraw and Dennison, 1994:460). Examples of declarative knowledge are clearly represented by the items in the instrument. According to Schraw and Dennison (1994:473 – 474) learners exhibit declarative knowledge when they know their cognitive strengths and weaknesses, what information is important and expected of them to learn, and when they know how to control and organise their learning.

In Physical Sciences, learners could apply declarative knowledge in order to select a study method which coincides with their learning style, in order to construct knowledge effectively. A suitable learning technique such as summarising, mind mapping or tabulating information could be selected in order to learn more effectively. Physical Sciences learners should also know their cognitive strengths and weaknesses. With regard to cognitive procedures, a learner might be able to recall or apply information, but struggle to analyse new information effectively. Once this weakness has been identified, learners could practice their analysing skills in order to improve not only learning, but also performance during homework or assessment tasks. With reference to knowledge a learner might be comfortable with factual and conceptual knowledge, but find the scientific method of inquiry slightly intimidating. With this knowledge, the learner should know to spend time on the Scientific method, rather than on re-learning concepts or facts which are already well known.

Physical Sciences learners should also practice declarative knowledge if they could identify what information is important to learn by being aware of expectations as set out by learning outcomes and teacher. When learners have to study electricity, for example, they could know all the terms and definitions and formulas which means they should be able to name different components such as voltmeters, ammeters, cells and switches. They might also be able to define terms such as current, potential difference or resistance. If they don't know how to apply their knowledge of these concepts, however, they won't be able to interpret or calculate voltmeter and ammeter readings, resistance of resistors, or internal resistance. They will consequently struggle to learn and solve problems during homework or assessment tasks. Learners should therefore carry knowledge of the expectations of what they should know (knowledge types), as well as what they are expected to do with the knowledge (cognitive processes). According to the DBE (2011:9), Physical Sciences learners should construct and apply scientific and technological knowledge. Being able to apply declarative knowledge is important for learners when they are constructing and applying knowledge in Physical Sciences, since they will then know what learning strategies or techniques to use and discern what information is important to learn. However, it is also important for learners to know how to construct knowledge effectively or how to solve a problem. They should also have knowledge of different procedures in order to perform different tasks as set out by the learning outcomes. This type of knowledge could be referred to as procedural knowledge and is discussed in the next section.

3.3.2.1.3 Conditional Knowledge

When learners are busy learning or solving a problem, they should choose strategies to do so based on the context of the task at hand, as well as their cognitive strengths and weaknesses. Learners should base these decisions on what Schraw (1998:114) labelled as conditional knowledge. Learners should demonstrate conditional knowledge by knowing when and why they apply certain strategies when presented with a cognitive task (Schraw *et al.*, 2006:114). Learners should choose strategies that relate to their personal cognitive strengths and that will enhance their learning in order to learn effectively. They should know what strategies suit their style of learning by applying declarative knowledge. By applying procedural knowledge, learners could choose and apply strategies that fit the requirements of the cognitive task at hand. Combined knowledge of declarative and procedural knowledge should result in strategy selection and application that is unique to the learning situation and the learner.

Other scholars, such as Flavell (1979:907), referred to knowledge of the variations in information available during a cognitive enterprise, and how to best manage the cognitive enterprise in order to be successful. Armbruster *et al.* (1983:2) made mention of a variable of metacognitive knowledge that refers to "…the features of the to-be-learned material that influence comprehension and memory."

Just as Flavell mentions the fact that the information could be delivered in various ways and that learners should take note of this, Armbruster *et al.* (1983:3) stated that the structure of the text to be learned will influence learning. Armbruster *et al.* (1983:10) further stated that effective learning depends on how aware learners are of the cognitive demands posed by the task they have to complete. Depending on the content learners have to study or the type of problem with which the learners are faced, they should choose appropriate strategies. In order to reach the goals of a cognitive task, or to adhere to these demands, learners should manage each task in the most appropriate way in order to succeed.

Schraw and Dennison (1994:472 – 474) confirmed that conditional knowledge includes knowing how to use different learning strategies for different learning situations, knowledge of how to motivate oneself to learn, and knowing how to use cognitive strengths to make up for cognitive weaknesses. Above it was stated that declarative and procedural knowledge should be utilised in order to demonstrate conceptual knowledge. This is also in particular the case in Physical Sciences. In Physical Sciences learners have to learn facts, theories, laws, models, and principles, and then use their knowledge to identify, explain, analyse, or evaluate claims, or situations (DBE, 2011:8). In order to learn and apply knowledge effectively, learners should know when and why to use certain strategies such as summarising, mnemonics or self-testing. The strategies that they use should be strategies which correspond with their learning styles, as well as the nature of the content to be learnt. The application of scientific knowledge is important to be successful in Physical Sciences and learners should also be able to to sequence problem solving strategies in order to apply knowledge effectively. Furthermore, learners should know how to motivate themselves to learn. From the above description it is clear that declarative and procedural knowledge will be integrated and learners should apply conceptual knowledge to effectively learn and solve problems in Physical Sciences.

Conditional knowledge cannot be viewed in isolation, since it relies heavily on the application of declarative and procedural knowledge**.** Flavell (1979:907) noted that metacognitive knowledge does not comprise three separate subcategories, but that the subcategories interact with each other as a person is learning, or when a person is busy with cognitive activities. As a result of the beliefs learners hold true about themselves and their cognitive skills and abilities, as well as strengths and weaknesses, they choose different strategies to successfully complete different tasks (Flavell, 1979:907). Learners' beliefs about their cognitive strengths and weaknesses, as well as the characteristics of the task, should inform their choice of strategies. Although some of these strategies might be cognitive strategies such as note taking, summarising, and skim reading, they might also refer to regulatory strategies such as planning, monitoring, and evaluation of comprehension and progress.

Anderson and Krathwohl (2001:56) mentioned that procedural knowledge might include knowledge of strategies to plan, monitor and regulate cognition. Although knowledge of these strategies refers to metacognitive knowledge, the actual implementation thereof refers to regulation of cognition, which is a metacognitive activity. Just as knowledge of cognition consists of different forms of knowledge, regulation of cognition also consists of multiple activities that are explored in greater detail next.

3.3.2.2 Regulation of Cognition

As already mentioned, metacognition could be divided into two main categories, namely knowledge of cognition and regulation of cognition. Regulation of cognition refers to strategies an individual would apply to control thinking and learning (Schraw & Moshman, 1995:354). Schraw (1998:114) concluded that all researchers acknowledge three regulatory skills in their description of metacognitive strategies, namely planning, monitoring and evaluation.

In his definition of metacognition, Flavell (1979:907) acknowledged strategies as the procedures that learners would follow to reach a goal. Armbruster *et al.* (1983:14) distinguished between two basic strategies, namely “fix-up” strategies to monitor comprehension and to correct any misconceptions, and studying strategies to enhance storage and retrieval of information. For the purpose of this study the framework as proposed by Schraw (1998) was used to conceptualise the regulation of cognition. Although Schraw (1998:115) listed the three main regulatory skills that are found in literature as planning, monitoring and evaluation, Schraw and Dennison (1994:460) also mentioned two other component skills of regulation, namely information organisation and de-bugging strategies. Regulation of cognition will now be conceptualised by discussing planning, information management strategies, comprehension monitoring, de-bugging strategies, and evaluation, as regulatory activities. All learning or problem solving activities in the Physical Sciences classroom should start with planning, which is discussed next.

3.3.2.2.1 Planning

Schraw (1998:115) described planning as the “selection of appropriate strategies and the allocation of resources that affect performance”. Schraw and Moshman (1995:354) referred to planning as the knowledge about cognition that is being used to regulate learning before a task is started. Schraw and Dennison (1994:472 – 474) defined planning activities as taking place before learning or problem solving begins. The learner should be thinking about what needs to be done, reading instructions, set appropriate goals and a possible time management plan, activate the necessary background knowledge, and choose the most effective way in which to solve the problem or learn the material (Schraw & Dennison, 1994:473).

Planning is an essential skill in Physical Sciences when learners are expected to do scientific investigations (DBE, 2011: 8). When learners are planning, they should first read the instructions carefully and make sure that they know the aim of the investigation. They should then plan and allocate their resources, such as time, in order to finish the investigation successfully and on time, whether they have one lesson or one month to complete it. They should also activate background knowledge by looking it up in the textbook, or revising a specific skill they might need in order to finish the investigation. Once they know what they have to do, they should choose the most effective way to complete the investigation on time and to meet the specific aim of the investigation. The same procedure could be applied when they are doing either a project or learning Physical Sciences, whether it is for revision for a test or exam, or merely consolidating what has been done in class on a given day.

Proper planning is key to effective learning, since it empowers learners to finish their tasks on time and with the correct outcomes in mind. Once learners have planned their tasks or learning activities, they can continue with the actual activities. Regulation of learning does, however, not stop with planning, and during the learning activity learners should apply more strategies to regulate their learning. After learners have planned their learning or problem solving, they should manage the information presented to them to construct new knowledge or to solve the problem. Being able to process information effectively implies proper information management skills which will now be discussed,

3.3.2.2.2 Information Management strategies

Information management is a metacognitive skill that refers to a learners' ability to process information more efficiently. During a task or during a lesson, learners are confronted with new information. In order to construct new knowledge from a learning experience, learners should manage the information by organising, elaborating and selective focusing (Schraw & Dennison 1994:475). Armbruster *et al.* (1983:18) referred to these strategies as studying strategies and list strategies such as underlining, summarising and self-questioning to help learners process information.

Schraw and Dennison (1994:472 – 474) listed various information management skills that learners could apply during the knowledge construction process to assist them in meaningful learning. Information management entails slowing down and focusing attention on overall meaning and importance of new information (Schraw & Dennison, 1994:473 – 474). Learners could also apply skills such as summarise new information, translate information into their own words or draw pictures to represent information so that they could learn it easier (Schraw & Dennison, 1994:473 – 474). While studying, learners could also apply information management skills by linking new information to prior knowledge and breaking studying into smaller steps to make the information more manageable (Schraw & Dennison, 1994:474).

In the case of Physical Sciences is it also important that learners manage new information in order to facilitate construction of new knowledge. Learners could also apply information management skills in Physical Sciences to solve problems. Sometimes it might be easier to represent information given in a text, in the form of a picture or diagram. When learners are solving problems, it might also be easier for them to break the procedure into smaller, more manageable, steps. Being able to apply information management skills will assist Physical Sciences learners in processing new information better, but it could also improve their problem solving skills.

When the information has been managed and learners are busy constructing knowledge or solving the problem, they should constantly monitor their comprehension and progress to make sure that they are still on track with the goals or problem solving procedure set out during planning.

3.3.2.2.3 Comprehension monitoring

Schraw and Moshman (1995:355) defined comprehension monitoring as “one’s on-line awareness of comprehension and task performance”. Schraw *et al.* (2006:114) mentioned the importance of self-testing to regulate learning. While a learner is busy studying (constructing knowledge) or completing a problem-solving task, it is important that the learner self-assess their comprehension, strategy use, as well as progress.

Schraw and Dennison (1994:472 – 474) provided examples of comprehension monitoring before and during learning or problem solving. Before learning or problem solving takes place, several options or alternative solutions should be considered before the problem is tackled or information is studied. During knowledge construction and problem solving, learners should pause, review, and ask questions to monitor comprehension of information, important relationships, and learning goals, as well as analyse effectiveness of learning strategies (Schraw & Dennison, 1994:473 – 474). Comprehension monitoring is therefore an important metacognitive skill, because it helps learners to evaluate their progress against the initial learning goals or outcomes set out during planning, but it also helps them to monitor and evaluate their information management skills, since they should monitor comprehension as well as the effectiveness of learning strategies.

In Physical Sciences learners should monitor their learning progress when they are provided with a problem solving activity or when they are studying new information. Learners should monitor their progress to make sure that they are meeting the goals and expectations identified during planning. They should also monitor the application of information management strategies to determine their effectiveness and how they could apply information management strategies to improve understanding.

When learners are monitoring their understanding or progress, they might discover that they do have misconceptions or misinterpretations which are influencing their ability to comprehend new information or solve a problem effectively. When this happens, learners should apply de-bugging strategies in order to identify misconceptions and correct them.

3.3.2.2.4 Debugging strategies

While Armbruster *et al.* (1983:14) referred to “fix-up” strategies to identify and correct misconceptions, Schraw and Dennison (1994: 475) defined this metacognitive strategy as “de-bugging”, since these strategies are used to correct comprehension and performance errors. Debugging strategies are necessary for effective learning, since learners should be able to correct any misconceptions before these misconceptions hamper effective learning or problem solving. When a learner doesn’t understand something or get confused, debugging strategies involve asking others for help, changing strategies, rereading information, re-evaluating assumptions, or revising information that is not clear (Schraw & Dennison, 1994:472 – 474).

In Physical Sciences, all learners will become confused or feel that they do not understand something at some point. They might feel this way because they misread instructions to a task, or because they are using learning strategies which do not coincide with their learning styles. There might also be a misinterpretation of previous knowledge, which is why learners are confused when new information is presented to them. Whatever the reason may be, debugging strategies are aimed at identifying misconceptions and correcting them, so that learners could successfully construct new knowledge or solve the problem.

Once new information has been learnt or the problem solved, learners should evaluate the process in order determine how effectively they have learnt.

3.3.2.2.5 Evaluation

Schraw (1998:115) referred to evaluation as the appraising of the products and efficiency of learning. Students should assess how they completed a certain task and decide whether the strategies used were successful and whether they utilised their resources optimally. This is done to ensure that the task should be executed even more effectively at the next opportunity. Schraw and Dennison (1994:472 – 474) stated that learners evaluate their learning by asking themselves whether there was an easier way to complete a task, and whether they have considered all the options. Evaluation also entails summarising what has been learnt, asking whether optimal learning took place, and being able to tell how well a learner performed in a test (Schraw & Dennison, 1994: 473 – 474).

Evaluation forms part of a cycle that learners have to complete in order for metacognitive learning to take place. Evaluation, being the last category in the cycle, informs planning during the next cognitive tasks or learning experience. When learners evaluate effectively, they should be able to rectify mistakes and improve learning from one attempt to the next. Before cognition can be regulated effectively, knowledge of cognition should be applied. Evaluation will also improve knowledge of cognition, as learners should evaluate their effectiveness of learning, which also entails revisiting beliefs they might have about their own cognition and learning in general. Due to evaluation, knowledge of cognition structure might be adapted and learners might select better and more effective methods, procedures and strategies when they tackle a similar problem or have to construct knowledge.

In Physical Sciences learners should also apply evaluation at the end of learning activities or problem solving tasks so that they can reflect on the knowledge they have about their cognition, as well as their knowledge and application of learning and problem solving strategies and procedures. In Physical Sciences, evaluation also informs the planning of the next activity, thereby sustaining the learning cycle.

It has been established that metacognition plays an important role in the construction of knowledge and the acquisition of cognitive skills in Physical Sciences. In order to construct a learning environment where meaningful learning, as well as metacognitive development are addressed, the characteristics of effective Physical Sciences learning had to be analysed so that they could be incorporated in the design of an effective Physical Sciences learning environment. De Corte (1996:37) defined effective learning as a process of meaning making and knowledge building typified by the following characteristics; constructive, cumulative, self-regulated, goal-directed, situated, and collaborative and individually different. These characteristics are discussed next in the context of Physical Sciences learning.

3.4 EFFECTIVE LEARNING

Metacognition has been highlighted as an important aspect of Physical Sciences learning. Metacognition enhances effective learning and more specifically so in Physical Sciences.

The characteristics of effective learning mentioned by De Corte (1996: 37 – 39) are discussed below in the context of the Physical Sciences to highlight the importance of metacognition in the learning of Physical Sciences.

3.4.1 Learning is constructive

De Corte (1996:37) argued that viewing learning as constructive implies that the learner should acquire knowledge and skills by means of active cognitive processing. It has been stated that learners should acquire knowledge and skills in Physical Sciences through interacting with the content that needs to be learnt, and through social interaction (see 3.2.2). De Corte (2007:23) added that learners should be involved in the process of knowledge and skills acquisition by interacting with the (learning) environment. Knowledge construction through social interaction, as well as interaction with content and the learning environment, points to active learning. The CAPS (DBE, 2011:4) affirmed that the curriculum is based on a principle of active and critical learning. In order for learning to be effective, it should therefore also be active so that learners may construct new knowledge and skills. Van Breda (2011:91) postulated that learners should be actively involved with the cognitive processing of new knowledge and information during the learning process so that they can give meaning to the content. Construction of own knowledge therefore implies active participants.

In the Physical Sciences classroom, learners should not enter the learning environment as passive participants who merely listen to and write down what is being said. Learners should make connections with prior knowledge and make notes in order to give meaning to the content that is being learnt. Learners should also be critical learners who do not only give correct answers, but understand how they arrived to the answer, and are able to control and monitor their cognitive processes. Since the regulation of cognition refers to metacognition, active constructive learning entails metacognitive involvement on the learners’ behalf.

3.4.2 Learning is cumulative

De Corte (1996:37) defined learning as being cumulative. Merrill (2002:46) confirmed this statement by proposing that learning is promoted when existing knowledge is activated as a foundation for new knowledge. This suggests that learning takes place when new knowledge is built upon the basis of old knowledge. Van Breda (2011:94) also argued that learning is built on prior knowledge and also addresses the issue of misconceptions that might form part of prior knowledge. If there are misconceptions in prior knowledge, new knowledge cannot be constructed correctly and the prior knowledge should be corrected first.

In Physical Sciences, metacognition plays an integral role in helping learners identify and address misconceptions and misunderstandings. In order for new knowledge to be accommodated into the schemata, the pre-existing knowledge should first be adapted (see 3.2.1). Since learning is cumulative, it is important for learners to make use of metacognitive strategies such as comprehension monitoring and de-bugging strategies (see 3.3.2.2.4). When learners constantly monitor their meaning making process they should be able to identify misconceptions as soon as possible, enabling them to rectify these. De-bugging strategies could also help learners to identify misconceptions.

3.4.3 Learning is self-regulated

De Corte (1996:37) advocated that learning is self-regulated. This places a responsibility on the shoulders of learners to take control of their own learning and academic success. Furthermore, De Corte (1996:37) also supported the idea that learners should use appropriate learning strategies, monitor and evaluate understanding and progress, and keep themselves motivated. Zimmermann (2002:66) defined a self-regulated learner as someone who can set specific personal goals, adopt strategies to attain those goals, monitors performance at attaining goals, restructuring physical and social context to attain goals, managing time to attain goals, and evaluate success in order to adapt future methods.

In Physical Sciences, learners should be actively involved with their own meaning making processes and self-regulation empowers them to do so. Learners should apply their metacognitive knowledge and skills to select strategies based on knowledge about their own cognition, and cognition in general, as well as knowledge about strategies, and to monitor their progress, and evaluate the outcome.

3.4.4 Learning is goal directed

De Corte (1996:38) also stated that learning is goal-directed. Since learning is self-regulated, and Zimmermann (2002:66) confirmed that self-regulated learners should set goals and work towards achieving those goals, it follows that effective learning should also be goal-directed. De Corte (1996:38) postulated that, since learning is constructive and self-regulated, learning should be most powerful when learners determine and define their own goals.

Physical Sciences teachers should therefore assist learners with defining their own goals and foster an explicit awareness and orientation towards this goal. It might prove challenging for learners to select and define their own learning goals, especially if the learning goals are already defined by a prescribed curriculum. De Corte (1996:38) did, however, confirm that if a learning goal is set by the teacher or textbook, it could still lead to powerful learning if the learners adopts the goal as a real learning intention. In Physical Sciences, learners should therefore be made aware of learning goals so that they can plan and monitor their learning accordingly.

3.4.5 Learning is situated and collaborative

Although not all learning takes place in the classroom, formal learning mostly flows from classroom activities. De Corte (2007:25) declared that learning is not an activity that takes place in isolation but has a social element to it, which is in line with Vygotsky's views. Physical Sciences learning could also be described as taking place through social interaction and mediation (see 3.2.2). Learning is not considered to be an activity that learners do exclusively on their own, but it happens in a certain social and cultural context (De Corte, 1996:38). Interactions between learner and learner, learner and teacher, and learner and content all contribute to the learning process. Learning opportunities should therefore be devised in order to promote these interactions. De Corte (1996:38) emphasised that the importance of these interactions lies in the fact that they stimulate reflection and self-assessment, which in turn stimulates metacognition.

3.4.6 Learning is individually different

It is generally accepted that all learners apply different learning strategies to learn. Since learning is individually different, the learning environment should accommodate learners with different approaches to learning as well as different cognitive strengths. In order to assist learners to develop to their full cognitive potential, learners should be guided to master performances independently in their zone of proximal development (de Corte, 1996:39).

In Physical Sciences, independent learning requires metacognitive awareness. The teacher plays an integral role in creating a learning environment were learners could develop individually and independently. A differentiated Physical Sciences classroom environment that fosters independent learning and metacognitive awareness should enable learners to master knowledge or skills that coincide with their zone of proximal development.

The learning environment plays an important role in creating the opportunities for meaningful Physical Sciences learning. The learning environment should encourage learners to construct the knowledge and skills necessary to be effective Physical Sciences learners. Metacognition has been identified as an important skill that could assist learners in their meaning making process in Physical Sciences. In order for the learning environment to be effective, it has to develop and promote metacognitive awareness among learners. A metacognitive learning environment for Physical Sciences can now be discussed.

3.5 A METACOGNITIVE LEARNING ENVIRONMENT

Schraw (1998:118) argued that to improve learners' metacognition, metacognitive awareness should be improved. Schraw (1998:123) strongly advocated that learners could be "taught" how to improve their metacognition. The author summarised the key factors to promote metacognitive awareness, namely promoting general awareness of metacognition, improving knowledge and regulation of cognition, and fostering environments that promote metacognitive awareness. Lately, Thomas (2003:180) has also contributed to the field of metacognitive development by concluding that the nature of the classroom environment is a key factor in the development of a student's metacognition.

Although there are many ways to stimulate and develop metacognitive awareness in Physical Sciences learners, such as promoting or giving metacognitive feedback (Lee, Lim & Grabowski, 2010:631), Schraw (1998:118) mentioned that by creating environments that foster metacognitive learning, learners should develop metacognitive awareness. The environment where learners receive instruction is a contributing factor towards effective learning, as well as the development of metacognitive awareness. Fraser (1984:60) reported that there is a relationship between classroom climate and learner performance. De Corte and Weinert (1996:39) promoted the idea of powerful teaching-learning environments to promote effective learning. Thomas and Au Kin Mee (2005:222) noted that metacognitive experiences where learners could consciously apply metacognitive knowledge and skills, and therefore become more metacognitively aware, should happen in the classroom. In order for these events to take place in the classroom, the classroom should first of all be conducive to metacognitive development. Except for improving knowledge of metacognitive knowledge and metacognitive strategies, as proposed by Schraw (1998:118), learners should also practice metacognitive and self-regulatory skills and the classroom should allow for that.

In order to develop a functional metacognitive learning environment it is important to study the characteristics of such a learning environment. Könings, Brand-Gruwel and Merriënboer (2005:646) reported that currently constructivism is seen as an important theory in learning. Therefore, constructivism theories will inform the development of learning environments to foster effective learning. It has already been established that learning is constructive, situated and collaborative. Keeping these three characteristics in mind, Thomas (2003:180) viewed learning as socially constructed and therefore believes that interaction between the role players, such as the learners and the teachers, is very important. The author specifically mentioned the role that discourse, language and social interaction play in the development of metacognitive awareness.

In order to promote learners' metacognitive awareness, a metacognitive learning environment should be structured. Thomas (2003:188) provided an overview of the characteristics of a metacognitive learning environment which can now be discussed.

3.5.1 Metacognitive demands

De Corte (1996:39) confirmed that the learning environment should create opportunities to acquire both cognitive and metacognitive skills. Since learners learn by socially interacting with other learners and the environment, it is important that they are asked or prompted to discuss how they learn and how they regulate their learning. Könings *et al.* (2005:648) confirmed that by including collaborative learning in the classroom, active learning is stimulated. Schraw (1998:118) acknowledged that teachers and peers play an important role in creating awareness of cognition and metacognition.

Thomas (2003:184) noted that in order to improve metacognitive awareness, learners should be asked by their teachers how they learn as well as how they could improve on their learning. Learners should be guided into an opportunity where they could discuss cognitive processing as well as metacognitive knowledge and skills, approaches to learning, their cognitive strengths and weaknesses, as well as their academic goals. By reflecting and talking about their current learning strategies, learners might realise how they could improve their studying strategies in order to master the subject. Könings *et al.* (2005:648) established that reflection and articulation assist learners in making their knowledge and problem solving strategies explicit. Some learners learn without explicitly thinking about how they actually process the knowledge. Once these abstract thoughts about learning have been made explicit and well defined, learners could reflect on how they learn in order to improve their learning processes. These conversations could therefore improve metacognitive awareness, since it compels learners to reflect on their own learning strategies and cognitive processes.

In the Physical Sciences classroom, learners could be asked to reflect and share in groups how they would tackle a multi-step problem on electricity. They should not only explain how they arrive at the answer, but also how they chose what procedural knowledge to use. They should also indicate how they monitored their progress, checking for any possible mistakes as they did their calculations and how they could evaluate whether their answer is correct or not. By taking part in this discourse, learners are compelled to explain their cognitive process, which helps them to understand and regulate their own cognition better

3.5.2 Student-student discourse

It has been established that learners construct knowledge through social interaction (See 3.2.2). Interacting with each other and the environment is therefore of utmost importance for meaningful Physical Sciences learning, since meaning is socially constructed, as advocated by Vygotsky (see 3.2.2). In the same way, learners could develop their metacognitive skills by engaging in discourse about metacognitive skills that relate to Physical Sciences learning. Schraw (1998:119) suggested that peers might be asked to model metacognitive knowledge or strategies through group discussions. Learners might be asked to explain how they solved a problem – to explain to their peers what strategies they selected, what knowledge they had to access, what steps they followed to get to the answer, how they sequenced those steps, and what common mistakes or misconceptions they had to watch out for.

In the Physical Sciences learning environment, time has to be allocated for learners to help each other reflect and to develop a language that they could use to speak about their learning. Thomas (2003:180) acknowledged that language of learning is a problem, since learners will not know how to express or explain certain concepts describing metacognitive knowledge and strategies if they are not skilled in the particular discourse. Learners therefore have to "practice" talking about issues related to learning and metacognition. By encouraging student-student discourse learners should become more aware of their metacognition.

3.5.3 Student - teacher discourse

In the same manner that learners interact with each other to ensure that active learning takes place, student-teacher discourse is also an important feature in a metacognitive learning environment. Thomas (2003:184) identified student-teacher discourse as the interaction that takes place between learners and their teacher when the learners discuss their learning process with their teacher.

The importance of feedback to foster metacognitive development has already been established (see 3.3.2.1.2). When learners engage in a conversation with their teacher about how they learn Physical Sciences, their teacher should be able to guide them through the use of constructive feedback on how they could improve their learning.

3.5.4 Student voice

Thomas (2003:180) argued that learners should be allowed to be autonomous and self-regulated learners. Self-regulation has been identified as a characteristic of meaningful learning (see 3.4.3). In a metacognitive learning environment, learners are allowed to question the teacher's pedagogical plans and methods. Thomas (2003:182) emphasised that learners’ questions, opinions and suggestions should be taken seriously and that they should be acknowledged the right to be in control of their own learning. This shared control allows learners to self-direct their learning.

In the Physical Sciences learning environment, learners should be afforded the opportunity to give feedback on how they experienced the learning and teaching of Physical Sciences. Not only could the teacher benefit from the feedback, but learners should be put in a position to reflect on their learning, which will enhance metacognitive awareness. Allowing the students to have an opinion will also be beneficial to distributed control in the classroom.

3.5.5 Distributed control

The feedback gained from allowing the students to voice their opinions, concerns and questions could be used to distribute the control in the classroom. Thomas (2003:182) elaborated that this implies that learners could be asked to assist the teacher in negotiating learning activities, since they know which learning strategies and activities should promote their understanding of the work.

In order for Physical Sciences learners to become truly independent, learners should collaborate with each other and the teacher to plan their learning. The learners could be asked to help the teacher select activities for classwork of homework from the textbook.

3.5.6 Teacher encouragement and support

The teacher has a responsibility to motivate learners to improve their Physical Sciences learning (Thomas, 2003:184). Teachers should encourage learners to improve their learning through improving metacognitive skills. Thomas (2003:184) reported that students need to be supported when they are developing their learning strategies, as well as their metacognitive strategies, until they are comfortable to use those strategies.

In the Physical Sciences classroom, teachers should provide learners with the opportunities to develop their metacognitive abilities. Motivating students and providing emotional support are also important aspects of a metacognitive learning environment.

3.5.7 Emotional Support

Thomas (2003:184) accentuated the importance of emotional support in the metacognitive learning environment. Personal beliefs have an impact on learning. Linnenbrink and Pintrich (2002:315) reported that self-efficacy has been positively related to academic success. In a classroom that is focused on metacognitive development, emotional support is of utmost importance. Emotional support may boost learners' self-efficacy. Thomas (2003:184) referred to a metacognitive learning environment as an environment that supports students in trying out new learning strategies, even when they make mistakes.

In the Physical Sciences classroom, learners should constantly reflect on their learning, try out new strategies and will inevitably make mistakes. In order to improve learners' chances for academic success, they need to be emotionally supported.

3.6 SUMMARY

In order to understand the importance of metacognition in learning Physical Sciences, the process of learning had to be studied first. This was done by referring to the works of Piaget and Vygotsky with regards to cognitive and social constructivism (see 3.2.1 and 3.2.2). A review of their research confirmed that learning is a process that needs to be managed by the learner. Metacognition was identified as being an important factor for successful Physical Sciences learning. By reviewing existing research, the different components of metacognition were identified. It was concluded that metacognition consists of two categories, namely knowledge of cognition (3.3.2.1), and regulation of cognition (3.3.2.2). Knowledge of cognition refers to knowledge that learners have about their cognition and cognition in general, and regulation of cognition refers to processes that learners could employ to manage and control their learning and the outcome thereof.

The categories of metacognition were analysed with reference to Physical Sciences learning, proving that metacognition does indeed play an important role in Physical Sciences learning. Furthermore, metacognition was discussed as being essential to effective Physical Sciences learning and it was confirmed that metacognition plays an important role in Physical Sciences learning. Once the importance of metacognition in Physical Sciences was established, possible ways to develop metacognitive awareness of learners were considered and the metacognitive learning environment emanated as a factor that could improve learners' metacognitive awareness (see 3.5). Characteristics of the metacognitive learning environment included metacognitive demands, student-student discourse, student-teacher discourse, distributed control, student voice, teacher encouragement and support, and emotional support.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 INTRODUCTION

From the literature review it should be clear that the classroom environment will not only influence learning but also the development of learners' metacognitive awareness. It is also clear that metacognition influences effective learning and academic success. Thomas and Au Kin Mee (2005:222) stated that classroom events could stimulate metacognition. A metacognitive learning environment has the ability to promote general metacognitive awareness amongst learners. Both variables, namely metacognitive awareness and the Physical Sciences classroom as a metacognitive learning environment, should be studied as well as the relationship between them.

In order to collect the data to investigate Physical Sciences learners and classrooms, the research needed to be planned first. In this chapter the aims of the research identified in Chapter 1 are explored and the research paradigm and the research methodology, as well as the research design are delineated. Once the research design was finalised, the population was analysed and sampling procedures decided upon, all of which are reported on in this chapter. The same goes for identifying the sample, and the data collection instruments. The quantitative data analysis methods and data verification are then discussed, as well as ethical considerations.

4.2 AIM OF RESEARCH

The research consisted of two sections, namely non-empirical research and empirical research. Du Toit (2007:37) emphasised that the function of non-empirical research is to give an interpretive criticism of the literature in order to understand the problem that gives rise to the research question.

In the non-empirical research of this study a theoretical framework was constructed. In Chapter 2, the knowledge and skills of Physical Sciences were discussed and a framework was structured that included knowledge and skills to be addressed in Physical Sciences (see 2.4). In Chapter 3 the process of Physical Sciences learning was explored and the role metacognition plays in Physical Sciences learning was also highlighted. It was identified that a possible way to enhance metacognitive awareness of learners could be to construct a metacognitive learning environment (see 3.5). The characteristics of an effective Physical Sciences learning environment that will stimulate metacognitive development were identified and analysed.

The secondary research questions that the literature study sought to answer were:

- What knowledge and skills do learners need to master in Physical Sciences?
- What role does metacognition play in Physical Sciences learning?
- What are the different components of metacognition?
- What are the characteristics of a metacognitive learning environment for the Physical Sciences?

The aim of the research was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. Studying the classroom meant that the teachers could be informed of elements of the classroom environment that do not contribute to metacognitive environment and elements of the classroom that do attribute to metacognitive development of learners could also be highlighted.

The main concern of the empirical research was therefore to answer the following secondary research questions:

- To what extent do learners demonstrate metacognitive awareness in the Physical Sciences classrooms in the Northern Cape?
- What are the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape?
- Is there a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools?
- Is there a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools?

Through exploring the secondary research questions the primary research question seeks to be answered:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

In order to answer the research questions, the researcher collected information from Physical Sciences learners to determine how they experienced their own metacognitive awareness, as well as their Physical Sciences learning environments.

4.3 RESEARCH PARADIGM

With regard to research in pursuit of understanding reality, Cohen, Manion and Morrison (2007:5) emphasised that the ontological assumptions will inform epistemological assumptions which will in turn give rise to the methodology, while the latter will influence the choice of instruments and data collection. This statement encapsulates the formation of the researcher's philosophical view, or paradigm, which directed this research. As Babbie (2010:34) pointed out, paradigms provide different ways of observing human social life and inspires different ways of doing research.

Cohen *et al.* (2007:33) referred to three major research paradigms in education, as well as social research namely, the positivist, interpretive and critical theory paradigms. In order to conceptualise a framework for choosing the paradigms that underlines this study, the characteristics of these three paradigms are summarised in Table 4.1 (Babbie, 2010:34; Cohen *et al.* 2007:27, 33; Nieuwenhuis, 2010:51)

Table 4.1: A Summary of three educational research paradigms

	Positivist	**Interpretive**	**Critical theory**
Ontology	Reality is objective	Reality is subjective	Reality is collective
Epistemology	Reality can be known through rational proof	Reality can be known through interaction with individuals and interpretation of narratives	Reality can be known through examining and interrogating social structures
Interests	Technical prediction and control	Practical understanding and interpretation	Emancipating emancipation and freedom
Research agenda	Generalising from the specific	Interpreting the specific	Critiquing the specific
Focus	Macro-theory (Large groups)	Micro-theory (Small groups)	Micro-theory and Macro-theory
Methodology	Quantitative	Qualitative	Action research

			Ideology critique
Instruments	Experiments Questionnaires Surveys	Interviews Open ended questionnaires	Interviews Case study

This study is conducted from a positivist perspective. The aim of the research is to determine to what extent the learning environments in Physical Sciences classrooms in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. Physical Sciences learners' metacognitive awareness, the Physical Sciences learning environments they are exposed to, as well as the possible correlation between the learners' metacognitive awareness and their learning environments were explored from a positivist point of view.

The researcher views reality as objective and therefore studied the reality objectively. The words "reality being studied" refer to the learning environments, as well as learners' metacognitive awareness. Since the researcher did not interfere with the research environment and conducted the research as an outsider, it could be argued that the research was conducted objectively, making it the ontology of positivist nature. Objectivity is argued to be a positivist approach (Cohen *et al.*, 2007:7; Nieuwenhuis, 2010:51). Babbie (2010:35) asserted that positivism is grounded in rational proof and assumes a knowable, objective reality. This confirms the positivist nature of the epistemological assumptions of the research.

The research design was of a quantitative nature and questionnaires were distributed to a large group of learners and numerical data were collected. Cohen *et al.* (2007:10) confirmed that quantitative research methods are synonymous with the positivist paradigm. This establishes that the methodology is also supportive of a positivist paradigm.

4.4 RESEARCH DESIGN

From section 4.3 it could be deduced that the researcher views reality as objective and that it could be known from the outside. When referring to Table 4.1, it is clear that the research methodology underpinning the positivist research paradigm is quantitative in nature. Quantitative data collection methods were therefore used to collect data for the purposes of this study. According to De Vos, Strydom, Fouché and Delport (2005:160) quantitative data-collection methods provide one of the most effective ways to create objective scientific knowledge.

Babbie (2010:117) emphasised the importance of research design by labelling it the “process of focusing perspective(s) for the purpose of a particular study”. The author also defined the process of research design as a set of decisions regarding what is to be studied, in which population, how it will be studied, and for what purpose. For this study, the metacognitive awareness of Physical Sciences learners as well as their perception of their Physical Sciences classrooms as metacognitive learning environments were studied. By using quantitative methods the researcher could construct objective scientific knowledge regarding the extent to which Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop their metacognitive awareness.

Mouton (2002:144) provided a clear outline of different research designs and maps them according to four dimensions:

- Empirical vs non-empirical
- Primary data vs secondary data
- Numerical vs Textual data
- High control (laboratory conditions) vs low control (natural field conditions)

Mouton (2002:148-180), as well as Cohen *et al.* (2007:84-86), provided a detailed overview of different research designs. For the purpose of this study a quantitative survey design was implemented. According to Mouton’s design classification the following four characteristics could be designated to a survey design (Mouton, 2002:144 and 152):

- Empirical
- Primary data
- Numerical data
- Medium control

Cohen *et al.* (2007:84) also provided a summary of key elements of different research designs, including a survey design. According to these authors a survey design has the purpose of gathering large-scale numerical data that is context free and could be statistically manipulated in order to make generalisations. Maree and Pietersen (2010a:155) also placed emphasis on the idea that surveys could be used to explore a phenomenon and to draw comparisons.

In this study a literature study as well as quantitative research were used to seek an answer to the primary research question, namely:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

The aim was to be realised through collecting data during an empirical study. Numerical data were collected using questionnaires. The researcher aimed to include a large sample from the population so that data collection could take place on a large scale. The data collected would be primary data, since it was collected by the researcher. The conditions were not laboratory conditions, since data were collected in the classrooms and at schools, and hence the control could be best described as medium. The conditions described above conformed to the description of a survey research design as defined by Mouton (2002:148 – 180) and Cohen *et al.* (2007:84 – 86).

The aim of the research, as well as the research paradigm and the research design had been discussed. The focus was then set on a survey design following a quantitative method. The investigative procedures can now be discussed.

4.5 POPULATION AND SAMPLING

4.5.1 Population

Grade 10 and 11 learners taking Physical Sciences as a subject in the Northern Cape Province formed part of the available population. Initially it was intended for Grade 12 learners to take part in the research, but they were not included in the study, since the data were collected in the fourth term during their final exams and the researcher did not want to disturb their exam preparations. The population consisted of both underperforming schools and performing schools, schools located in townships, urban areas, and rural areas. Some of these schools participated in the Dinaledi School Project and are referred to as Dinaledi schools, while schools not participating in the Dinaledi School Project are referred to as non-Dinaledi schools.

4.5.2 Sampling

At the time of the study the researcher lived and taught in the Frances Baard District in the Northern Cape, and it was for convenience and financial reasons that the sample for the study was chosen from this specific area. Convenience sampling was used in order to get as many learners' as possible to take part in the study. Maree and Pietersen (2010b:178) stated that larger samples represent the population better than smaller samples. For this reason, as many as possible high schools in and around Kimberley in the Frances Baard district presenting Physical Sciences as a subject were asked to take part in the survey.

In total, 816 Grade 10 and 11 Physical Sciences learners took part in the study from 14 high schools participating in the study. From the 816 learners, 445 were from Dinaledi schools and 371 were from non-Dinaledi schools.

4.6 DATA COLLECTION INSTRUMENTS

4.6.1 Variables

Since the aim of the study was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness, the two main variables for this study were:

- Metacognitive awareness of the learners
- Characteristics of the Physical Sciences learning environment

Since the literature suggests that a metacognitive learning environment promotes metacognitive awareness, the learning environment was the independent variable, while learners' metacognitive awareness was the dependant variable.

As stated in 4.5.1, both Dinaledi and non-Dinaledi schools participated in the survey. In this chapter, reference is made to three groups:

- All schools
- Dinaledi schools
- Non-Dinaledi schools

All schools refers to the whole group – all 816 learners. *Dinaledi schools* refers to schools that are part of the Dinaledi Schools project, while *non-Dinaledi schools* refers to schools that are not part of the Dinaledi Schools project.

The metacognitive awareness of learners in all schools, Dinaledi schools and non-Dinaledi schools were investigated. In this instance the group was the independent variable while the metacognitive awareness was the dependant variable. Similarly, in identifying the characteristics of the Physical Sciences learning environment, the group was the independent variable, while the characteristics formed the dependant variable.

The constant variable was that learners in question presented Physical Sciences as subject in either Grade 10 or 11.

Other variables that could also have an impact on learners' metacognitive awareness and the learning environment, but were not included in this study, were socio-economic status, living conditions, language of instruction and mother tongue, as well as general management of the school.

4.6.2 Questionnaire design

The aim of this study was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. The questionnaire collected data about learners' metacognitive awareness in Physical Sciences and the Physical Sciences learning environment. The questionnaire consisted of three sections, namely Section A, B and C (See Appendix G and H).

4.6.2.1 Section A: Demographic background information

Section A dealt with demographic background. The learners had to indicate whether they were male or female, what language they spoke at home, their age, as well as the mark that they received for Physical Sciences during the June examination of that year.

4.6.2.2 Section B: Metacognitive awareness

In order to determine to what extent the Physical Sciences learners in the Northern Cape are aware of their metacognition, the Metacognitive Awareness Inventory (MAI) of Schraw and Dennison (1994:472 – 474) was used. The instrument has two main constructs, namely knowledge of cognition and regulation of cognition. Abbreviations were given in parenthesis. These abbreviations did not appear in the questionnaires but are further used in Chapter 5.

Knowledge of cognition consists of the following constructs:

- Procedural Knowledge (PK) (See 3.3.2.1.1)
- Declarative Knowledge (DK) (See 3.3.2.1.2)
- Conditional Knowledge (CK) (See 3.3.2.1.3)

Regulation of cognition refers to the following constructs:

- Planning (P) (See3.3.2.2.1)

- Information management strategies (IMS) (See 3.3.2.2.2)
- Comprehension Monitoring (CM) (See 3.3.2.2.3)
- Debugging strategies (DS) (See 3.3.2.2.4)
- Evaluation (E) (See 3.3.2.2.5)

Table 4.2 below lists the item numbers with their constructs for the two main constructs, knowledge of cognition regulation of cognition and, as well as their sub-constructs.

Table 4.2: Section B: Constructs and item numbers

CONSTRUCTS	**ITEM NUMBERS**
Regulation of Cognition	
Planning	4, 6, 8, 22, 23, 42, 45
Information management strategies	9, 13, 30, 31, 37, 39, 41, 43, 47, 48
Debugging strategies	25, 40, 44, 51, 52
Comprehension monitoring	1, 2, 11, 21, 28, 34, 49
Evaluation	7, 24, 36, 38, 19, 50
Knowledge of Cognition	
Procedural Knowledge	3 , 14 , 27 , 33
Declarative Knowledge	5, 10, 12, 16, 17, 20, 32, 46
Conditional Knowledge	15, 18, 26, 29, 35

4.6.2.3 Section C: Metacognitive learning environment

The Metacognitive Orientated Learning environment Scale for Science (MOLES-s) was designed by Thomas (2003:190 – 194) to provide a way to gain knowledge on learners' perceptions of their learning environments regarding metacognitive orientation. The MOLES-s was included in Section C of the questionnaire and the following constructs were addressed:

- Metacognitive demands (See 3.5.1)
- Student-student discourse (See 3.5.2)
- Student-teacher discourse (See 3.5.3)
- Student voice (See 3.5.4)
- Distributed control (See 3.5.5)
- Teacher encouragement and support (See 3.5.6)
- Emotional support (See 3.5.7)

Table 4.3 lists the item numbers with their constructs for the constructs of the MOLES-s.

Table 4.3: Section C: Constructs and item numbers

CONSTRUCTS	ITEM NUMBERS
Metacognitive demands	1, 2, 3, 4, 5
Student-student discourse	6, 7, 8, 9, 10
Student-teacher discourse	11, 12, 13, 14, 15
Student voice	16, 17, 18, 19, 20
Distributed control	21, 22, 23, 24, 25
Teacher encouragement and support	26, 27, 28, 29, 30
Emotional support	31, 32, 33, 34, 35

For Section B and Section C the learners had to answer the questions by choosing the appropriate answer on the provided 5-point Likert scale. The scale provided five options, namely:

1. Almost never
2. Seldom
3. Sometimes
4. Often
5. Almost always

Learners had to give only one answer per item.

Since Afrikaans is the language of learning and teaching in some schools in the Northern Cape, the questionnaire was translated from English to Afrikaans. Both an English and an Afrikaans version of the questionnaire were made available to the learners. The MAI was also revised before it was translated to Afrikaans to rewrite some of the questions in a simpler English. The questionnaire was revised and translated with the help of a language editor to make sure that the meanings stayed the same. Since English is not the mother tongue of the majority of learners in the Northern Cape, rewriting the questionnaire in simpler English would accommodate learners from the South African, and specifically, Northern Cape context.

4.6.2.4 Pilot study

Since the Afrikaans questionnaire was translated from the reviewed English questionnaire, the Afrikaans questionnaire was used in the pilot study. For the pilot study the researcher administered the questionnaire to twelve Afrikaans-speaking Grade 12 learners taking Physical Sciences. The demographic information of the learners were as follows:

Table 4.4: Frequency of gender for pilot study

Gender	Male	Female
Frequency	6	6

Table 4.5: Frequency of Home Language for pilot study

Language	Afrikaans	Tswana
Frequency	11	1

Table 4.6: Frequency of age for pilot study

Age	17	18	20
Frequency	2	9	1

The questionnaires were collected, the data captured and analysed.

To determine the internal reliability of the translated instrument, the Alpha Cronbach coefficient was calculated (Pietersen & Maree, 2010a:216). For the pilot study the Cronbach Alpha reliability coefficient was calculated for the whole questionnaire and the following results were obtained:

According to Pietersen and Maree (2010a: 216) a Cronbach Alpha reliability coefficient with a value of 0.9 or higher indicates a high reliability. For the pilot study the Cronbach Alpha for the questionnaire was 0.953, which indicated a high reliability. The pilot study proved the translated questionnaire to be reliable. Since the translated Afrikaans questionnaire was translated from the reviewed English questionnaire, both the English and the Afrikaans questionnaire were therefore considered ready to be administered to the sample group of learners.

4.6.3 Reliability and validity of questionnaire

4.6.3.1 Reliability

Babbie (2010:150) defined reliability as a quality measure that suggests that a particular technique will yield the same results if applied repeatedly. In the context of the questionnaire used, the questionnaire would have to elicit the same responses if administered repeatedly to the same respondents.

To determine the reliability of the questionnaire, Cronbach's alpha reliability coefficient was calculated for each construct, Section B and Section C, from the data collected from the sample during the survey. Pietersen and Maree (2010a:216) explained that the reliability coefficient could be used to determine internal reliability and would have values between 0 and 1. The closer the value is to one, the more reliable the questionnaire. The closer the value lies to zero, the more the internal reliability of the questionnaire has to be brought into question. Pietersen and Maree (2010a:216), as well as Van Breda (2011:214) suggested the following guidelines for interpreting Cronbach's alpha coefficient:

Table 4.7: Guidelines for interpreting Cronbach's alpha reliability coefficient

Cronbach's Alpha reliability coefficient	Reliability
$\alpha \geq 0,9$	High
$\alpha \geq 0,8$	Moderate
$\alpha \geq 0,7$	Low
$\alpha \geq 0,6$	Very Low but acceptable
$\alpha < 0,6$	Unacceptable

The values obtained for the questionnaire would be judged against these criteria.

4.6.3.2 Validity

Cohen *et al.* (2007:133) acknowledged that it is nearly impossible to obtain 100% validity for quantitative research. The authors stated that this is attributed to the human nature of the respondents and a measure of standard error. The authors did, however, urge researchers to optimise validity and minimise invalidity for meaningful research. There are various ways of determining the validity of questionnaires and data collection, but for the purpose of this study the focus was on the following three kinds of validity, namely face validity, content validity, and construct validity.

4.6.3.2.1 Face validity

Pietersen and Maree (2010a:217) described face validity as whether an instrument "looks" valid. For this study, the instrument had to gather demographic information, information about metacognitive awareness, as well as information on the learning environment. The questionnaire consisted of three sections each of which collected demographic information as well as information on metacognitive awareness and the learning environment. The researcher's' promoter scrutinised the questionnaire to ensure that the instrument did in fact elicit relevant data to answer the research questions and address the research problem.

4.6.3.2.2 Content and construct validity

In order to meet the requirements of content and construct validity, the instrument should demonstrate that it fairly and comprehensively covers the items that it intends to cover (Cohen *et al.*, 2007:137).

In this study the researcher ensured content and construct validity by using existing questionnaires. The MAI had been tested to prove that it is valid and that it provides a reliable test of metacognitive awareness among older learners (Schraw & Dennison, 1994:470). Although the MAI was adapted slightly, the changes were only affected by a linguist during translation so that their original meanings stayed the same. Thomas (2003:185) also concurred that the MOLES-s had been proven to have construct and content validity, since the different constructs measure distinct aspects of the learning environment – hence it covers the items that it intends to cover.

Furthermore, the researcher, together with the promoter, examined the questionnaire and decided that it was indeed valid based on the content and the constructs.

4.7 DATA ANALYSIS

De Vos *et al.* (2005:218) stated that data are analysed by means of various methods in order to answer the research questions. The correct data analysis procedures should be identified and applied in order to answer the research questions. Descriptive and inferential data analyses would be used to describe and make inferences about the data collected in order to answer the secondary research questions that sought to be answered through empirical research:

- To what extent do learners demonstrate metacognitive awareness in the Physical Sciences classrooms in the Northern Cape?
- What are the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape?
- Is there a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools?
- Is there a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools?

4.7.1 Descriptive statistics

In order to answer the research questions above, descriptive statistical procedures were applied to organise and summarise data in a meaningful way (Pietersen & Maree, 2010b:183).

The questionnaire was used to collect quantitative data. To answer Section B and C a Likert Scale with values ranging from 1 to 5 was used. Pietersen and Maree (2010b:186) mentioned that the distribution of such values could be described in terms of its central tendency, variation and shape. For Section B and C the mean value for each construct were calculated together with the standard deviation.

The mean value indicates the location or centrality of the data (Jansen, 2010:19). Since the Likert scale only had values of 1 – 5 it is possible to arrive at a mean value which is not an integer but rather a decimal value. In order to interpret these values in a sensible way, the researcher attributed the following meanings to values in certain intervals:

- From 1.00 to 1.50 – Almost never
- From 1.51 to 2.50 – Seldom
- From 2.51 to 3.50 – Sometimes
- From 3.51 to 4.50 – Often
- From 4.51 to 5 – Almost always

The standard deviation indicates the dispersion of the data (Jansen, 2010:19) and indicates to what extent the data is clustered together or spread out across the range (Pietersen and Maree, 2010b:188). An increase in value indicates that the data are more spread out while a decrease in value indicates that the data are clustered around a single point (Pietersen and Maree, 2010b:188).

The interpretations made from the data collected in Section B were used to describe learners' metacognitive awareness. The interpretations made from the data collected in Section C were used to summarise the characteristics of the Physical Sciences learning environments in the Northern Cape. The researcher also compared the mean values of each construct measured in Section B and Section C for both the Dinaledi schools group, and the non-Dinaledi schools group to determine if there was a difference between the metacognitive awareness of learners and the learning environments in the Dinaledi schools and the non-Dinaledi schools.

4.7.2 Inferential Statistics

According to Pietersen and Maree (2010d:198) there are instances where simply summarising and describing the data are not enough. For this study, generalisations had to be made about the population using the data collected from the sample. Inferential statistic procedures were employed in order to make generalisations from the sample to describe the metacognitive awareness of Physical Sciences learners, as well as metacognitive learning environments for Physical Sciences found in the population.

The primary research question that had to be answered through the study was:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

The question investigated Physical Sciences learning environments and the metacognitive awareness of the learners. The difference between the metacognitive awareness of learners from Dinaledi schools and non-Dinaledi schools was determined by comparing the mean values for metacognitive awareness. In the same way, the mean values of the metacognitive learning environment characteristics of Physical Sciences classrooms for Dinaledi and non-Dinaledi schools were also compared. In order to determine whether the differences between the mean values for Dinaledi schools and non-Dinaledi schools are of any practical significance, the effect size was calculated. The effect size is a measure of the magnitude of the difference between the mean values for the two groups and can be calculated using Cohen's d (Pietersen & Maree, 2010d:211). Cohen *et al.* (2004:521) provides the following guidelines for interpreting the magnitude of d.

Table 4.8: **Interpretation of Cohen's d**

d	Meaning
0 – 0.20	weak effect
0.21 – 0.50	modest effect
0.51 – 1.00	moderate effect
>1.00	strong effect

The effect size calculated for the difference between the mean values for the Dinaledi and non-Dinaledi schools was interpreted using Table 4.8.

As part of the answer to the overarching question, it was investigated whether a correlation existed between Physical Sciences learning environments and metacognitive awareness. The Pearson correlation coefficient for the sample, which is usually denoted as *r* (Pietersen & Maree, 2010c:236) was used to calculate the correlation between the constructs of metacognitive awareness and metacognitive learning environments (see 4.6.2.2. & 4.6.2.3). Pietersen and Maree (2010c:234) explained that this statistical analysis gives an indication of how strong the relationship between two quantitative variables are. According to Cohen *et al*. (2011:536), correlations ranging from 0.20 to 0.35 show only very slight relationship between the variables while correlations ranging from 0.35 to 0.65 could be statistically significant beyond the 1% level.

In order to draw sensible conclusions from the correlation values, Pietersen and Maree (2010c:225) suggested that hypotheses should be stated quite clearly so that they could be tested. Pietersen and Maree (2010d:203) also stipulated that for each belief that has to be tested two hypotheses should be formulated, namely a null hypotheses (H_0) and an alternative hypotheses (H_A). For this study the two hypotheses that were tested are:

- H_0: $\rho=0$ There is no significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment
- $H_{A:}$ $\rho > 0$ There is a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment

The correlations are drawn from the data collected from the sample, but the hypotheses relate to the population. In the two hypothesis statements above, ρ is used to denote the correlation in the population (Pietersen & Maree, 2010d:204). Therefore, if $\rho = 0$ it means that there is no correlation between the constructs in the population. If ρ is greater than zero there is a positive correlation between the constructs of metacognitive awareness and learning environment in the population, which could imply that the metacognitive learning environment could contribute to the development of learners' metacognitive awareness.

Finding a positive correlation between the two variables is, however, not adequate in itself. In order to reject the null hypothesis, the data has to differ significantly from the null hypothesis (Pietersen & Maree, 2010d:204). Even if a positive correlation is found in the sample, in order to reject the null hypothesis and accept the alternative hypothesis the probability value, or p-value, needs to be considered. The p-value is the probability of observing the specific value of the test statistic, or a more extreme value (Pietersen & Maree, 2010d:207). The test statistic measures how close the data are to the null hypothesis (Pietersen & Maree, 2010d:204). For this study, a sig. (2-tailed) value was calculated for the p-value. Since it was a two-tailed probability value and the hypothesis was directional, the sig. (2-tailed) value would have to be divided by 2 in order to yield the p-value.

In order for the outcome of the hypothesis test to be statistically significant, the p-value of the test had to be compared to the significance level (α) (Pietersen & Maree, 2010d:208 – 209). The common significance level values that are usually specified by researchers are between 1% and 5%, as suggested by Pietersen and Maree (2010d:205). Since the alternative hypothesis is directional (it states that $\rho>0$), it is a one-sided test to the right (Pietersen & Maree, 2010d:208). In order to reject the null hypothesis and accept the alternative hypothesis the p-value should be less than the significance level, α (Pietersen & Maree, 2010d:209).

Based on what has been discussed above, in order to make crude group predictions, the cut-off point for correlations would be taken as $r > 0.35$, while the statistical significance for this study was taken as $\alpha = 0.01$ or 1%. In order to reject the null hypothesis and accept the alternative hypothesis, $r > 0.35$ and $p < 0.01$.

The Pearson correlation coefficient between metacognitive awareness and learning environment, as well as the sig. (2-tailed) value was calculated for the following three groups:

- Correlation between metacognitive awareness and the Physical Sciences learning environment for all learners.
- Correlation between metacognitive awareness and the Physical Sciences learning environment for learners from Dinaledi Schools.
- Correlation between metacognitive awareness and the Physical Sciences learning environment for learners from non-Dinaledi schools.

4.8 ETHICAL CONSIDERATIONS

In order to start the research the researcher attained permission from the University of the Free State to conduct the research (See Appendix A). The researcher also approached the Northern Cape Department of Education (NCDoE) to obtain permission to conduct the research in schools under their jurisdiction. The permission to conduct the research was granted by the NCDoE (See Appendix B and Appendix C). After the NCDoE gave their consent, the researcher visited each school chosen to be a part of the sample to ask permission from the principal to conduct research at their school (See Appendix D). A date and time was then decided upon so that arrangements could be made in advance to ensure minimal disruption of learners' school time table. In some instances the researcher was able to speak to the Physical Sciences teachers as well and could explain the procedure to them as they would have to assist the researcher on the day of data collection. The researcher also used this visit prior to the administration of questionnaires to have letters sent to the parents of the learners involved via the Physical Sciences teacher (See Appendix E). For a learner to complete the relevant questionnaire the learner and the parent had to complete and sign a letter indicating that they gave their consent to the researcher to hand the questionnaire to the learner (See Appendix F).

The next time the researcher visited the schools was about a week later and during this visit the questionnaires were then handed to the learners. Before learners could however complete the questionnaire they had to provide the consent letter signed by the parent / guardian, as well as a letter signed by the learners themselves to give consent to the researcher to use their completed questionnaires for research purposes.

Getting parents' consent forms from the learners proved to be a challenge. There were several reasons why this could have happened. A possible reason may be that learners did not live with their parents due to poor socio-economic circumstances. As a teacher explained, some of his learners came from child-headed households where there were no parents. It is also possible that some of the parents were illiterate and could not read the letter attached to the form in order to give their permission. In these instances the teachers would act according to the *in-loco parentis* role, and completed and signed a permission form for the learners without consent letters.

4.9 DATA COLLECTION

The data were collected during the fourth term of 2012 and the study was completed in 2016 and submitted to the UFS at the end of January 2017 for assessment purposes.

As stated above, the data were collected in 2012. The questionnaires were handed out during school time or after school and learners completed them. The researcher administered and collected the questionnaires herself~~,~~ with the exception of one school where the headmaster insisted that the Physical Sciences teacher administer the questionnaires. All the Grade 10 and 11 learners presenting Physical Sciences in the schools that were part of the sample were asked to take part in completing the questionnaire.

4.10 SUMMARY

The focus of this chapter was on the design and execution of the empirical research. The empirical research was done to answer the research questions stated in 4.7. This was done by identifying the research paradigm to be positivistic in nature and a quantitative research method was used to guide the research design. A quantitative survey design was adopted and questionnaires were used as an instrument to collect data. A pilot study was conducted on the Afrikaans questionnaire and it was proved to be reliable and valid. The population, as stipulated in the research question, consisted of learners presenting Physical Sciences in the Northern Cape. A sample was selected using the convenience sampling method. In the next chapter, Chapter 5, the analysed data are presented and interpretations of the analyses given.

CHAPTER 5
DATA ANALYSES AND INTERPRETATION

5.1 INTRODUCTION

The main focus of this study was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. In order to do so, the learning environments, as well as learners' metacognitive awareness had to be investigated. As explained in the previous chapter this was done by employing quantitative research methodology. Questionnaires were handed to learners in order to collect data about their experience of their Physical Sciences learning environment, as well as their metacognitive awareness. Van Breda (2011:209) emphasised that the raw data should first be organised and interpreted in order to answer the research questions which guide the study. In the previous chapter the data analyses procedures were explained. This chapter is dedicated to the analysis and interpretation of the data in order to provide possible explanations and suggestions to determine to what extent the Physical Sciences learning environments in the Northern Cape awarded learners the opportunity to develop metacognitive awareness.

This chapter focuses on the following aspects:

- Reliability of the questionnaire.
- Demographic information of the learners.
- Metacognitive awareness of learners in all schools, Dinaledi Schools and non-Dinaledi schools.
- Characteristics of Physical Sciences learning environments structured in all schools, Dinaledi Schools and non-Dinaledi schools.
- Relationship between metacognitive awareness and the Physical Sciences learning environment in all schools, Dinaledi Schools and non-Dinaledi schools.

Firstly, the reliability of the questionnaire is discussed.

5.2 RELIABILITY OF QUESTIONNAIRE

In order to make sure that the data collected during the study is reliable, the reliability of the questionnaires was be determined by calculating Cronbach's Alpha reliability coefficient. In Table 5.1 Cronbach's Alpha reliability coefficient for the different constructs under metacognitive awareness is provided as well as the Cronbach's Alpha reliability coefficient for the overall section of metacognitive awareness. The number of items that were used to test each construct are also indicated.

Table 5.1: Cronbach's alpha reliability coefficient for Section B: Metacognitive awareness

	Cronbach's alpha	Number of Items
Section B: Metacognitive Awareness	.923	52
Knowledge of cognition		
Procedural Knowledge	.444*	4
Declarative Knowledge	.639	8
Conditional Knowledge	.523*	5
Regulation of Cognition		
Planning	.692	7
Information management Systems	.736	10
Debugging strategies	.601	5
Comprehension Monitoring	.643	7
Evaluation	.620	6

In order to interpret the reliability of Section B and the constructs in Section B, the criteria established in

Table 4.7 regarding Cronbach's alpha reliability coefficient had to be applied.

From Table 5.1, two values (*) were identified which are smaller than 0,6. Van Breda (2011:216) cited Pallant to justify low reliability coefficient values and argued that when fewer than ten items are used to test a construct, the Cronbach Alpha reliability coefficients may be low. The construct procedural knowledge had 4 items, while the construct conditional knowledge had 5 items. Note that the construct debugging strategies also had only 5 items and only has a Cronbach's Alpha coefficient of 0.601, the third lowest value in the table. From Table 5.1 it could also be noted that as the number of items increase, so does the Cronbach's

Alpha coefficient for that construct. Therefore, the low Cronbach's alpha reliability coefficients for the constructs could be associated with the small number of items per construct.

Even though some constructs in Section B proved to have low internal reliability due to the low number of items per construct, the internal reliability of Section B was high, as the Cronbach's Alpha reliability coefficient for Section B was measured to be 0.923.

In Table 5.2 Cronbach's Alpha reliability coefficient for the different constructs under learning environment is provided, as well as the Cronbach's Alpha reliability coefficient for the overall section of the learning environment. The number of items that were used to test each construct are also indicated.

Table 5.2: Cronbach's alpha reliability coefficient for Section C: Learning Environment

	Cronbach's alpha	N of Items
Section C: Learning Environment	.916	35
Metacognitive demands	.803	5
Student-Student discourse	.803	5
Student-Teacher discourse	.883	5
Student Voice	.683	5
Distributed control	.855	5
Teacher Encouragement and Support	.812	5
Emotional Support	.812	5

Table 5.2 above represents Cronbach's alpha reliability coefficients for the constructs of Section C. The criteria established in

Table 4.7 regarding Cronbach's alpha reliability coefficient had to be applied to interpret these values.

Compared to the values obtained for Section B, Section C seemed to have higher reliability values, even though each construct only had 5 items. The construct *student voice* had the lowest reliability value of 0.683, but this was still acceptable. The Cronbach's Alpha reliability coefficient for Section C was 0.916, which is slightly less than the coefficient calculated for Section B, but still high. In total, Section C had fewer items that Section B, which might account for the slight difference in values. Section C could, however, be considered to have high internal reliability.

Section B and Section C of the questionnaire had been compiled from two existing questionnaires (see 4.6.2.2 and 4.6.2.3) that had been standardised. This contributed to the high internal reliability of the two sections.

5.3 RESULTS OF THE EMPIRICAL INVESTIGATION

The empirical investigation was executed by utilizing a questionnaire. This instrument was used to collect data to investigate learners' metacognitive awareness, the characteristics of the Physical Sciences learning environments, as well as to study possible correlations between learners' metacognitive awareness and the Physical Sciences learning environments. This was conducted for the three groups, namely all schools, Dinaledi schools, and non-Dinaledi schools (see 1.2 and 4.6.1). Demographic information was also collected and analysed, and are presented below.

5.3.1 Demographic information

5.3.1.1 Gender

The first question in the questionnaire referred to gender of the participants. The following information was collected:

Table 5.3: Gender of participants

Gender	Male	Female	No response	Total
Frequency	385	416	15	816
Valid Percentages[3]	48.1	51.9		100

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[3] Since not all the learners answered all the questions due to human error or because they did not want to disclose certain information about themselves, the valid percentage does not include the missing values when calculating the total. This definition for valid percentage will be used throughout this chapter.

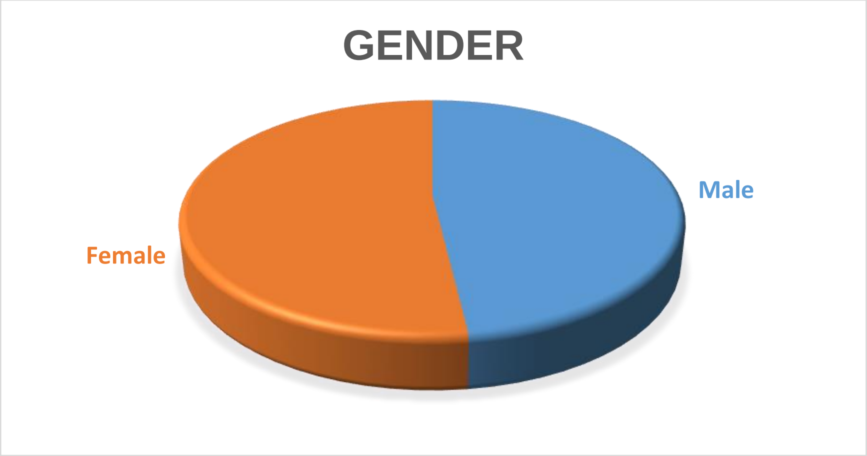

Figure 5.1: **Gender of participants**

From the 816 learners 15 neglected to indicate whether they were male or female. This is possibly due to the fact that this was the first question below the example question so it is possible that they missed it. From the pie chart it is clear that the gender mixture was close to a balanced ratio in the sample.

5.3.1.2 Home language

The languages of teaching and learning of all subjects (including Physical Sciences) in South African secondary schools are English and Afrikaans. Although teachers might use the learners' home language to convey important information in class, the textbooks and support material are still only available in English or Afrikaans. It is therefore important to know the home language of these learners to give a complete view of the demographic details of the sample.

Table 5.4: **Home language of participants**

Language	Afrikaans	English	Sesotho	Setswana	IsiXhosa	IsiZulu	Other	No response	Total
Frequency	214	92	20	398	50	8	1	33	816
Valid Percentages	27.3	11.7	2.6	50.8	6.4	1.0	0.1		100

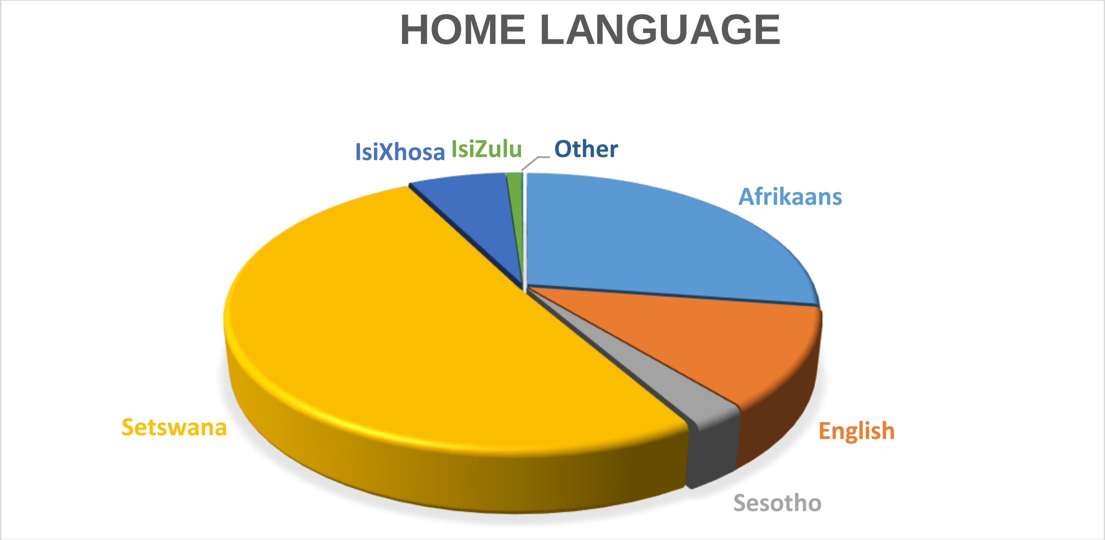

Figure 5.2: Home Language of participants

From the pie chart it could be concluded that more than half of the learners would not be examined in their home language, but rather in a first additional or even second additional language. It should also be noted that, even if a learner's home language was Afrikaans, the learner might be enrolled at a school where instruction was in English, thereby increasing the percentage of learners who were not being taught in their home language.

5.3.1.3 Age

The learners were asked to indicate their age on the questionnaire. The following data were collected:

Table 5.5: Age of participants

Age	**16**	**17**	**18**	**19**	**20**	**21**	**Older**	**No response**	**Total**
Frequency	318	289	115	48	16	5	2	23	816
Valid percentages	40.1	36.4	14.5	6.1	2.0	0.6	0.3	2.8	100

The figure below represents the data given in the table on the previous page:

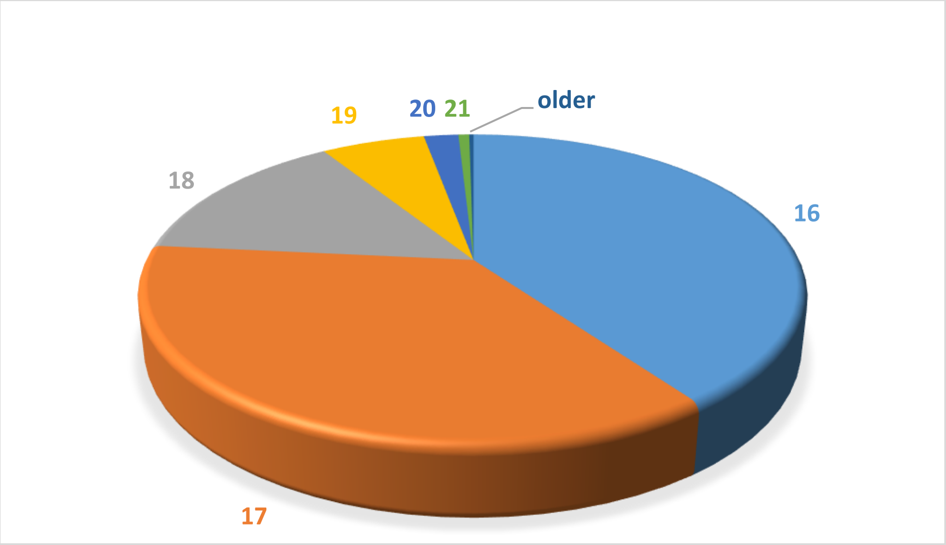

Figure 5.3: Age of participants

Learners who've completed the questionnaire were in Grade 10 (usually 16 years old) and in Grade 11 (usually 17 years old). This is displayed in Figure 5.3. What is concerning though is the large number of learners (23.5%) who were older than the expected age of learners from the specific grades who formed the sample. This could be due to the fact that learners have been repeating grades due to poor performances at school.

In the questionnaire, learners were also asked to indicate in what grade they were the previous year (2011). The options provided were Grade 11 and Grade 12. Since it was originally intended that Grade 12 learners would take part in the study, the participants could have either been in Grade 11 the previous year or were rewriting Grade 12 Physical Sciences (learners repeating Grade 12 Physical Sciences to obtain their National Senior Certificate would have be asked to take part in the study individually, as most public schools do not allow learners to return if they failed their Grade 12 year). However, since only Grade 10 and 11 learners were included, the options in the questionnaire were irrelevant and the results are not included in the study.

The questionnaire also asked learners to indicate the mark they obtained for the Chemistry and Physics paper during the June exam. It was found that most learners did not know what their marks were, and it was suspected that some learners indicated the level achieved (1 – 7), while others gave an estimated percentage. It would also be difficult for learners to remember their second term results in the fourth term. Due to the confusion, the results of this question were also not included in the study.

Now that the demographic composition of the sample group had been established, it was necessary to interrogate the descriptive data with regard to metacognitive awareness and learning environments in order to create a description of learners' metacognitive awareness and their perceived learning environment.

5.3.2 Results of the participating learners with regard to Metacognitive Awareness

The focus of this section is to answer the secondary research questions:

- To what extent do learners demonstrate metacognitive awareness in the Physical Sciences classroom?
- Is there a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools?

In order to answer the questions the researcher investigated and evaluated evidence of metacognition awareness in Physical Sciences classrooms.

In Chapter 3 metacognition was described by referring to two categories (see 3.3.2.1 and 3.3.2.2).

- Knowledge of cognition
- Regulation of cognition

Each category had subgroups which formed the constructs tested in the study. Knowledge of cognition was divided into three subcategories. Abbreviations for these terms are provided in parenthesis for use in this chapter:

- Procedural Knowledge (PK)
- Declarative Knowledge (DK)
- Conditional Knowledge (CK)

(See 3.3.2.1)

Regulation of cognition was divided into five subcategories, namely

- Planning (P)
- Information management strategies (IMS)
- Debugging strategies (DS)
- Comprehension Monitoring (CM)
- Evaluation (E)

(See 3.3.2.2)

The data concerning the metacognitive awareness of Physical Sciences learners of all three groups can now be presented.

Table 5.6: Learners' responses on metacognitive awareness for all schools

Group	Construct	Mean value of construct	Standard Deviation
ALL SCHOOLS	***Knowledge of Cognition***	**3.62**	
	Procedural Knowledge	3.48	0.75
	Declarative Knowledge	3.70	0.61
	Conditional Knowledge	3.60	0.66
	Regulation of Cognition	**3.55**	
	Planning	3.59	0.71
	Information Management Strategies	3.49	0.67
	Debugging strategies	3.80	0.70
	Comprehension monitoring	3.51	0.65
	Evaluation	3.46	0.72
	METACOGNITIVE AWARENESS	**3.57**	0.68

Table 5.6 provides the mean value of the constructs that describe learners' metacognitive awareness. A Likert scale used to collect the data made use of integers while these values are decimal numbers. The data were interpreted according to the scale set out in Chapter 4 in 4.7.1.

- From 1.00 to 1.50 – Almost never
- From 1.51 to 2.50 – Seldom
- From 2.51 to 3.50 – Sometimes
- From 3.51 to 4.50 – Often
- From 4.51 to 5 – Almost always

Applying the scale to interpret the table, the following was noted:

Learners indicated that they *sometimes* apply the following while they are learning Physical Sciences:

- Information management strategies
- Evaluation
- Procedural knowledge

Learners indicated that they *often* apply the following while learning Physical Sciences:

- Declarative knowledge
- Conditional knowledge
- Planning
- Debugging strategies
- Comprehension monitoring

In general, a mean value of 3.57 indicated that learners were *often* aware of their metacognition and that they consequently *often* applied knowledge of cognition and regulation of cognition.

The standard deviation (see 4.7.1) for the mean of the constructs ranged from 0.61 – 0.75. Since the Likert scale was divided into integers of one, the standard deviation indicated that that the data were centred around the mean values.

Above the responses from all learners had been studied as a collective. In the following two tables show the responses of learners from Dinaledi Schools and learners from non-Dinaledi Schools.

Table 5.7: Learners' responses on metacognitive awareness for Dinaledi schools

Group	Construct	Mean value of construct	Standard Deviation
DINALEDI SCHOOLS	***Knowledge of Cognition***	**3.63**	
	Procedural Knowledge	3.51	0.75
	Declarative Knowledge	3.69	0.65
	Conditional Knowledge	3.62	0.66
	Regulation of Cognition	**3.60**	
	Planning	3.63	0.73
	Information Management Strategies	3.53	0.69
	Debugging strategies	3.79	0.71
	Comprehension monitoring	3.58	0.67
	Evaluation	3.56	0.71
	METACOGNITIVE AWARENESS	**3.61**	0.57

When applying the scale discussed in 4.7.1 to interpret the mean values, it was found that learners from Dinaledi schools *often* applied all of construct for metacognitive awareness in Physical Sciences, as listed below:

- Procedural Knowledge
- Declarative knowledge
- Conditional Knowledge
- Planning
- Information Management Strategies
- Debugging Strategies
- Comprehension monitoring
- Evaluation

Learners from Dinaledi schools reported that they applied knowledge of cognition and regulation of cognition *often* while learning Physical Sciences. The mean value for metacognitive awareness was 3.61, indicating that learners from Dinaledi schools *often* demonstrated metacognitive awareness in Physical Sciences.

The standard deviation for the mean of the constructs ranged from 0.57 – 0.75 indicating that the data were centred around the mean values.

Table 5.8: Learners' responses on metacognitive awareness for non-Dinaledi schools

Group	Construct	Mean value of construct	Standard Deviation
NON-DINALEDI SCHOOLS	***Knowledge of Cognition***	**3.61**	
	Procedural Knowledge	3.43	0.74
	Declarative Knowledge	3.72	0.56
	Conditional Knowledge	3.58	0.66
	Regulation of Cognition	**3.49**	
	Planning	3.54	0.69
	Information Management Strategies	3.46	0.63
	Debugging strategies	3.82	0.69
	Comprehension monitoring	3.42	0.61
	Evaluation	3.33	0.70
	METACOGNITIVE AWARENESS	**3.52**	0.75

Using the scale as set out in 4.7.1 the information was analysed. Learners from non-Dinaledi schools indicated that they *sometimes* applied the following while learning Physical Sciences:

- Procedural Knowledge
- Information Management Strategies
- Comprehension monitoring
- Evaluation

Learners from non-Dinaledi schools responded that they *often* applied the following while learning Physical Sciences:

- Declarative knowledge
- Conditional knowledge
- Planning
- Debugging Strategies

Learners from non-Dinaledi schools indicated that although they *often* applied knowledge of cognition they only *sometimes* applied regulation of cognition. The mean value for metacognitive awareness was 3.52, indicating that learners from non-Dinaledi schools *often* demonstrated metacognitive awareness in Physical Sciences.

The standard deviation for the mean of the items ranged from 0.56 – 0.75, indicating that the data were centred around the mean values.

In order to investigate whether there was a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools, the responses from Dinaledi schools and non-Dinaledi schools are compared in Table 5.9 and Table 5.10

Table 5.9: Comparison of means for metacognitive awareness for Dinaledi and non-Dinaledi schools

Construct	**Mean value of constructs**	
	Dinaledi schools	**non-Dinaledi schools**
Knowledge of Cognition	**3.63**	**3.61**
Procedural Knowledge	3.51	3.43
Declarative Knowledge	3.69	3.72
Conditional Knowledge	3.62	3.58
Regulation of Cognition	**3.60**	**3.49**
Planning	3.63	3.54
Information Management Strategies	3.53	3.46
Debugging strategies	3.79	3.82
Comprehension monitoring	3.58	3.42
Evaluation	3.56	3.33
METACOGNITIVE AWARENESS	**3.61**	**3.52**

For each construct, the larger mean value is underlined. The effect size of the mean differences was calculated as d = 0.122. Using the information provided in Table 4.8, the value of d indicates a weak effect. This means that there is no practical significance to the difference between the mean values of metacognitive awareness for the two groups. This indicates that, due to the very small differences between the two groups, there is no significant difference between the metacognitive awareness of learners in Dinaledi schools and non-Dinaledi schools.

Although the practical significance was found to be weak, there is a tendency to be noted regarding the metacognitive awareness of Physical Sciences. When interpreting the mean values in Table 5.9, it is noted that both groups indicated that they *often* demonstrated metacognitive awareness. The Dinaledi school group was higher up the scale, whereas the non-Dinaledi school group was close to the lower level of the *often* scale (see 4.7.1 for scale). Both groups indicated that they *often* apply knowledge of cognition, but the non-Dinaledi school group had a lower mean value than the Dinaledi school group for this construct. Learners in Dinaledi schools indicated that they *often* apply regulation of cognition, while learners' from non-Dinaledi schools indicated that they only *sometimes* applied regulation of cognition.

The Dinaledi schools group had greater mean values for all the constructs except two; declarative knowledge and debugging strategies*,* meaning that the learners from the non-Dinaledi schools indicated that they applied these two aspects of metacognition slightly more frequently than the learners from Dinaledi schools. Learners from Dinaledi schools did however indicate that they applied the remaining aspects (procedural knowledge, conditional knowledge, planning, information management strategies, comprehension monitoring and evaluation) more frequently than learners from non-Dinaledi schools.

Table 5.10 summarises the frequencies of the demonstration of constructs relating to regulation of cognition and demonstration of different categories of knowledge of cognition.

Table 5.10: Comparison of frequency of metacognitive awareness constructs demonstrated by learners from Dinaledi and non-Dinaledi schools

Frequency	Almost Never	Seldom	Sometimes	Often	Almost Always
DINALEDI SCHOOLS				PK DK CK P IMS DS CM E	
NON-DINALEDI SCHOOLS			PK IMS CM E	DK CK P DS	

Table 5.10 is in support of the difference between the means of the two school groups discussed previously. All constructs of the Dinaledi schools fell in the category *often,* indicating that they *often* demonstrate all the constructs. Learners from non Dinaledi schools indicated that they only *sometimes* apply procedural knowledge, information management strategies, comprehension monitoring and evaluation. Learners from non-Dinaledi schools did however indicate that they also *often* apply declarative knowledge, conditional knowledge, planning and debugging strategies.

It is, however, conclusive that the mean for metacognitive awareness for Dinaledi schools was higher than the mean for metacognitive awareness for non-Dinaledi schools (see Table 5.9), which could indicate that learners in the Dinaledi schools were more aware of their metacognition than learners in non-Dinaledi schools. This is, however true of the sample, and not necessarily of the whole population.

5.3.3 Results of the participating learners with regard to Metacognitive Learning Environment

The focus of this section is to answer the following secondary research questions:

- What are the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape?
- Is there a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools?

In order to answer these secondary research questions the researcher identified the characteristics of Physical Sciences learning environments in the schools which formed part of the sample in the Northern Cape and investigated whether there was a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools.

In Chapter 3 (see 3.5) the metacognitive learning environment was described by referring to the following seven characteristics:

- Metacognitive demands
- Student-student discourse
- Student teacher discourse
- Student voice
- Distributed control
- Teacher encouragement and support
- Emotional support

The Physical Sciences learning environments of the following three groups were investigated to identify which characteristics of a metacognitive learning environment were present:

- All schools
- Dinaledi schools
- non-Dinaledi schools

Table 5.11: Learners' responses on the Physical Sciences learning environment for all schools

Group	Construct	Mean value of construct	Standard deviation
ALL SCHOOLS	Metacognitive demands	3.57	0.96
	Student-student discourse	3.26	1.01
	Student teacher discourse	2.96	1.08
	Student voice	3.89	0.83
	Distributed control	2.28	1.07
	Teacher encouragement and support	3.90	0.94
	Emotional support	3.94	0.92
	METACOGNITIVE LEARNING ENVIRONMENT	**3.40**	0.97

According to the criteria set out in 4.7.1, the following occurred *often* in Physical Sciences classrooms:

- Metacognitive demands
- Student Voice
- Teacher encouragement and support
- Emotional support

The following constructs were indicated to occur *sometimes* in Physical Sciences classrooms:

- Student-student discourse
- Student-teacher discourse

The construct, distributed control, was the only construct that was *seldom* observed in the Physical Sciences classrooms.

Overall, the mean value for the metacognitive learning environment was 3.40, indicating that the Physical Sciences classroom in the sample were only *sometimes* observed as being metacognitive learning environments.

The standard deviation for the mean of the items ranged from 0.92 – 1.08. Seeing that the scale used only goes from 1 – 5, a standard deviation of 1.08 indicates that the values were slightly spread out and not as closely centred around the central value as for the data collected in Section B of the questionnaire.

The responses from the Dinaledi and non-Dinaledi schools will now be investigated.

Table 5.12: Learners' responses on the Physical Sciences learning environment for Dinaledi schools

Group	Construct	Mean value of construct	Standard deviation
DINALEDI SCHOOLS	Metacognitive demands	3.61	1.01
	Student-student discourse	3.35	1.00
	Student teacher discourse	3.04	1.11
	Student voice	3.83	0.86
	Distributed control	2.31	1.13
	Teacher encouragement and support	3.85	1.03
	Emotional support	3.72	0.98
	METACOGNITIVE LEARNING ENVIRONMENT	**3.37**	0.7

According to the scale in 4.7.1, these constructs were observed *often* in Physical Sciences classrooms of Dinaledi schools:

- Metacognitive demands
- Student Voice
- Teacher encouragement and support
- Emotional support

For the following constructs only occurred *sometimes* in Physical Sciences classrooms in Dinaledi schools:

- Student-student discourse
- Student-Teacher discourse

Distributed control had the lowest mean value and *seldom* occurred in the Physical Sciences classrooms in Dinaledi schools.

Overall, the Physical Sciences classrooms in Dinaledi schools were *sometimes* observed to be a metacognitive learning environment, as the mean value assigned to the metacognitive learning environment was 3.37.

The standard deviation for the mean of the items ranged from 0.70 – 1.13 indicating that the individual responses were not heavily concentrated around the central mean value.

Table 5.13: Learners' responses on the Physical Sciences learning environment for non-Dinaledi schools

Group	Construct	Mean value of construct	Standard deviation
NON-DINALEDI SCHOOLS	Metacognitive demands	3.53	0.90
	Student-student discourse	3.15	1.01
	Student teacher discourse	2.86	1.04
	Student voice	3.97	0.79
	Distributed control	2.25	1.00
	Teacher encouragement and support	3.97	0.81
	Emotional support	4.19	0.78
	METACOGNITIVE LEARNING ENVIRONMENT	**3.41**	0.58

With reference to the scale from 4.7.1, the following constructs occurred *often* in the Physical Sciences classroom of non-Dinaledi schools:

- Metacognitive demands
- Student Voice
- Teacher encouragement and support
- Emotional Support

The constructs that only occurred *sometimes* in Physical Sciences classrooms in non-Dinaledi schools were:

- Student-student discourse
- Student-Teacher discourse

As was the case with Dinaledi schools, distributed control had the lowest mean value and was *seldom* observed in these Physical Sciences classrooms in non-Dinaledi schools.

The overall mean value for the metacognitive learning environment for the non-Dinaledi schools was 3.41. The Physical Sciences classrooms in non-Dinaledi schools were *sometimes* observed as a metacognitive learning environments.

The standard deviation for the mean of the items ranged from 0.58 – 1.01 indicating that the data were slightly spread out from the mean value. It is also interesting to note that the standard deviation for the construct *emotional support* (which received the highest mean value) was the lowest standard deviation recorded for all of the constructs in Section C across all groups, suggesting that the responses were not distributed throughout the range but rather centralised around the mean value.

To determine whether there was a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools, the responses from Dinaledi and non-Dinaledi schools were compared and are presented in and Table 5.14.

Table 5.14: Comparison of Physical Sciences learning environment means for Dinaledi and non-Dinaledi schools

Construct	Mean value of construct	
	Dinaledi	**Non-Dinaledi**
Metacognitive demands	3.61	3.53
Student-student discourse	3.35	3.15
Student teacher discourse	3.04	2.86
Student voice	3.83	3.97
Distributed control	2.31	2.25
Teacher encouragement and support	3.85	3.97
Emotional support	3.72	4.19
METACOGNITIVE LEARNING ENVIRONMENT	**3.37**	**3.41**

The effect size of the mean differences was calculated as d = 0.062. Using the information provided in Table 4.8, the value of d indicates a weak effect. This means that there is no practical significance to the difference between the mean values of the Physical Sciences learning environment for the two groups. This indicates that there is no practical significant difference between the Physical Sciences learning environments constructed in Dinaledi schools and non-Dinaledi schools.

Although the practical significance was found to be weak, the values can still be interpreted to give insight into the characteristics of Physical Sciences learning environments. In each instance, the greater mean value is underlined. It could be observed that the Dinaledi schools did not always have the highest mean values when analysing the metacognitive learning environment as was the case for metacognitive awareness. When comparing the mean values for the two groups, the lowest mean values in both instances were for the constructs *student-student discourse, student-teacher discourse* and *distributed control*. The three constructs that obtained the highest mean values for both groups were *student voice, teacher* *encouragement and support* and *emotional support* and for all three constructs the non-Dinaledi schools had the greater mean value.

The mean for the metacognitive learning environment for the non-Dinaledi schools was higher than the mean for the metacognitive learning environment for Dinaledi schools. The two mean values do however represent the same scale, which is that leaners *sometimes* observed the Physical Sciences classroom as being a metacognitive learning environment.

The frequency with which the metacognitive learning environment constructs are experienced by the two groups of learners are summarised below:

Table 5.15: Comparison of the frequency of constructs of a metacognitive learning environment observed in Physical Sciences classrooms in Dinaledi and non-Dinaledi schools

	Almost never	Seldom	Sometimes	Often	Almost always
DINALEDI SCHOOLS		DC	SSD STD	MD SV TES ES	
NON-DINALEDI SCHOOLS		DC	SSD STD	MD SV TES ES	

The Physical Sciences learning environment created in Dinaledi and non-Dinaledi schools seemed to be quite similar based on the results reflected in Table 5.15. However, Table 5.14 shows that there were slight differences in mean values, but overall it seemed that the Physical Sciences learning environment in these two types of schools were similar. From the responses of learners, the Physical Sciences classrooms of the schools included in the sample seemed to be more teacher-orientated, since distributed control was seldom allowed, which means that the teacher was in control of the classroom most of the time. In addition, the constructs student-student discourse and student teacher discourse were only *sometimes* observed. This is an indication that learners were not taking part in discourse with each other or with the teacher regarding the subject Physical Sciences often enough.

It does however appear that the characteristics of *metacognitive demands, student voice*, *teacher encouragement*, and *emotional support* were often observed in the Physical Sciences classrooms as has already been mentioned earlier in this chapter.

When comparing the mean values from data collected from Dinaledi and non-Dinaledi schools, learners from Dinaledi schools demonstrated metacognitive awareness in Physical Sciences to a greater extent than learners from non-Dinaledi schools (see 5.3.2). Since learners from Dinaledi schools were more aware of their metacognition than learners from non-Dinaledi schools, and since Dinaledi schools receive additional funding to improve the Physical Sciences learning environment, it was natural to suspect that the Physical Sciences learning environment in the Dinaledi schools should have had a greater mean value for being a metacognitive learning environment than for non-Dinaledi schools. When the mean values for metacognitive learning environments were studied it emerged that Physical Sciences learning environments in non-Dinaledi schools had a higher mean value for being a metacognitive learning environment than Physical Sciences learning environments in Dinaledi schools.

The primary research question that needed to be answered in this study relates to both metacognitive awareness and the metacognitive learning environment:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

In order to answer the primary research question, and as discussed in Chapter 4, (see 4.7.2) inferential statistics were applied to determine the correlation between a metacognitive learning environment and metacognitive awareness.

5.3.4 Correlations between metacognitive awareness and the Physical Sciences learning environment

In order to answer the primary research question,

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

two hypotheses were formulated and tested: (see 4.7.2)

- H_0: $\rho=0$ There is no significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment
- H_A: $\rho > 0$ There is a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment

In order to test the hypotheses, the correlation between the metacognitive awareness and the Physical Sciences learning environment was determined. As already explained in 4.7.2, the Pearson correlation coefficient was calculated for the correlation between metacognitive awareness and Physical Sciences learning environment. The sig. 2-tailed value was also calculated.

The hypotheses were tested for all three groups involved in the study:

- All Schools
- Dinaledi schools
- Non-Dinaledi schools

Table 5.16: The Pearson correlation coefficient between metacognitive awareness and the Physical Sciences learning environment for all schools

Constructs		Metacognitive awareness	Physical Sciences learning environment
Metacognitive awareness	Pearson Correlation	1	.437
	Sig. (2-tailed)	-	.000
	p-value		.000
	N	814	812
Physical Sciences learning environment	Pearson Correlation	.437	1
	Sig. (2-tailed)	.000	-
	p-value	.000	
	N	812	814

According to the parameters set out in 4.7.2, the alternative hypothesis could be accepted if $r > 0.35$ and if the p-value was less than α. The Pearson correlation coefficient indicates that there was a positive correlation between metacognitive awareness and the Physical Sciences learning environment, as $r = 0.437$. The p-value = 0.000, which was less than 0,01.

The sample yields $\rho = 0.437$, which was significantly greater than 0, tested at the 1% level of significance. The null hypothesis could therefore be rejected, meaning that there was a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment for all schools in the Northern Cape.

The correlation between metacognitive awareness and the Physical Sciences learning environment for Dinaledi schools is presented below.

Table 5.17: The Pearson correlation coefficient between metacognitive awareness and the Physical Sciences learning environment for Dinaledi schools

Constructs		Metacognitive awareness	Physical Sciences learning environments
Metacognitive awareness	Pearson Correlation	1	.445
	Sig. (2-tailed)	-	.000
	p-value		.000
	N	444	442
Physical Sciences learning environments	Pearson Correlation	.445	1
	Sig. (2-tailed)	.000	-
	p-value	.000	
	N	442	443

According to the parameters set out in 4.7.2, the alternative hypothesis could be accepted if $r > 0.35$ and if the p-value was less than α. The Pearson correlation coefficient indicated that there was a positive correlation between metacognitive awareness and the Physical Sciences learning environment, as $r = 0.445$. The p-value = 0.000, which was less than 0,01.

The sample yielded $\rho = 0.445$ which, was significantly greater than 0, tested at the 1% level of significance. The null hypothesis could therefore be rejected, meaning that there was a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment for Dinaledi schools in the Northern Cape.

The correlation between metacognitive awareness and the Physical Sciences learning environment for non-Dinaledi schools is presented next.

Table 5.18: The Pearson correlation coefficient between metacognitive awareness and the Physical Sciences learning environment for non-Dinaledi schools

Constructs		Metacognitive awareness	Physical Sciences learning environment
Metacognitive awareness	Pearson Correlation	1	.436
	Sig. (2-tailed)	-	.000
	p-value		.000
	N	370	370
Physical Sciences learning environment	Pearson Correlation	.436	1
	Sig. (2-tailed)	.000	-
	p-value	.000	
	N	370	371

According to the parameters set out in 4.7.2, the alternative hypothesis could be accepted if $r > 0.35$ and if the p-value was less than α. The Pearson correlation coefficient indicated that there was a positive correlation between metacognitive awareness and the Physical Sciences learning environment, as $r = 0.436$. The p-value = 0.000, which was less than 0,01.

The sample yields $\rho = 0.436$ which was significantly greater than 0, tested at the 1% level of significance. The null hypothesis could therefore be rejected, meaning that there was a significant statistical correlation between metacognitive awareness and the Physical Sciences learning environment for non-Dinaledi schools in the Northern Cape.

What these correlations suggest is that there was a relationship between the Physical Sciences learning environment that learners were exposed to and their metacognitive awareness in the subject. This interpretation agreed with the statements made by other researchers (see 1.2) that the learning environment does play a crucial role in the development of metacognition in learners. The characteristics that had to be identified in the Physical Sciences learning environment were those of a metacognitive learning environment (see 3.5). The correlation suggested that if a Physical Sciences learning environment is structured as a metacognitive learning environment, then the metacognitive awareness of learners should develop. The opposite might also hold true, that if the Physical Sciences learning environment is not a metacognitive learning environment then the metacognitive awareness of learners might not develop. When considering the mean values attributed to metacognitive awareness and the Physical Sciences learning environment in conjunction with the correlation between metacognitive awareness and Physical Sciences learning environment, it could be said that the Physical Sciences classrooms in the Northern Cape often awarded learners the opportunity to develop their metacognitive awareness. The full extent to which Physical Sciences learning environments in the Northern Cape allowed learners the opportunity to develop their metacognitive awareness, is discussed in Chapter 6.

5.4 SUMMARY

This chapter focused on the analyses and interpretation of the data that were collected from the sample. The data were collected by means of a questionnaire that consisted of three sections. Section A addressed biographical data, Section B addressed metacognitive awareness, and Section C addressed the learning environment in Grade 10 and Grade 11 Physical Sciences classrooms. The questionnaire was found to be reliable with a high Cronbach's alpha coefficient of 0.923 for Section B, and of 0.916 for Section C. The data were then analysed and interpreted.

In this chapter the following objectives were addressed:

- Investigate learners' metacognitive awareness in Physical Sciences classrooms in the Northern Cape;
- Identify the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape;
- Investigate whether there is a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools;
- Investigate whether there is a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools.

From the biographical data that were collected and analysed it was discovered that the sample consisted of 48.1% boys and 51.9% girls with the majority of learners being 16 – 18 years old, although 23.5% of learners are older than they should be for their respective grades (see 5.3.1.1). It was also found that more than half of the learners were not taught Physical Sciences in their home language (see 5.3.1.2).

Regarding the metacognitive awareness in Physical Sciences classrooms learners from both Dinaledi and non-Dinaledi schools indicated that they often demonstrated metacognitive awareness. The mean value for metacognitive awareness was 3.61 for Dinaledi schools and 3.52 for non-Dinaledi schools. The difference in mean values could be an indicator that learners from Dinaledi schools demonstrated metacognitive awareness slightly more often that learners from non-Dinaledi schools. The data collected in regard with the learning environment revealed that the learners from both non-Dinaledi schools and Dinaledi schools often observed metacognitive learning environment characteristics in their Physical Sciences classrooms. The non-Dinaledi schools had a mean value of 3.41, while the Dinaledi schools had a mean value 3.37, indicating that the characteristics for a metacognitive learning environment was observed slightly more often in Physical Sciences classrooms in non-Dinaledi schools, than in Dinaledi schools.

Lastly, the correlation between metacognitive awareness and the Physical Sciences learning environment was also investigated to determine if the characteristics of a metacognitive learning environment reported in the Physical Sciences classroom could contribute to the metacognitive awareness of learners. The opposite could also hold true, namely that the lack of characteristics of a metacognitive learning environment in the Physical Sciences classroom could be a cause of lack of metacognitive awareness. For all three groups, it was found that there was a statistically significant correlation between the metacognitive awareness of learners and the Physical Sciences learning environment.

To answer the primary research question,

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

the researcher considered the analysed and interpreted data presented in this chapter to come to a conclusion. The primary research question is answered in Chapter 6, the final chapter of this study.

CHAPTER 6
FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The aim of this study was to investigate to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. In this chapter, the last chapter of the study, the researcher reflects on whether this aim was reached by reporting on the findings made in the empirical research, as well as the literature study. From the findings, conclusions were drawn regarding the metacognitive awareness of learners and metacognitive learning environments. Finally, recommendations are made based on the researcher’s interpretation of the conclusions on how Physical Sciences teachers could structure a learning environment that would enhance learners’ metacognitive awareness.

6.2 SUMMARY OF CHAPTERS

Learners performed poorly in the subject Physical Sciences (see Table 1.1), which led to a great deal of concern among role players and the situation had to be investigated. In Chapter 1, the researcher explained the importance of examining the metacognitive awareness of Physical Sciences learners, since it has been suggested that there is a relationship between metacognitive awareness and academic achievement (see 1.2). The learning environment was identified as a factor that strongly influences the metacognitive awareness of learners, and therefore the Physical Sciences learning environment was also investigated. The primary research question of the study was:

> *To what extent do the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness?*

The following secondary research questions were formulated to explore the primary research question:

- What knowledge and skills do learners need to master in Physical Sciences?
- What role does metacognition play in Physical Sciences learning?
- What are the different components of metacognition?

- What are the characteristics of a metacognitive learning environment for the Physical Sciences?
- To what extent do learners demonstrate metacognitive awareness in the Physical Sciences classrooms in the Northern Cape?
- What are the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape?
- Is there a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools?
- Is there a difference between the Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools?

In Chapter 2, the nature and structure of Physical Sciences was discussed and it was established that Physical Sciences has a dual nature, namely a substantive structure and a syntactical structure. The substantive structure addresses Physical Sciences knowledge, while the syntactical structure addresses the skills that should be developed in the subject. A framework for Physical Sciences was also constructed that would address the two dimensional nature of the subject, since it outlines the knowledge and skills that should be developed in the subject.

While Chapter 2 focused on what learners need to master in Physical Sciences, Chapter 3 focused on how those knowledge and skills are learnt. The learning theories of Piaget and Vygotsky were studied and the researcher concluded that knowledge should be actively constructed by learners in a suitable learning environment. Metacognition was identified as one of the key elements to guide construction of knowledge in Physical Sciences, since learners need to perform cognitive tasks to construct knowledge and will need metacognitive knowledge and strategies to manage their learning. The importance of metacognitive awareness in the Physical Sciences classroom was identified. The significance of a metacognitive learning environment in the Physical Sciences classroom was also emphasized as a key factor in the development of learners' metacognitive awareness.

In Chapter 4, the researcher accounted for how the phenomenon of metacognition awareness and metacognitive learning environments were investigated. The foundations for the research were explored. The research paradigm was, firstly, identified to be of a positivist nature. The research design was established next as being a survey design for which a quantitative research method would be used. The population, consisting of all learners taking Physical Sciences in the Northern Cape, was identified, and the sampling method, namely convenience sampling, was also discussed. The data collection instrument, being the questionnaire, was also discussed and it was indicated that it consisted out of three main sections. Section A focused on demographic information, Section B focused on the metacognitive awareness of learners in Physical Sciences, while Section C focused on the Physical Sciences classroom. The pilot study was also discussed. The Afrikaans version, translated from the reviewed English version, was used in the pilot study. Since the Afrikaans questionnaire was found to be reliable and valid, it implied that the reviewed English questionnaire was also valid to use a data collecting instrument. The data analysis procedures were also indicated and both descriptive and inferential statistics were used in analysing the data in Chapter 5. Lastly, the researcher reported on the ethical considerations that had to be taken into account and how the researcher addressed these considerations.

In Chapter 5, the researcher reported on the empirical investigation. The data that was collected from learners presenting Physical Sciences was analysed and interpreted in order to address the aim of the study. Descriptive statistics were used to determine the mean values and standard deviation for constructs. Inferential statistics were applied to determine the practical significance of the difference between the mean values for metacognitive awareness and the Physical Sciences learning environment. Inferential statistics were also used to determine the relationship between the metacognitive awareness of learners in Physical Sciences and the characteristics of the Physical Sciences classrooms.

What follows in this chapter is a summary of the research. Findings and conclusions are discussed to determine to what extent the Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness. The researcher provides answers for the primary research question in this final chapter by revisiting the objectives and summarising what has been established in each instance, namely:

- Investigate the knowledge and skills that learners need to master in Physical Sciences.
- Highlight the role that metacognition plays in Physical Sciences learning.
- Review the existing research into the different components of metacognition.
- Review the existing research into metacognitive learning environments for Physical Sciences classrooms.
- Investigate learners’ metacognitive awareness in Physical Sciences classrooms in the Northern Cape.
- Identify the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape.

- Investigate whether there is a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools.
- Investigate whether there is a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools.
- Provide recommendations based on the finding of this research that will enhance learners' performance in Physical Sciences.

6.3 FINDINGS AND CONCLUSIONS

6.3.1 The knowledge and skills that learners need to master in Physical Sciences

It was established that Physical Sciences has a two dimensional nature, namely a substantive and the syntactical structure (see 2.2). The substantive structure (see 2.2.1) refered to the knowledge that Physical Sciences learners need to have, namely facts, concepts, and generalisations. The syntactical structure (see 2.2.2) refered to the skills needed to master in Physical Sciences, such as sensorimotor skills, cognitive skills, techniques, observation, and a scientific language system, as well as discovery skills to take part in the scientific approach of constructing and applying knowledge.

The taxonomy that was discussed was the revised taxonomy of Anderson and Krathwohl (see 2.3.1) and consisted of two dimensions, namely a cognitive processing category dimension, and a knowledge type dimension. The knowledge types that were identified to be important in Physical Sciences are factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge (see 2.3.2). The knowledge types were further divided into knowledge subtypes. Six cognitive categories were also identified, namely remember, understand, apply, analyse, evaluate, and create. These six categories were further divided into numerous cognitive processes that each define the category (see 2.3.3). Incorporating the knowledge types and cognitive processes into the nature and structure of Physical Sciences, a framework for Physical Sciences knowledge and skills was created (see 2.4) to outline the knowledge and skills that Physical Sciences learners should be able to demonstrate to be successful in the subject. The framework also served to show the interconnectedness between the knowledge types and skills and also illustrates how learners could use inductive reasoning or deductive reasoning in Physical Sciences. While investigating the knowledge and skills learners need to master in Physical Sciences, it emerged that the learners should apply metacognitive knowledge and strategies to assist them to learn the different types of knowledge (factual knowledge is learnt differently from conceptual knowledge), to know what cognitive processes to apply to get to the desired outcome, especially with regards to problem solving and problems that have not been seen before (where procedural knowledge cannot be applied). It was therefore concluded that metacognition does play an important role in mastering the knowledge and skills in Physical Sciences. The extent to which metacognition influences Physical Sciences learning is discussed next.

6.3.2 Metacognition and Physical Sciences learning

It has been established that learners should learn Physical Sciences through socially interacting with mediators in an environment structured to help them to actively construct knowledge through assimilation and accommodation of knowledge (see 3.2). Since learning is an active task and learners should be constructing their own knowledge and information it cannot merely be passed on to the learner but they should rather be actively involved in constructing their own knowledge. Constructing knowledge is a process that takes place through accommodation and assimilation of knowledge, and through mediation. It is suggested that learners could make use of metacognition to plan, monitor, adapt, and evaluate the learning process so that they could learn effectively (see 3.3).

Metacognition has been identified as a learners’ awareness of his or her own learning and learning in general (see 3.3). After consulting various sources, it has been determined that metacognition could be divided into two main components, namely knowledge of cognition, and regulation of cognition.

Knowledge of cognition refers to the knowledge that a learner should have about his or her cognition of cognition in general (see 3.3.2.1). Knowledge of cognition could be further divided into three components, namely declarative knowledge, procedural knowledge, and conditional knowledge. Declarative knowledge (see 3.3.2.1.2) refers to the knowledge that learners have about themselves and about factors that could influence their performance. Procedural knowledge refers to the knowledge learners have about different learning or problem solving strategies (see 3.3.2.1.1), while conditional knowledge refers to learners knowing when and why they apply certain strategies when presented with a cognitive task (see 3.3.2.1.3).

Regulation of cognition refers to the strategies an individual would apply to control thinking and learning (see 3.3.2.2). These include strategies such as planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. Planning refers to a learner’s ability to select appropriate strategies and use the appropriate resources or tools to reach a learning outcome or objective (see 3.3.2.2.1). Information management is a regulatory skill where learners process new information to construct knowledge (see 3.3.2.2.2). Comprehension monitoring refers to a learner's ability to be aware of comprehension and performance while completing a task (see 3.3.2.2.3). De-bugging strategies could be used to identify and correct misconceptions (see 3.3.2.2.4), while evaluation could be defined as appraising the products and efficiency of learning (3.3.2.2.5). The role that knowledge of cognition and regulation of cognition plays in the learning of Physical Sciences was also discussed and the importance of metacognition in Physical Sciences learning was established.

Furthermore, the relationship between metacognition and effective Physical Sciences learning was also highlighted and it was found that metacognition is a key factor in effective learning (see 3.4). By applying knowledge of their cognition and by regulating their cognition, Physical Sciences learners could learn in a way that is constructive (3.4.1), cumulative (3.4.2), self-regulated (3.4.3), goal orientated (3.4.4), situated and collaborative (3.4.5), and individually different (3.4.6).

It could therefore be concluded that the objective to highlight the role that metacognition plays in metacognition was reached, as well as the objective to review the different components of metacognition.

6.3.3 Characteristics of a metacognitive learning environment for the Physical Sciences

A metacognitive learning environment is necessary to develop metacognitive awareness and usage among learners in Physical Sciences. The researcher studied literature sources to characterise a metacognitive learning environment for the Physical Sciences classroom (see 3.5). The following criteria were identified for the metacognitive learning environment:

- Metacognitive demands
- Student-student discourse
- Student-teacher discourse
- Student voice
- Distributed control
- Teacher encouragement and support
- Emotional support

The concept Metacognitive demands refers to challenging learners to reflect on how they learn Physical Sciences, as well as how they think they could improve their Physical Sciences learning (see 3.5.1). Learners should be encouraged to explicitly define how they learn, solve problems and think in order to develop their metacognition. Explicitly thinking about thinking is not a process that occurs naturally to learners. Student-student discourse should be allowed and encouraged to re-inforce explicitly defined learning, thinking, and problem solving. Learners should be prompted to engage in dialogue about how they learn and how they could improve their learning, since learning takes place in social context (see 3.5.2 and 3.5.3). Since learners are encouraged to define and explain their learning processes, they should also be allowed to question the teacher's methods and strategies, and their queries, opinions and suggestions should be taken seriously (see 3.5.4). Giving learners the opportunity to make suggestions and to question classroom practices will increase self-regulation and learner autonomy, which are important in establishing a metacognitive learning environment. Once questions, queries, suggestions and opinions have been voiced, learners should be allowed to assist the teacher in negotiating learning activities, which will improve their understanding of the subject and enhance meaningful learning (see 3.5.5).

Since the metacognitive learning environment poses many new challenges – such as taking control of one's own learning – the teacher should encourage and support learners to develop their self-regulatory and metacognitive skills. Learners may struggle to meet metacognitive demands or they might find it daunting to interact with other learners about learning or even to make suggestions to the teacher about how the learning activities might be adapted to meet their learning needs Teacher encouragement and support in the metacognitive learning environment are therefore of high importance so that learners could feel safe and learn with ease (see 3.5.6). Furthermore, teachers should make sure that there is enough emotional support for the learners to be successful in the learning environment. Emotional support does not only originate from the teacher as learners could also support each other emotionally, but the teacher is responsible for creating a climate where there are emotional support structures in place. Learners should feel safe in the learning environment so that when they do make a mistake it is seen as part of the learning process and not a reflection on them as a person (see 3.5.7).

It could therefore be concluded that the objective to review existing research into metacognitive learning environments for Physical Sciences classrooms, was reached.

It is necessary to discuss learner's experiences of the learning environment that was structured for Physical Sciences in the Northern Cape to see if it met the demands for developing learners' metacognition.

6.3.4 Learners' metacognitive awareness in Physical Sciences classrooms in the Northern Cape

In order to determine the extent of Northern Cape Physical Sciences learners' metacognitive awareness, empirical data were collected. The empirical study revealed that learners in the Northern Cape presenting Physical Sciences as a subject, were *often* aware of their metacognition, with a mean value of 3.57. This means that they were often aware of their metacognition when executing tasks in Physical Sciences (see 5.3.2).

Apart from determining the metacognitive awareness of Physical Sciences learners in the Northern Cape, it was also the objective of the research to investigate whether there was a difference between the metacognitive awareness of learners in Dinaledi schools and non-Dinaledi schools. In order to investigate this matter, the metacognitive awareness of learners from Dinaledi schools were compared to the metacognitive awareness of learners from non-Dinaledi schools.

It was found that both groups of learners were often aware of their metacognition when engaged in Physical Sciences tasks (see 3.5.2). For metacognitive awareness, the Dinaledi schools had a mean value of 3.60 while the non-Dinaledi schools group had a mean value of 3.52. These two mean values were comparable and indicated the same level of metacognitive awareness, namely that these learners were *often* aware of their metacognitive awareness, and a weak practical significant difference was found between the two groups.

On closer inspection of the different components of metacognition, Physical Sciences learners from Dinaledi schools indicated that they *often* applied all the subcomponents of metacognition, namely procedural knowledge, declarative knowledge, conditional knowledge, planning, information management systems, debugging strategies, comprehension monitoring, and evaluation (see 3.5.2). Physical Sciences learners from the non-Dinaledi schools indicated that they *often* applied procedural knowledge, declarative knowledge, planning and debugging strategies but that they only *sometimes* applied conditional knowledge, information management strategies, comprehension monitoring, and evaluation (see 3.5.2). The Physical Sciences learners from non-Dinaledi schools only demonstrated half of the subcomponents of metacognitive awareness on the *often* scale, which contributed to the lower mean value for metacognitive awareness when compared to Dinaledi schools.

It could thus be concluded that the objective for investigating whether there was a difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools have been reached. It was determined that there was no practical statistical difference between the metacognitive awareness of learners in Dinaledi and non-Dinaledi schools. Both groups also indicated that they are *often* aware of their metacognition. The learners from non-Dinaledi schools did however indicate that they do not demonstrate all aspects of metacognition as frequently as the learners from Dinaledi schools.

6.3.5 Identify the characteristics of the learning environments that are structured for Physical Sciences in the Northern Cape

The overarching aim of the research was to determine to what extent the Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. In order to reach the aim, the researcher first had to identify the characteristics of a metacognitive learning environment that were being observed in the sample, namely Grade 10 and Grade 11 Physical Sciences classrooms. The empirical research suggests that Physical Sciences classrooms in the Northern Cape were *sometimes* observed as being metacognitive learning environments (see 5.3.3).

Apart from determining the metacognitive awareness of Physical Sciences learners in the Northern Cape, it was also the objective of the research to investigate whether there was a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools. The schools were divided into two groups, Dinaledi schools and non-Dinaledi schools. Dinaledi schools received additional funding to promote subjects such as mathematics and Physical Sciences, while non-Dinaledi schools did not, which means that Dinaledi schools did receive additional resources that they could have applied to improve Physical Sciences learning environments (see 1.2). In order to investigate this matter, the characteristics of a metacognitive learning environment observed in Physical Sciences classrooms in Dinaledi schools were compared to those of non-Dinaledi schools.

The means of the different characteristics of a metacognitive learning environment were inspected closely. Both Dinaledi and non-Dinaledi schools reported that distributed control was *seldom* experienced, which indicated that in Physical Sciences classrooms in the sample, teachers were mostly in control and responsible for what happened in the classroom and it could be an indication of teacher centred teaching strategies. In non-Dinaledi schools distributed control had a lower mean value than in Dinaledi schools, which possibly indicated that in non-Dinaledi schools Physical Sciences classrooms might be slightly more teacher-centred.

Learners from Dinaledi and non-Dinaledi schools indicated that the characteristics, student-student discourse and student-teacher discourse were only *sometimes* observed (see 5.3.3).

If the learning environment does not allow opportunities for distributed control, discourse will not be observed often and learners will only sometimes be allowed to engage with each other and the teacher regarding learning, thinking and problem solving. Once again, the Dinaledi schools had higher mean values for discourse indicating that in Physical Sciences classrooms in Dinaledi schools learners and teachers engaged slightly more in dialogue about learning, thinking and problem solving in Physical Sciences.

The characteristics, metacognitive demands, student voice, teacher encouragement and support, and emotional support were *often* observed by Physical Sciences learners in both Dinaledi and non-Dinaledi schools. It is interesting to note that, although distributed control was not observed often in the Physical Sciences learning environment, the learners were often allowed to make suggestions and to question classroom practices, as indicated by the characteristic *student voice*. When comparing the mean values for the characteristics falling in the *often* scale, it was found that Dinaledi schools had a higher mean value for metacognitive demands than non-Dinaledi schools. This might suggest that in Dinaledi schools learners were more often challenged to think about how they learned Physical Sciences and how they solved problems in the subject. The mean values for teacher encouragement and support, emotional support, and student voice, were considerably higher for non-Dinaledi schools than for Dinaledi schools. The mean value for emotional support had a mean value of 4.19, the highest mean value recorded of all the constructs in the questionnaire. This suggests that in Dinaledi schools learners were allowed to make suggestions and question classroom practices more often than in non-Dinaledi schools. They also received more encouragement and support from their teachers, which allowed them to try different ways to improve their Physical Sciences learning. Physical Sciences classrooms in non-Dinaledi schools also had more emotional support structures in place so that they could be successful in the subject.

It is interesting to note that despite the fact that Dinaledi schools received funding to improve the Physical Sciences learning environment, non-Dinaledi schools had a mean value of 3.41 for observing the Physical Sciences classroom to be a metacognitive learning environment, while Dinaledi schools had a mean value of 3.37. The Physical Sciences learning environment in both Dinaledi and non-Dinaledi schools was *sometimes* observed to be a metacognitive learning environment (see 5.3.3). Although non-Dinaledi schools had a greater mean value for the metacognitive learning environment than Dinaledi schools, the difference between the mean values of the two groups were found to have a weak practical significance (see 5.3.3)

It could therefore be concluded that the objective for investigating whether there was a difference between the Physical Sciences learning environments in Dinaledi Schools and non-Dinaledi Schools had been reached. It was determined that there although there was a slight difference between the Physical Sciences learning environments in Dinaledi and non-Dinaledi schools, there was no practical significant difference between the Physical Sciences learning environments in the two types of schools, as learners from groups reported that they *often* observe metacognitive learning environment characteristics in their Physical Sciences classrooms.

6.3.6 The extent to which Physical Sciences learning environments in the Northern Cape afford learners the opportunity to develop metacognitive awareness

The aim of the research was to determine to what extent Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. This was done by first investigating the knowledge and skills learners need to master in Physical Sciences. Metacognition was identified as playing a possible role in acquiring knowledge and skills in Physical Sciences. The need for metacognitive awareness in Physical Sciences learning was highlighted by analysing how Physical Sciences learning takes places. Existing research into the components of metacognition was then reviewed and when the components were analysed with reference to Physical Sciences learning, the importance of metacognitive awareness in effective Physical Sciences learning was established. The metacognitive learning environment was then identified as a factor that could improve learners' metacognitive awareness, and existing research into metacognitive learning environments was reviewed and applied to Physical Sciences classrooms. Learners' metacognitive awareness in Physical Sciences classrooms in the Northern Cape was investigated and the difference between learners' metacognitive awareness in Dinaledi schools and non-Dinaledi schools was also established. The characteristics of learning environments that were structured for Physical Sciences in the Northern Cape were also identified and the difference between Physical Sciences learning environments in Dinaledi schools and non-Dinaledi schools was also established. The correlation between learners' metacognitive awareness in Physical Sciences and their Physical Sciences learning environments was also established. The literature and empirical research done in this study now provides the researcher with evidence to provide an answer to the primary research question.

From the data that was analysed, it was determined that there was a significant positive correlation between the Physical Sciences learning environment and learners' metacognitive awareness in Physical Sciences. This was the case for all schools in the Northern Cape, both for Dinaledi schools and non-Dinaledi schools (see 5.3.4). This indicates that the characteristics of the learning environment did have an impact on learners' metacognitive awareness. The research suggests that in Physical Sciences classrooms, where characteristics of the metacognitive learning environment are more frequently observed, the learners in that classroom had higher levels of metacognitive awareness in the subject. The opposite is then also suggested to be true – in Physical Sciences classrooms where characteristics of the metacognitive learning environment are less frequently observed, the learners in that classroom had lower levels of metacognitive awareness in the subject. If the metacognitive awareness of learners has to be improved, one possible way to do this would be to adapt the learning environment to be a metacognitive learning environment. In a metacognitive learning environment learners are challenged to use and develop their metacognitive awareness, which can result in learners developing their metacognitive awareness – resulting in the relationship between metacognitive awareness and metacognitive learning environments.

In order to answer the primary research question and come to a conclusion, all the research had to be taken into account. Since there was a relationship between Physical Sciences learning environments in the Northern Cape and the metacognitive awareness of learners in Physical Sciences classrooms in the Northern Cape, the extent to which the learning environment allowed for metacognitive development could be interpreted in terms of metacognitive awareness of the learners in the learning environment. It was established that Physical Sciences classrooms in the Northern Cape were overall *sometimes* observed as being metacognitive learning environments. The Dinaledi schools and the non-Dinaledi schools also showed the same results. Learners were only *sometimes* afforded the opportunity to develop in the Physical Sciences classroom, while they were *often* afforded the opportunity to develop declarative knowledge, conditional knowledge, planning, debugging strategies, and comprehension monitoring. In Dinaledi schools learners were *often* afforded the opportunity to develop all of the aspects of metacognitive awareness in their Physical Sciences classroom. In the non-Dinaledi schools learners were *sometimes* afforded the opportunity to develop procedural knowledge, information management strategies, comprehension monitoring, and evaluation, while they were *often* afforded the opportunity to develop declarative knowledge, conditional knowledge, planning, and debugging strategies in their Physical Sciences classrooms.

It could therefore be concluded that the aim of this study, to determine to what extent Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness, was reached and it was determined that Physical

Sciences learning environments in the Northern Cape do not always afforded learners the opportunities to develop their metacognitive awareness in Physical Sciences.

6.4 RECOMMENDATIONS

It was established that the Physical Sciences learning environments in Grade 10 and Grade 11 classes in the Northern Cape did not always provide learners with the opportunity to develop their metacognitive awareness in the subject. Based on the findings and conclusions made in this research, recommendations that might enhance learners' performance in Physical Sciences are consequently made here.

Since there is a correlation between the learning environment and learners' metacognitive awareness, the recommendations address the characteristics of the metacognitive learning environment and how these characteristics could be incorporated into Physical Sciences classrooms in the Northern Cape.

6.4.1 Distributing control in the Physical Sciences classroom

Distributed control was the characteristic of a metacognitive learning environment that was reported to be seldom observed in Physical Sciences classrooms in the Northern Cape (see 5.3.3). Distributed control means that the learners assist the teacher in negotiating learning activities (see 3.5.5). Distributed control could be achieved in Physical Sciences classrooms if teachers involved learners in planning what needs to be studied, what activities will be done, as well as time frames. In Physical Sciences, the teacher could distribute control by asking learners to assist in planning what needs to be studied for a Physical Sciences test or what topic for an assignment should be. Learners could also assist the teacher in selecting activities that should be done for homework, classwork or practical activities. The learners could also help the teacher decide how much time they should spend on an activity and if they are ready to start a new unit in Physical Sciences. The CAPS document prescribes the content and also indicates the time frame in which it should be completed, but since learning is cumulative (see 3.4.2), new knowledge cannot be constructed if the prior knowledge is not in place. Asking learners to give feedback on how well they understand a topic before moving on to the next one is therefore crucial.

The characteristic *student voice* was reported to be observed often in the Physical Sciences classroom. Although this characteristic was observed more than *distributed control*, there is still room for improvement. When *distributing control* in the classroom and learners are asked for their input, their suggestions, opinions and ideas should be taken seriously (see 3.5.4).

Student voice should be heard by providing opportunities to learners to give feedback on Physical Sciences learning experiences, which will assist teachers in addressing the learners learning needs.

Distributed control could, however, only be achieved if learners know their strengths and weaknesses regarding Physical Sciences learning through applying declarative knowledge (see 3.3.2.1.2). *Student voice* is the characteristic which could assist in this regard. They should also know what they understand and what they don’t understand about a certain topic in order to help select activities that will be beneficial to their learning process. This requires learners to apply comprehension monitoring (see 3.3.2.2.3). Since there is a positive correlation between the Physical Sciences learning environment and metacognitive awareness, allowing distributed control in the Physical Sciences learning environment could help learners to develop metacognitive awareness by addressing the two components identified above.

6.4.2 Discussing learning and metacognition in the Physical Sciences classroom

Student-student discourse and *student-teacher discourse* were identified as two characteristics of the metacognitive learning environment that were *sometimes* observed in the Physical Sciences classrooms in the Northern Cape. In order to create the environment where learners could engage in discussions about Physical Sciences learning, as well as metacognitive awareness in Physical Sciences, learners should first be prompted to think about their Physical Sciences learning. Metacognitive demands were reported to be observed often in Physical Sciences classrooms in the Northern Cape (see 5.3.3). This means that Physical Sciences teachers often asked their learners to think about how they learn Physical Sciences, how they solved problems in Physical Sciences, what makes it difficult for them to learn Physical Sciences and how they could improve their Physical Sciences learning, but it needs to be taken a step further. Since knowledge is constructed through mediation (see 3.2.2 and 3.5.2) dialogue is necessary in the Physical Sciences classroom to facilitate metacognitive development. Once the teacher has asked the learners to reflect on their Physical Sciences learning they could initiate discussions during which learners could discuss how they learn Physical Sciences, how they think when they learn Physical Sciences, and what they could do to improve their Physical Sciences learning. The same type of discussion could be initiated when learners are given a problem to solve. They could be prompted to discuss what cognitive strategies they will use, what steps they will follow to solve the problem, and why they will follow the steps in that order.

More than half of the learners from the sample were not taught Physical Sciences in their home language (see 5.3.1.2). Engaging learners in discussions regarding their Physical Sciences learning could also increase their competence in the language of instruction and help them to think in the language of instruction.

When asking learners to talk about their learning and problem solving strategies is this way, they could become aware of their procedural knowledge (see 3.3.2.1.1), because they have to focus on the strategies and procedures they would use to learn Physical Sciences or solve a problem. Conditional knowledge (3.3.2.1.3) could also be applied when learners have to explain how and why they used certain strategies. Learners might also apply regulation of cognition when discourse is allowed in the Physical Sciences classroom during problem solving and learning.

Learners could also be asked to explain their reasoning to another learner or the teacher while they are solving the problem. Regulation of cognition which includes planning (see 3.3.2.2.1), information management strategies (see 3.3.2.2.2), comprehension monitoring (see 3.3.2.2.3), debugging strategies (see 3.3.2.2.4), and evaluation (see 3.3.2.2.5) will then also be developed as learners will reflect on their problem solving practices.

6.4.3 Providing support in the Physical Sciences classroom

Emotional support and *teacher encouragement and support* were two characteristics that were indicated to occur *often* in the Physical Sciences classroom. Support in the Physical Sciences classroom requires that the teacher provides encouragement and support for learners to improve their Physical Sciences learning (see 3.5.6), as well as emotional support to improve learner self-efficacy (see 3.5.7). Learners are more likely to take part in discussions regarding their Physical Sciences learning in a learning environment where all learners are treated fairly, equally, and are respected by the teacher and other learners. Teachers could create a supporting Physical Sciences learning environment by encouraging learners to improve their Physical Sciences learning, trying new ways of learning Physical Sciences, and taking part in discussions about Physical Sciences learning. When teachers encourage learners to discuss their Physical Sciences learning, they also address characteristics of student-student discourse and student-teacher discourse (see 6.4.2, 3.5.2 and 3.5.3).

6.5 LIMITATIONS OF THE STUDY

Although the researcher managed to provide answers to the research questions posed, there are still limitations to the study that have to be elucidated:

- The researcher only included Grade 10 and Grade 11 learners in the sample group. The data are also not represented separately, but combined for Grade 10 and 11 learners. If more grades were included in the study, such as Grades 8 and 9, and even Grade 12, it could have been possible to see if metacognitive abilities improved with age or not.
- The data collected about the Physical Sciences classrooms as metacognitive learning environments represent perceptions of the learners in the classroom. It would be interesting to triangulate the perceptions which the learners have about their learning environments with qualitative data obtained from classroom visits and observations. This might yield richer and more accurate representations of the Physical Sciences classrooms in the Northern Cape.
- Due to various reasons, as discussed in Chapter 1 and Chapter 4, the data were collected in 2012, but the study was only completed in 2016 and submitted for assessment in January 2017 due to unforeseen circumstances. The results represented in this study are therefore not a representation of current Physical Sciences classrooms.

6.6 FUTURE RESEARCH

The following topics were identified as areas of interest for future studies:

- Metacognition is a generic skill, yet it has to be practiced in a specific subject to ensure that learners could apply their metacognitive abilities in that subject. It would be interesting to test the metacognitive awareness of the same learners in different subjects and see how these compare.
- The role of the teacher with regard to metacognitive development could also be studied. Although active and self-regulated learning are advocated for metacognitive development, the teacher plays a vitally important role in structuring and facilitating learning experiences in which this type of learning could take place.
- Discourse was highlighted as an important characteristic of metacognitive learning environments (see 3.5.2 and 3.5.3). In many instances, the language of learning and teaching was not the same as either the learners' home language or mother tongue.

A possible future study could look at the impact that exposure to discourse about learning and thinking in the subject Physical Sciences could have on learners' metacognitive awareness and performances.

- Although no practical significant difference were found between the Dinaledi schools and non-Dinaledi schools in terms of metacognitive awareness and the Physical Sciences learning environment, the learners from non-Dinaledi schools did indicate that they do not demonstrate all aspects of metacognitive awareness as frequently as learners from Dinaledi schools do (see 5.3.2). The reason for these discrepancies could also be investigated in future studies.

6.7 CONCLUDING REMARKS

The aim of this study was to determine to what extent Physical Sciences learning environments in the Northern Cape afforded learners the opportunity to develop metacognitive awareness. The aim was reached and it was found that Physical Sciences learning environments only sometimes afforded learners the opportunity to develop metacognitive awareness. Since there is a positive correlation between metacognitive awareness and the Physical Sciences learning environment, the metacognitive awareness of learners could be improved by adapting the Physical Sciences learning environment by distributing control, allowing opportunities for discussion about learning and metacognition, and providing support. Developing learners' metacognitive awareness in Physical Sciences could have a positive effect on their performances in the subject in order to address the poor Physical Sciences results in the Northern Cape.

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APPENDIX A: ETHICS APPROVAL OF PROJECT

Faculty of Education
Ethics Office

Room 12
Winkie Direko Building
Faculty of Education
University of the Free State
P.O. Box 339
Bloemfontein 9300
South Africa

T: +27(0)51 401 9922
F: +27(0)51 401 2010

www.ufs.ac.za
BarclayA@ufs.ac.za

23 May 2012

ETHICAL CLEARANCE APPLICATION:

CREATING A METACOGNITIVE LEARNING ENVIRONMENT IN PHYSICAL SCIENCE CLASSROOMS

Dear Ms Heidi Hanekom

With reference to your application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence, is:

UFS-EDU-2012-0020

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension in writing.

We request that any changes that may take place during the course of your research project be submitted in writing to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise. At the conclusion of your research project, please submit a project report stating how the research progressed and confirming any changes to methodology or practice that arose during the project itself. This report should be under 500 words long and should contain only a brief summary focusing primarily on ethical considerations, issues that may have arisen and steps taken to deal with them during the course of the research.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours sincerely,

Andrew Barclay
Faculty Ethics Officer

APPENDIX B:
LETTER OF APPROVAL TO CONDUCT RESEARCH IN HIGH SCHOOLS IN THE NORTHERN CAPE PROVINCE

0538329557 01:05:10 p.m. 07-08-2012 3 /4

PLEASE COMPLETE THE FOLLOWING AND RETURN:

I, H.H. ESAU (name and surname) in my position as CHIEF DIRECTOR: DISTRICTS grant permission for the research, as described in the letter to which this form is attached, to be conducted by Ms H Hanekom.

Signature:

Date: 20/08/2012

Condition that research outcome must be availed to the NC Dept. of Education and identified schools & no normal schooling programme should be disrupted.

(CD: DISTRICTS)

APPENDIX C:
LETTER TO DEPARTMENT OF EDUCATION FOR PERMISSION TO CONDUCT RESEARCH

19 June 2012

DEPARTMENT OF EDUCATION: FRANCES BAARD DISTRICT

Private Bag X5041

Kimberley

8300

Dear Mr Esau

APPLICATION FOR CONDUCTING OF RESEARCH IN THE NORTHERN CAPE PROVINCE

I wish to apply for permission to conduct research in the Northern Cape Department of Education for my Masters studies at the University of the Free State. My research topic is metacognitive learning environments in Physical Sciences classrooms.

The study will focus on the improvement of Grade 12 learners' Physical Sciences performances by enhancing their metacognitive abilities in a metacognitive-oriented learning environment. Data will be collected to identify to what extent the current learning environment allows Physical Sciences learners to develop their metacognitive abilities. The research will also aim at providing recommendations for developing Physical Sciences teachers' competence in creating learning environments that develop metacognition in learners.

The data will be collected by means of questionnaires. The questionnaires will be distributed among schools, in the Frances Baard district, who present Physical Sciences as a subject and will be completed by Grade 12 Physical Sciences learners. The questionnaires will be completed anonymously and parents' / guardians' will be informed.

Please feel free to contact me or my supervisor should there be any questions or problems.

Thank you for your attention.

Yours sincerely

Ms H HANEKOM (RESEARCHER)	Dr ER DU TOIT (SUPERVISOR)
Hanekom	EduToit.
Contact: 082 084 8237	Contact: 051 401 3211
E-mail: dannhauserheidi5@gmail.com	E-mail: dutoiter@ufs.ac.za

PLEASE COMPLETE THE FOLLOWING AND RETURN:

I, ……………………………………………………………………(name and surname) in my position as………………………………. ………………………...grant permission for the research, as described in the letter to which this form is attached, to be conducted by Ms H Hanekom.

Signature:	Date:
…………………………..	………………………….

APPENDIX D:
LETTER TO PRINCIPALS FOR PERMISSION TO CONDUCT RESEARCH AT SCHOOLS

15 October 2012

Dear Sir / Madam

APPLICATION FOR CONDUCTING RESEARCH AT ST. BONIFACE HIGH SCHOOL

I wish to apply for permission to conduct research at St. Boniface High School for my Masters studies at the University of the Free State. My research topic is metacognitive learning environments in Physical Sciences classrooms.

The study will focus on the improvement of Northern Cape Grade 12 learners' Physical Sciences performance by enhancing their metacognitive abilities in a metacognitive-oriented learning environment. Data will be collected to identify to what extent the current learning environment allows Physical Sciences learners to develop their metacognitive abilities. The research will also aim at providing recommendations on developing Physical Sciences teachers' competence in creating learning environments to develop metacognition in learners.

The data will be collected by means of a questionnaires. The questionnaires will be completed by Grade 10 and 11 Physical Sciences learners. Questionnaires will be completed anonymously and with parents' / guardians' permission. The questionnaire will take 30 minutes to complete.

The data obtained will only be used for my Master studies.

Please feel free to contact me or my supervisor should there be any questions or problems.

Thank you for your attention.

Yours sincerely

Ms H HANEKOM (RESEARCHER) Dr ER DU TOIT (SUPERVISOR)

HHanekom EduToit.

_________________________ _________________________ Contact: 082 084 8237 Contact: 051 401 3211

E-mail: dannhauserheidi5@gmail.com E-mail: dutoiter@ufs.ac.ZA

PLEASE COMPLETE THE FOLLOWING AND RETURN:

I, ………………………………………………………………………… principal of ……………………………………………………………………….. High School grant permission to Ms. H. Hanekom to conduct research, as described in the letter attached to this form, at the school.

Signature: Date:

……………………………………………………….. …………………………..

APPENDIX E:
LETTER TO PARENTS FOR PERMISSION TO ADMINISTER QUESTIONNAIRES TO THEIR CHILDREN

October 2012

Dear Sir / Madam

PERMISSION TO CONDUCT RESEARCH

I wish to ask permission to administer a questionnaire to your child as part of my Masters studies at the University of the Free State.

The purpose of the study is to explore Physical Sciences classrooms in the Northern Cape, as well as learners' use of thinking skills in the subject.

The completion of the questionnaire is voluntary, but it will be greatly appreciated if your child does complete a questionnaire. The questionnaires will be completed anonymously and all information gathered will be private and confidential and will not be made public to the school or any other person.

If you have any questions, queries or problems, please feel free to contact me or my supervisor.

Thank you for your attention.

Yours sincerely

Ms H HANEKOM (RESEARCHER) Dr ER DU TOIT (SUPERVISOR)

HHanekom EduToit.

Contact: 082 084 8237 Contact: 051 401 3211

E-mail: dannhauserheidi5@gmail.com E-mail: dutoiter@ufs.ac.za

---

PLEASE COMPLETE AND RETURN TO THE SCHOOL

I, ………………………………………………………………………., parent /guardian of ………………………………………………………………………. grant permission for the completion of the questionnaire as described in the letter attached to this form.

Signature:…………………………… Date:…………………………

APPENDIX F:
LETTER TO LEARNERS FOR PERMISSION TO ADMINISTER QUESTIONNAIRES TO THEM

October 2012

Dear Physical Sciences Learner

PERMISSION TO CONDUCT RESEARCH

I wish to ask you to complete a questionnaire as part of my Masters studies at the University of the Free State.

The purpose of the study is to explore Physical Sciences classrooms in the Northern Cape as well as learners' use of thinking skills in the subject.

You are under no obligation to complete the questionnaire. The questionnaire will be completed anonymously (you won't have to write down your name) and the information gathered will be private and will not be shown to any other person.

Thank you for your attention.

Yours sincerely,

Ms H HANEKOM (RESEARCHER)	Dr ER DU TOIT (SUPERVISOR)
HHanekom	EduToit.
Contact: 082 084 8237	Contact: 051 401 3211
E-mail: dannhauserheidi5@gmail.com	E-mail: dutoiter@ufs.ac.za

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PLEASE COMPLETE AND RETURN

I, …………………………………………………………………….(name and surname) understand that I do not have to complete the questionnaire, but that I am willing to do so.

Signature: ……………………………………… Date: ……………………………

APPENDIX G:
QUESTIONNAIRE (ENGLISH)

QUESTIONNAIRE

QUESTIONNAIRE TO PHYSICAL SCIENCES LEARNERS CONCERNING ASPECTS ON THEIR METACOGNITIVE AWARENESS IN PHYSICAL SCIENCES AND THEIR EXPERIENCE OF THEIR PHYSICAL SCIENCES CLASSROOM AS A METACOGNITIVE LEARNING ENVIRONMENT.

The questionnaire is compiled in three sections:

- Section A: Demographic particulars
- Section B: Metacognitive Awareness
- Section C: Metacognitive Orientated Leaning Environment in the Physical Sciences classroom.

General Information:

1. This questionnaire consists of 8 pages. To complete this questionnaire will not take more than 30 minutes.
2. The purpose of the research is to investigate whether Physical Sciences classrooms provide the opportunity for learners to develop certain thinking skills.
3. It is important that you answer all the questions as **honestly** as possible. Remember, this is not an assessment of you or your school.
4. Your response will be very valuable for my research. The identity of your school or yourself will not be revealed. These questionnaires will only be handled by myself. All information will be kept strictly confidential.

Thank you for being willing to complete this questionnaire.

SECTION A: DEMOGRAPHIC PARTICULARS

Circle around the number of the statement of your choice.

Example

I live in South Africa	[✓ 1]
I do not live in South Africa	2

1. Sex	
Male	1
Female	2
2. Home Language	
Afrikaans	1
English	2
Sotho	3
Tswana	4
Xhosa	5
Zulu	6
Other (Write down)	7
3. Age (in years)	
16	1
17	2
18	3
19	4
20	5
21	6
Older	7
4. In which grade were you in 2011	
10	1
11	2
12	3
5. Percentage that you received in the June 2012 exam for Physical Sciences	
Paper 1 (Physics)	Paper 2 (Chemistry)

SECTION B: METACOGNITIVE AWARENESS

This section investigates aspects concerning metacognitive awareness. The following is important:

- There are no right or wrong answers
- Answer these questions about how you study Physical Sciences as accurately as possible
- Choose one of the five point answers that best describes when you do something and circle it.
    1. Almost never
    2. Seldom
    3. Sometimes
    4. Often
    5. Almost always

Example:

I like to eat sweets	1	2	3	[✓ 4]	5

If you like to eat sweets **often**, you circle 4.

1. Almost never	2. Seldom	3. Sometimes	4. Often	5. Almost always

1.	I ask myself regularly if I am achieving my goals in Physical Sciences.	1	2	3	4	5
2.	I look at more than one possibility to solve a Physical Sciences problem before I answer.	1	2	3	4	5
3.	In Physical Sciences I try to use ways of doing things that have worked in the past.	1	2	3	4	5
4.	When I learn Physical Sciences I make sure that I don’t spend too much time learning one thing, so that I will have enough time to learn everything in.	1	2	3	4	5
5.	I know what I am good at and what I am weaker at when it comes to Physical Sciences.	1	2	3	4	5

6.	I think about what I really need to learn before I begin a Physical Sciences task	1	2	3	4	5
7.	When I have finished a Physical Sciences test, I know if my marks are going to be good or bad..	1	2	3	4	5
8.	I set specific goals before I begin a Physical Sciences task.	1	2	3	4	5
9.	When I learn Physical Sciences, I slow down when I get to important information.	1	2	3	4	5
10.	In Physical Sciences, I know what kind of information is most important to learn.	1	2	3	4	5
11.	I ask myself if I have looked at all the possibilities when solving a Physical Sciences problem.	1	2	3	4	5
12.	I am good at organising Physical Sciences information.	1	2	3	4	5
13.	I try my best to focus my attention on important Physical Sciences information.	1	2	3	4	5
14.	I have a specific goal in mind for each strategy I use in Physical Sciences.	1	2	3	4	5
15.	I learn Physical Sciences best when I already know something about the work I am learning.	1	2	3	4	5
16.	I know what the teacher wants me to learn for Physical Sciences.	1	2	3	4	5
17.	I am good at remembering Physical Sciences information.	1	2	3	4	5
18.	I learn Physical Sciences in different ways for different situations.	1	2	3	4	5
19.	After I finish a task in Physical Sciences, I ask myself if there was an easier way to do it.	1	2	3	4	5
20.	I could control how well I learn Physical Sciences.	1	2	3	4	5
21.	I regularly think backwards to help me understand important relationships between variables in Physical Sciences.	1	2	3	4	5

22.	I ask myself questions about the work before I start learning Physical Sciences.	1	2	3	4	5
23.	I think of more than one different way to solve a Physical Sciences problem and choose the best one.	1	2	3	4	5
24.	I summarise what I’ve learned after I finish learning Physical Sciences.	1	2	3	4	5
25.	I ask others for help when I don’t understand something in Physical Sciences.	1	2	3	4	5
26.	I could tell myself to learn Physical Sciences when I don’t really want to.	1	2	3	4	5
27.	I am aware of the ways in which I learn my Physical Sciences work.	1	2	3	4	5
28.	While I learn Physical Sciences, I try to think about whether my way of learning is useful or not.	1	2	3	4	5
29.	I use what I’m good at to make up for what I’m bad at when it comes to Physical Sciences.	1	2	3	4	5
30.	I give all my attention to the meaning and importance of new Physical Sciences information.	1	2	3	4	5
31.	I make up my own examples to make Physical Sciences information more meaningful to me.	1	2	3	4	5
32.	I know when I understand something in Physical Sciences or not.	1	2	3	4	5
33.	Without thinking about it, I automatically use helpful ways of learning Physical Sciences.	1	2	3	4	5
34.	When learning Physical Sciences, I regularly stop learning to quickly see whether I understand the work or not.	1	2	3	4	5
35.	I know when to use each different way of learning, so that I could learn well for each Physical Sciences situation.	1	2	3	4	5
36.	When I have finished a Physical Sciences task, I ask myself how well I achieved my goal.	1	2	3	4	5
37.	When I learn Physical Sciences, I draw pictures or diagrams to help me understand and remember the work.	1	2	3	4	5
38.	After I solve a Physical Sciences problem, I ask myself if I thought of all the possible ways of solving it.	1	2	3	4	5

39.	I try to write new Physical Sciences information in my own words.	1	2	3	4	5
40.	When I don't understand something in Physical Sciences, I try to learn it in a different way.	1	2	3	4	5
41.	When learning Physical Sciences, I look at the way the work in the text book is organised and I use this knowledge to help me learn the work.	1	2	3	4	5
42.	I read instructions carefully before I begin a Physical Sciences task.	1	2	3	4	5
43.	When I'm learning something new in Physical Sciences I ask myself if what I'm learning is related to what I already know.	1	2	3	4	5
44.	When I get confused in Physical Sciences, I look again at what I thought was right, to see if it wasn't maybe wrong.	1	2	3	4	5
45.	I try to use my time well, so that I make sure that I achieve my goals for Physical Sciences.	1	2	3	4	5
46.	I learn more in Physical Sciences when I am interested in what I'm learning.	1	2	3	4	5
47.	When learning Physical Sciences, I try to break learning down into smaller steps.	1	2	3	4	5
48.	I try to remember and understand the bigger picture in Physical Sciences rather than smaller bits of information.	1	2	3	4	5
49.	I ask myself questions about how well I am doing while I am learning something new in Physical Sciences.	1	2	3	4	5
50.	I ask myself if I learned as much as I could have after I have finished a Physical Sciences task.	1	2	3	4	5
51.	I stop and go back over new Physical Sciences information that I don't understand.	1	2	3	4	5
52.	I stop and read Physical Sciences information again when I get confused.	1	2	3	4	5

Adapted from:

SCHRAW, G. & DENNISON, R.S. 1994. Assessing Metacognitive awareness. *Contemporary Educational Psychology*. 19(4): 460 – 475.

SECTION C: METACOGNITIVE ORIENTATED LEANING ENVIRONMENT IN THE PHYSICAL SCIENCES CLASSROOM.

This section investigates what is actually happening in your Physical Sciences classroom. The following is important:

- There are no right or wrong answers.
- Answer these questions about what happens in your Physical Sciences classroom as accurately as possible.
- Choose one of the five point answers that best describes when you do something and circle it.
    1. Almost never
    2. Seldom
    3. Sometimes
    4. Often
    5. Almost always

Example:

I like to eat sweets	1	2	3	[✓ 4]	5

If you like to eat sweets **often**, you circle 4.

1. Almost never	2. Seldom	3. Sometimes	4. Often	5. Almost always

In this Physical Sciences classroom…

1.	Learners are asked by their teacher to think about how they learn Physical Sciences.	1	2	3	4	5
2.	Learners are asked by the teacher to explain how they solve Physical Sciences problems.	1	2	3	4	5
3.	Learners are asked by their teacher to think about what makes it difficult for them to learn Physical Sciences.	1	2	3	4	5
4.	Learners are asked by their teacher to think about how they could become better learners of Physical Sciences.	1	2	3	4	5
5.	Learners are asked by the teacher to try new ways of learning Physical Sciences.	1	2	3	4	5
6.	Learners discuss with each other how they learn Physical Sciences.	1	2	3	4	5

7.	Learners discuss with each other how they think when they learn Physical Sciences.	1	2	3	4	5
8.	Learners discuss with each other about different ways of learning Physical Sciences.	1	2	3	4	5
9.	Learners discuss with each other about how well they are learning Physical Sciences.	1	2	3	4	5
10.	Learners discuss with each other about how they could make their learning of Physical Sciences better.	1	2	3	4	5
11.	Learners discuss with the teacher about how they learn Physical Sciences.	1	2	3	4	5
12.	Learners discuss with the teacher about how they think when they learn Physical Sciences.	1	2	3	4	5
13.	Learners discuss with the teacher about different ways of learning Physical Sciences.	1	2	3	4	5
14.	Learners discuss with the teacher about how well they are learning Physical Sciences.	1	2	3	4	5
15.	Learners discuss with the teacher about how they could improve their learning of Physical Sciences.	1	2	3	4	5
16.	It is OK for the learners to tell the teacher when they don’t understand Physical Sciences.	1	2	3	4	5
17.	It is OK for the learners to ask the teacher why they have to do a certain Physical Sciences activity.	1	2	3	4	5
18.	It is OK for the learners to suggest other Physical Sciences learning activities than the ones suggested by the teacher.	1	2	3	4	5
19.	It is OK for learners to speak out about Physical Sciences activities that are confusing.	1	2	3	4	5
20.	It is OK for learners to speak out about anything that prevents them from learning Physical Sciences.	1	2	3	4	5
21.	Learners help the teacher plan what needs to be learned for Physical Sciences.	1	2	3	4	5
22.	Learners help the teacher decide which Physical Sciences activities they do.	1	2	3	4	5
23.	Learners help the teacher decide which Physical Sciences activities are best for them.	1	2	3	4	5
24.	Learners help the teacher decide how much time they spend on Physical Sciences activities.	1	2	3	4	5

25.	Learners help the teacher decide when it is time to begin a new unit in Physical Sciences.	1	2	3	4	5
26.	The teacher encourages students to try to improve how they learn Physical Sciences.	1	2	3	4	5
27.	The teacher encourages students to try different ways to learn Physical Sciences	1	2	3	4	5
28.	The teacher supports learners who try to improve their Physical Sciences learning.	1	2	3	4	5
29.	The teacher supports learners who try new ways of learning Physical Sciences	1	2	3	4	5
30.	The teacher encourages learners to talk to each other about how they learn Physical Sciences.	1	2	3	4	5
31.	In the Physical Sciences class learners are treated fairly.	1	2	3	4	5
32.	In the Physical Sciences class learners' efforts are valid.	1	2	3	4	5
33.	In the Physical Sciences class learners' ideas are respected.	1	2	3	4	5
34.	In the Physical Sciences class learners' individual differences are respected.	1	2	3	4	5
35.	In the Physical Sciences class learners and the teacher trust each other.	1	2	3	4	5

Adapted from:

THOMAS, G.P. 2003. Conceptualization, Development and Validation of an Instrument for Investigating the Metacognitive Orientation of Sciences Classroom Learning Environments: The Metacognitive Orientation Learning Environment Scale – Sciences (MOLES-S). *Learning Environments Research*. 6(2):175 – 197.

APPENDIX H:
QUESTIONNAIRE (AFRIKAANS)

VRAELYS

VRAELYS AAN GRAAD 12 FISIESE WETENSKAP LEERDERS RAKENDE ASPEKTE OOR METAKOGNETIEWE BEWUSTHEUD IN FISIESE WETENSKAPPE ASOOK HUL ERVARING VAN HUL FISIESE WETENSKAP KLASKAMER AS ‘N METAKOGNETIEWE LEEROMGEWING.

Die vraelys is saamgestel uit drie afdelings:

- Afdeling A: Demografiese besonderhede
- Afdeling B: Metakognetiewe bewustheid
- Afdeling C: Metakognetiewe georiënteerde leeromgewing in die Fisiese Wetenskap klaskamer

Algemene Inligting:

1. Hierdie vraelys bestaan uit 8 bladsye. Dit sal nie langer as 30 minute duur on hierdie vraelys in te vul nie.

2. Die doel van die navorsing is om ondersoek in te stel of Fisiese Wetenskap klaskamers leerders die geleentheid bied om sekere denk vaardighede te ontwikkel.

3. Dit is belangrik dat jy al die vrae so **eerlik** as moontlik beantwoord. Onthou, hierdie is nie ‘n assessering van jou of jou skool nie.

4. Jou deelname sal baie waardevol wees vir my navorsing. Die identiteit van jou en jou skool sal nie blootgestel word nie. Hierdie vraelyste sal slegs deur my hanteer word. Alle inligting bly streng vertroulik.

Baie dankie vir jou bereidwilligheid om die vraelys te voltooi.

AFDELING A: DEMOGRAFIESE BESONDERHEDE

Omkring die nommer van die stelling van jou keuse.

Voorbeeld:

Ek woon in Suid-Afrika	[✓ 1]
Ek woon nie in Suid-Afrika nie	2

1. Geslag	
Manlik	1
Vroulik	2
2. Huistaal	
Afrikaans	1
Engels	2
Sotho	3
Tswana	4
Xhosa	5
Zulu	6
Ander	7
3. Ouderdom (in jare)	
16	1
17	2
18	3
19	4
20	5
21	6
Ouer	7
4. In watter grad was jy in 2011?	
11	1
12	2
5. Persentasie wat jy ontvang het in die Junie eksamen vir Fisiese Wetenskappe	
Vraestel 1 (Fisika)	Vraestel 2(Chemie)

AFDELING B: METAKOGNETIEWE BEWUSTHEID

Hierdie afdeling ondersoek aspekte rakende metakognetiewe bewustheid. Die volgende is belangrik:

- Daar is geen regte of verkeerde antwoorde nie
- Antwoord hierdie vrae oor hoe jy Fisiese Wetenskappe leer so akkuraat as moontlik.
- Kies een van die vyf punt antwoorde wat die beste verduidelik hoe jy iets doen en omkring dit.
    1. Amper nooit
    2. Selde
    3. Soms
    4. Gereeld
    5. Amper altyd

Voorbeeld:

Ek hou daarvan om lekkers te eet.	1	2	3	4	[✓ 5]

As jy daarvan hou om **gereeld** lekkers te eet, dan omkring jy 4.

1. Amper nooit	2. Selde	3. Soms	4. Gereeld	5. Amper altyd

1	Ek vra myself gereeld of ek besig is om my doelwitte in Fisiese Wetenskappe te bereik	1	2	3	4	5
2	Ek kyk na meer as een moontlike oplossing vir ’n Fisiese Wetenskap probleem, voordat ek antwoord.	1	2	3	4	5
3	In Fisiese Wetenskap probeer om dinge weer op dieselfde manier te doen, as dit in die verlede gewerk het.	1	2	3	4	5
4	Wanneer ek Fisiese Wetenskap leer maak ek seker dat ek nie te veel tyd aan een ding spandeer nie, sodat ek genoeg tyd het om alles te leer.	1	2	3	4	5
5	Ek weet waarin ek goed is en waarin ek swakker is, wanneer dit by Fisiese Wetenskap kom.	1	2	3	4	5
6	Ek dink aan wat ek regtig moet leer, voordat ek met ’n Fisiese Wetenskap taak begin.	1	2	3	4	5

7	Ek weet onmiddellik na ’n Fisiese Wetenskap toets of my punte goed of swak gaan wees.	1	2	3	4	5
8	Ek stel spesifieke doelwitte vir myself, voordat ek met ’n Fisiese Wetenskap taak begin	1	2	3	4	5
9	Wanneer ek Fisiese Wetenskap leer, gaan ek stadiger deur belangrike inligting.	1	2	3	4	5
10	Ek weet watter soort inligting die belangrikste is om te leer in Fisiese Wetenskap.	1	2	3	4	5
11	Ek vra myself of ek na al die moontlikhede gekyk het wanneer ek ’n Fisiese Wetenskap probleem oplos.	1	2	3	4	5
12	Ek is goed daarmee om Fisiese Wetenskap inligting te organiseer.	1	2	3	4	5
13	Ek probeer my bes om my aandag op belangrike Fisiese Wetenskap inligting te fokus.	1	2	3	4	5
14	Vir elke strategie wat ek in Fisiese Wetenskap gebruik, het ek ’n spesifieke doel in gedagte.	1	2	3	4	5
15	Ek leer Fisiese Wetenskap op my beste wanneer ek reeds iets weet van die werk wat ek besig is om te leer.	1	2	3	4	5
16	Ek weet wat die onderwyser wil hê ek moet leer vir Fisiese Wetenskappe.	1	2	3	4	5
17	Ek is goed daarmee om Fisiese Wetenskap inligting te onthou.	1	2	3	4	5
18	Ek leer Fisiese Wetenskap op verskillende maniere vir verskillende situasies.	1	2	3	4	5
19	Wanneer ek ’n Fisiese Wetenskap taak klaargemaak het, vra ek myself of daar ’n makliker manier was om dit te doen.	1	2	3	4	5
20	Ek het beheer oor hoe goed ek Fisiese Wetenskap leer.	1	2	3	4	5
21	Ek dink gereeld terug om my te help om belangrike verhoudings te verstaan.	1	2	3	4	5
22	Voordat ek Fisiese Wetenskap begin leer, vra ek myself vrae oor die werk.	1	2	3	4	5
23	Ek dink aan meer as een verskillende manier om ’n Fisiese Wetenskap probleem op te los en kies dan die beste een.	1	2	3	4	5
24	Nadat ek Fisiese Wetenskap geleer het, som ek die werk wat ek geleer het op.	1	2	3	4	5
25	Ek vra vir hulp wanneer ek iets in Fisiese Wetenskap nie verstaan nie.	1	2	3	4	5

26	Ek kan myself sovêr kry om Fisiese Wetenskap te leer, selfs al wil ek nie regtig nie.	1	2	3	4	5
27	Ek is bewus van die maniere waarop ek my Fisiese Wetenskap werk leer.	1	2	3	4	5
28	Terwyl ek Fisiese Wetenskap leer probeer ek dink of my manier van leer regtig werk of nie.	1	2	3	4	5
29	In Fisiese Wetenskap gebruik ek dit waarin ek goed is om op te maak vir dit waarin ek swakker is.	1	2	3	4	5
30	Ek gee al my aandag aan die betekenis en belangrikheid van nuwe Fisiese Wetenskap inligting.	1	2	3	4	5
31	Ek dink my eie voorbeelde uit om Fisiese wetenskap inligting meer betekenisvol vir myself te maak.	1	2	3	4	5
32	Ek weet wanneer ek iets in Fisiese Wetenskap verstaan of nie.	1	2	3	4	5
33	Sonder om daaroor te dink, gebruik ek outomaties hulpvolle maniere om Fisiese Wetenskap te leer.	1	2	3	4	5
34	Terwyl ek Fisiese Wetenskap leer hou ek gereeld op leer om vinnig te kyk of ek die werk verstaan of nie.	1	2	3	4	5
35	Ek weet wanneer om elke verskillende manier van leer te gebruik, sodat ek goed kan leer vir elke Fisiese Wetenskap situasie.	1	2	3	4	5
36	Wanneer ek ’n Fisiese Wetenskap taak afgehandel het, vra ek myself hoe goed ek my doelwit bereik het.	1	2	3	4	5
37	Wanneer ek Fisiese Wetenskap leer teken ek prentjies of diagramme om my te help om die werk te verstaan en onthou.	1	2	3	4	5
38	Nadat ek ’n Fisiese Wetenskap probleem opgelos het, vra ek myself of ek aan al die moontlike oplossings daarvoor gedink het.	1	2	3	4	5
39	Ek probeer om nuwe Fisiese Wetenskap inligting in my eie woorde oor te skryf.	1	2	3	4	5
40	Wanneer ek iets in Fisiese Wetenskap nie verstaan nie, probeer ek om dit op ’n ander manier te leer.	1	2	3	4	5
41	Wanneer ek Fisiese Wetenskap leer, kyk ek na die manier waarop die werk in die boek georganiseer is en gebruik die kennis om my te help om die werk te leer.	1	2	3	4	5
42	Ek lees instruksies versigtig deur voordat ek met ’n Fisiese Wetenskap taak begin.	1	2	3	4	5

43	wanneer ek iets nuuts in Fisiese Wetenskap leer, vra ek myself of wat ek besig is om te leer enigiets te doen het met wat ek reeds weet.	1	2	3	4	5
44	Wanneer ek deurmekaar raak in Fisiese Wetenskap, probeer ek weer kyk na dit wat ek gedink het reg was, om te sien of dit nie dalk verkeerd was nie.	1	2	3	4	5
45	Ek probeer my tyd goed gebruik, sodat ek seker maak dat ek my Fisiese Wetenskap doelwitte bereik.	1	2	3	4	5
46	Ek leer meer in Fisiese Wetenskap wanneer die werk vir my interessant is.	1	2	3	4	5
47	Wanneer ek Fisiese Wetenskap leer probeer ek om my leerproses in kleiner stappe op te breek.	1	2	3	4	5
48	Ek probeer om die groter prentjie in Fisiese Wetenskap te verstaan en onthou, eerder as al die kleiner stukkies inligting.	1	2	3	4	5
49	Ek vra myself vrae oor hoe goed ek doen, terwyl ek besig is om iets nuuts in Fisiese Wetenskap te leer.	1	2	3	4	5
50	Ek vra myself of ek soveel geleer het as wat ek kon, nadat ek ’n Fisiese Wetenskap taak klaargemaak het.	1	2	3	4	5
51	Ek stop en gaan weer oor nuwe Fisiese Wetenskap inligting wat ek nie verstaan nie.	1	2	3	4	5
52	Ek stop en lees weer deur Fisiese Wetenskap inligting wanneer ek deurmekaar raak.	1	2	3	4	5

Aangepas vanuit:

SCHRAW, G. & DENNISON, R.S. 1994. Assessing Metacognitive awareness. *Contemporary Educational Psychology*. 19(4): 460 – 475.

AFDELING C: METAKOGNITIEWE GEORIëNTEERDE LEEROMGEWING IN DIE FISIESE WETENSKAP KLASKEMER.

Die afdeling ondersoek wat eintlik besig is om te gebeur in jou Fisiese Wetenskap klaskamer. Die volgende is belangrik:

- Daar is geen regte of verkeerde antwoorde nie.
- Beantwoord hierdie vrae oor jou Fisiese Wetenskap klaskamer so akkuraat as moontlik.
- Kies een van die vyf punt antwoorde wat die beste beskryf hoe jy iets doen en omkring dit.
  1. Amper nooit
  2. Selde
  3. Soms
  4. Gereeld
  5. Amper altyd

Voorbeeld:

Ek hou daarvan om lekkers te eet	1	2	3	[✓ 4]	5

As jy daarvan hou om gereeld lekkers te eet, dan omkring jy 4.

1. Amper nooit	2. Selde	3. Soms	4. Gereeld	5. Amper altyd

In hierdie Fisiese Wetenskap klaskamer…

1.	Leerders word deur hul onderwyser gevra om na te dink aan hoe hulle Fisiese Wetenskap leer.	1	2	3	4	5
2.	Leerders word deur hul onderwyser gevra om te verduidelik hoe hulle Fisiese Wetenskap-probleme oplos.	1	2	3	4	5
3.	Leerders word deur hul onderwyser gevra om na te dink oor wat dit vir hulle moeilik maak om Fisiese Wetenskap te leer.	1	2	3	4	5
4.	Leerders word deur hul onderwyser gevra om na te dink oor hoe hulle beter leerders van Fisiese Wetenskap kan word.	1	2	3	4	5

5.	Leerders word deur hul onderwyser gevra om nuwe maniere om Fisiese Wetenskap te leer te probeer.	1	2	3	4	5
6.	Leerders bespreek met mekaar hoe hulle Fisiese Wetenskap leer.	1	2	3	4	5
7.	Leerders bespreek met mekaar hoe hulle dink wanneer hulle Fisiese Wetenskap leer.	1	2	3	4	5
8.	Leerders bespreek met mekaar die verskillende maniere om Fisiese Wetenskap te leer	1	2	3	4	5
9.	Leerders bespreek met mekaar hoe goed hulle besig is om Fisiese Wetenskap te leer.	1	2	3	4	5
10.	Leerders bespreek met mekaar hoe hulle hul leer van Fisiese Wetenskap kan verbeter.	1	2	3	4	5
11.	Leerders bespreek met die onderwyser hoe hulle Fisiese Wetenskap leer.	1	2	3	4	5
12.	Leerders bespreek met die onderwyser hoe hulle dink wanneer hulle Fisiese Wetenskap leer.	1	2	3	4	5
13.	Leerders bespreek met die onderwyser die verskillende maniere om Fisiese Wetenskap te leer.	1	2	3	4	5
14.	Leerders bespreek met die onderwyser hoe goed hulle besig is om Fisiese Wetenskap te leer.	1	2	3	4	5
15.	Leerders bespreek met die onderwyser hoe hulle die manier waarop hulle Fisiese Wetenskap leer kan verbeter.	1	2	3	4	5
16.	Dit is aanvaarbaar vir die leerders om vir die onderwyser te sê as hulle Fisiese Wetenskap nie verstaan nie.	1	2	3	4	5
17.	Dit is aanvaarbaar vir die leerders om vir die onderwyser te vra waarom hulle ’n sekere Fisiese Wetenskap aktiwiteit moet doen.	1	2	3	4	5
18.	Dit is aanvaarbaar vir die leerders om ander Fisiese Wetenskap-leeraktiwiteite voor te stel, wat van die onderwyser s’n verskil.	1	2	3	4	5
19.	Dit is aanvaarbaar vir die leerders om te praat oor Fisiese Wetenskap aktiwiteite wat verwarrend is.	1	2	3	4	5
20.	Dit is aanvaarbaar vir die leerders om te praat oor enigiets wat hulle verhoed om Fisiese Wetenskap te leer.	1	2	3	4	5
21.	Leerders help die onderwyser om dít wat vir Fisiese Wetenskap geleer moet word te beplan.	1	2	3	4	5
22.	Leerders help die onderwyser om te besluit watter Fisiese Wetenskap aktiwiteite hulle moet doen.	1	2	3	4	5

23.	Leerders help die onderwyser om te besluit watter Fisiese Wetenskap aktiwiteite die beste vir hulle is.	1	2	3	4	5
24.	Leerders help die onderwyser om te besluit hoeveel tyd hulle aan Fisiese Wetenskap aktiwiteite moet spandeer.	1	2	3	4	5
25.	Leerders help die onderwyser om te besluit wanneer dit tyd is om met ’n nuwe eenheid in Fisiese Wetenskap te begin.	1	2	3	4	5
26.	Die onderwyser moedig die leerders aan om die manier waarop hulle Fisiese Wetenskap leer te verbeter.	1	2	3	4	5
27.	Die onderwyser moedig die leerders aan om verskillende maniere om Fisiese Wetenskap te leer te probeer.	1	2	3	4	5
28.	Die onderwyser ondersteun die leerders wat prober om die leer van hul Fisiese Wetenskap te verbeter.	1	2	3	4	5
29.	Die onderwyser ondersteun leerders wat nuwe maniere om Fisiese Wetenskap te leer probeer	1	2	3	4	5
30.	Die onderwyser moedig leerders aan om met mekaar te praat oor hoe hulle Fisiese Wetenskap leer.	1	2	3	4	5
31.	In die Fisiese Wetenskap klas word leerders regverdig behandel.	1	2	3	4	5
32.	In die Fisiese Wetenskap klas word leerders se pogings erken.	1	2	3	4	5
33.	In die Fisiese Wetenskap klas word leerders se idees gerespekteer.	1	2	3	4	5
34.	In die Fisiese Wetenskap klas word leerders se individuele response gerespekteer.	1	2	3	4	5
35.	In die Fisiese Wetenskap klas vertrou die leerders en die onderwyser mekaar.	1	2	3	4	5

Aangepas vanuit:

THOMAS, G.P. 2003. Conceptualization, Development and Validation of an Instrument for Investigating the Metacognitive Orientation of Sciences Classroom Learning Environments: The Metacognitive Orientation Learning Environment Scale – Sciences (MOLES-S). *Learning Environments Research*. 6(2):175 – 197.