Science Talk: Exploring Students and Teachers Understanding of Argumentation in Grade 11 Science Classrooms.

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A research report submitted to the faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Masters of Science by combination of coursework and research report.

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ABSTRACT

The merits of argumentation for science teaching and learning have been established not just for South Africa, but globally. However, little is known about what both students and teachers understand by argumentation for science learning and teaching. This study aimed to investigate what seventy nine students and two teachers understood about argumentation and to examine the nature of students written scientific arguments. A sample of 79 students from two high schools in the north of Johannesburg, South Africa, was selected to complete a questionnaire that included a single Multiple Choice Question task. Students' respective teachers were interviewed for their understanding on argumentation. The interviews were inductively analysed to extract themes related on teachers' perspectives on argumentation. The MCQ task item was analysed using Toulmins Argumentation Pattern as adapted by Erduran *et al*, to show levels of argumentation. The rest of the questions on the questionnaire were analysed according to my research questions to get students' understanding on argumentation.

Three main findings were found from the study. *Firstly, s*tudents understand what a good scientific argument constitutes of. They mentioned debates and discussions as an opportunity to engage in an argument. *Secondly*, teachers demonstrated an understanding that argumentation requires facts and evidence to support claims. Meanwhile, findings also show that teachers value science arguments as they demand students to use evidence, rather than opinions to support their claims. *Thirdly*, most students struggled to construct levels at a higher level. This meant that most students wrote arguments that consisted of a claim, data/ evidence or a weak warrant. Hence, arguments were at levels 1, 2 and seldom at level 3. Students written scientific arguments revealed that only 24 out of 79 students were able select the correct scientific answer. The remaining fifty students selected the wrong answer and their arguments were based on the incorrect scientific justification that, when a solid substance is in a gaseous phase in a closed system it would have lesser mass, simply because gas weighs less than a solid. This was a common misconception that most students had.

These outcomes imply that there is a need to train teachers how to help students write valid scientific arguments, the inclusion of more debates and consideration to ideas as to how students can construct written argument. Lastly, those argumentation practices should assist teachers on how to minimise students' misconception on the law of the conservation of mass. As such, argumentation can serve as an instruction for learner-centred approach to teaching and learning of science.

Keywords: *argumentation, written argument, nature of an argument*

DECLARATION

I Maletsau Jacqualine Mphahlele declare that this research report is my own, unaided work. It is being submitted for partial fulfilment of the degree of M.Sc. in Science Education in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University, nor has it been prepared under the guidance or with the assistance of any other body or organization or person outside the University of the Witwatersrand, Johannesburg.

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Maletsau. J Mphahlele

__21st_day of October in the year 2016

DEDICATION

I would like to honour my mother's memory; Grace Modikoa Mphahlele with this research project, her integral love for me will live on within me. Thank you Noko!

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I would like to thank the all mighty God for giving me faith and spiritual strength throughout this study. In addition, I want to thank the following people, most importantly my supervisor, **Dr. Audrey Msimanga** who provided me with constructive comments and advice throughout this research project.

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Thank you very much!

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CHAPTER 1: BACKGROUND TO THE STUDY

1.1 Introduction

The purpose of this research project was to explore students' and teachers' understanding of argumentation. Particular attention was placed on construction of 'science arguments' in both teaching and learning of science. This was done by investigating how Grade 11 science students and their teachers understand argumentation for science learning and teaching. The study also tried to find out to what extent students can produce scientifically valid written arguments.

Classroom talk has always been a crucial part of teaching and learning. Talk in a classroom takes both the social and specific scientific forms, such as those of argumentation. Talk cannot be excluded from a normal classroom set up, however the purpose of talk can be devoted to the aims of a particular task. Argumentation is a definitive science talk in which students must use evidence to support their claims (Osborne, Erduran, Simon & Monk, 2001; Simon, Erduran & Osborne, 2002). As such, argumentation is a talk that contributes to how students talk and write science. Hence, argumentation is both a teaching and learning tool.

1.2 Context

Looking at the history of South Africa's different curricula, Diwu (2010) notes that although C2005 required teachers to help students to bridge the everyday knowledge to school science, it did not specify how students and teachers could engage in the kinds of classroom dialogue that could achieve this. Even the revised curriculum, National Curriculum Statement (NCS) was not clear on how to produce students that are not only competent in science content, but also able to think critically and have appropriate reasoning skills (Diwu, 2010).

The current curriculum in South Africa emphasises that students should be exposed to "active and critical learning, which encourages an active and critical approach to learning, rather than rote and uncritical learning of given truths" (Department of Education, 2011, p, 4). I see argumentation as a tool which can provide the skills for negotiating knowledge construction and understanding. It is also important that teachers support their students on how to construct convincing arguments.

Argumentation involves the public exercise of reasoning and externalisation of thinking in order to develop scientific knowledge. Argumentation skills in this case, can assist to recognise specific aims of the curriculum. The Physical Science Curriculum and Assessment Policy Statement (CAPS) document for example, requires students to be able to classify, communicate, measure, design and investigate, as well as to draw and evaluate conclusions, formulate models, hypothesise, identify and control variables, along with inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills (DoE, 2011). Most of these are encompassed in argumentation thus, require relevant support and understanding of argumentation as a teaching and learning tool in science classrooms in order to realise these objectives.

Furthermore, Lubben, Sadeck, Scholtz and Braund (2010) argue that one of the ways that teachers can help students think critically is through engaging in arguments on science concepts. Meanwhile, science education aims to produce students who can engage in science practices that include doing science, talking science and writing science. However, students struggle with these practices and require additional instructional support (McNeill & Pimentel, 2010). Argumentation is a tool that can help students self-monitor their own scientific reasoning and meaningful participation in doing science. As such, Lemke, (1990) argues that doing science is always directed and well-informed by talking science, to ourselves or with others.

Classroom practices that students and teachers engage in, shape the way arguments are executed in their everyday science talk and writing. A key goal in science classrooms is to engage students in a social process of knowledge construction. Thus, competence in argumentation requires both verbal and writing skills. During this process, students support their claims with relevant evidence and reasoning drawing from their everyday knowledge and experiences. This in turn, can help to develop their scientific knowledge.

1.3 Problem Statement

The high level problems in our science classrooms include exam driven system (Diwu, 2010), rote learning and teacher-centred teaching approach. Exam driven system is where science is taught and learnt in such a way that is motivated by what is going to be tested in the examinations. Exam driven system results in students relying on rote learning just so they can repeat facts that they study for examinations. Lastly, exam driven system and rote learning are often characterised by what is called teacher-centred teaching approach, this teaching approach is dominated by lessons were the teacher is the one transmitting knowledge to the students. The lessons are characterised by minimal student talk.

One of the challenges of implementing a curriculum in South Africa is an “examination-driven education system” (Ogunniyi, 2006, p.118 cited by Diwu, 2010). This is a dominant problem in the country as it promotes rote learning and memorization, whereas argumentation promotes conceptual understanding and deep learning. However, argumentation is not given much attention, either during class activity or during laboratory work, in order to assist students to understand science concepts (Osborne, Erduran, Simon & Monk, 2001). Argumentation is a practice that can guide teaching for conceptual understanding. The practice of argumentation is crucial in everyday classroom context, as it allows students to engage critically with science concepts to justify their scientific claims. Therefore, teaching and learning can go beyond just mere preparation for examination.

There has been considerable amount of research on argumentation, however in South Africa little research has been done on student argumentation. One other study by Webb, William and Meiring (2008) was found. The authors investigated argumentation using concept cartoons and writing frames to develop students’ thinking for writing arguments. In addition, Webb *et al*, (2008) observed that very little classroom talk occurred amongst Grade 9 learners and their teachers in South Africa. Where the talk did happen, their argumentation levels were very low. Other studies done in South Africa for example, Diwu (2010), Lubben *et al*, (2010), Msimanga and Lelliott (2012) investigated dialogical argumentation through verbal interactions. The majority of research on written arguments is carried out with students in developed countries internationally e.g. Aydeniz, and Gurcay, (2013), Schen (2013) and Kelly and Takao, (2002). In these studies it was observed that students are generally better at identifying stronger arguments than being able to write detailed reasoning for their choice.

There is a difference between tutored and untutored students on argumentation. Tutored students are those that would have got some sort of teaching or training on what and how argumentation in science education are executed, the teaching or training could be from both the verbal or written arguments. Untutored students on argumentation could be those who have not gotten any form of teaching or training on what and how argumentation in science classrooms can be used for teachings and learning of science content.

Many South African teachers have not yet been tutored in argumentation. This present study was conducted within the context of such classrooms. Due to the scope of my masters' study which involved only a six-eight month long research project, I was not able to conduct any intervention. The findings of my study were to provide baseline information on students and teachers who have not been tutored on argumentation. The aim was to find out students' and teachers' understanding of argumentation and how untutored students use argumentation in writing. Future work can then involve interventions to expose teachers to both spoken and written argumentation. That research can be followed by observation of changes in teacher and student practices of argumentation after tutoring.

Argumentation quality is influenced by how it is being conducted and managed as well as the level of students' understanding of that particular scientific concept. Also, students' everyday knowledge influences how they learn the scientific knowledge in the science classroom. Therefore, the teacher needs to be able to mediate high quality arguments and should also mediate students' understanding of concepts. This should be done by insisting on accuracy of evidence that students give to support their claims.

The challenge in science education is that much emphasis has been placed on what students should believe as scientific knowledge rather than, why they should believe it, as scientific knowledge (Osborne *et al*, 2001; Cavagnetto, 2010). As a result, students are left with beliefs which they cannot justify when discussing with fellow students. This is due to a common classroom practice where talk often becomes a one way process during which the teacher dominates or that is dominated by the teacher.

Studies done in South African classrooms indicate that students are "not able to access the resources available to them, including laboratory experiments to construct and argue their view point" (Lubben *et al*, 2010, p.2152).This means that students are not taught how to construct a convincing argument. Also, the levels at which students are able to argue about a concept depends directly on their understanding of the concept, which influences how they respond to verbal and written responses on argumentation about a particular concept (Lubben *et al*, 2010; Diwu, 2010). As such, knowledge of content and practical affects students' ability to argue.

My study aimed to investigate how untutored students constructed scientific arguments in their written tasks. To do so, the study first looked at students' and teachers' understanding of argumentation as a teaching and learning tool.

1.4 Rationale and Purpose of the study

The data that I collected for my honours research project in 2014 revealed that most students in my sample were aware of the concept of argumentation. However, they could not construct scientifically valid arguments or support their claims in their written tasks.. For my honours research, I worked with one school in Johannesburg and for this study; I continued with the same research and increased its scope by working with two schools. This way I was able to collect a wider set of data that can help provide an understanding of the difficulties students in Grade 11 have with understanding and engaging with scientific argumentation in their written task. This area of written argument is under-researched in South Africa and my findings can help inform future research in developing students' argumentation skills. The research questions which guidedmy study were:

i. What are students' understandings of argumentation as a tool for science learning?
ii. What are teachers' understandings of argumentation as a tool for science teaching?
iii. What is the nature of student's written scientific arguments?

Argumentation is a promising teaching and learning tool embedded within the socio-cultural perspectives of learning. It is viewed by some researchers as a theory of social construction of knowledge (Scholtz, Braund, Hodges, Koopman, & Lubben, 2008). As the South African curriculum has changed over the years, the emphasis on the production of scientifically literate citizens who can argue and make valid sound arguments persists. With this in mind, it can be said that argumentation should become a habit in a science classroom. Furthermore, teachers should encourage its practice amongst students through discussions and their writing activities.

1.6 Significance of the study

My research is necessary in order to establish the underlying thoughts of both students' and teachers' on argumentation as a teaching and learning tool in science classrooms. Argumentation plays an important role in science education. It can help students to understand science concepts, while developing their ability to comprehend how to self-monitor their own scientific reasoning.

Teachers' initial understanding of argumentation influences implementation of this teaching and learning tool in science classrooms. With this in mind, it is vital that teacher's understanding towards argumentation be studied and developed (Simon, Erduran & Osborne, 2006). This information can be the basis of teachers' professional development which according to Simon *et al*, (2006) "should be on their existing understanding of the importance of evidence in an argument..." (p. 256). As such, this implies that teacher perceptions about argumentation need to be studied.

I believe that investigating students' written arguments might be the beginning of a solution to conceptual understanding of science concepts. This is because students' written arguments may enable teachers to identify difficulties and obstacles that students encounter when developing written arguments. This should enable students to address and rectify their inability to construct scientifically valid arguments. The importance of argumentation is to create chances for students to discuss their ideas and engage in scientific knowledge construction with their teacher and fellow students (Lemke, 1990). I believe that students and teachers as well as the science education system, stand to benefit from the findings of this study. Lastly, the teachers will be named Mr B and Mr G respectively, throughout this report.

1.7 Chapter summary and structure of the research report:

Chapter one provided the background of the study. *Chapter Two* provides a literature review of sources relevant to the study by listing influential research conducted in South Africa and other countries. I will then give an explanation of what argumentation is, how it is used, how to use it as a teaching and learning tool in a science context and its benefits. Further, I will explain the meaning of its role in science education, the purpose of written arguments for learning science and lastly, the challenges with argumentation in science classrooms. In this chapter, the review shall show how the study draws on the Vygotskian conceptual framework and the description of a good argument by Toulmin (1958).

Chapter Three discusses the methodology used for the study and how it responds to the research questions. I will explain the research paradigm, research approach, and analytic framework. Lastly, this chapter will explain data analysis and reasons for the selected sample.

Chapter Four provides data analysis, showing how the responses answered the three research questions. I will provide a background to the method of analysis using TAP. The study only describes findings from a sample of 79 students, thus I do not try to make any generalisations about students and teachers understanding about argumentation.

Chapter Five provides a summary of how the data answers my research questions using themes and clustered responses according to their similarities from the analysed questionnaires, MCQ and interviews. I will then address the limitations, make suggestions and recommendations about how teachers and students can recognise argumentation as a tool for teaching and learning.

1.8 Conclusion

This chapter provided a background to explore students' and teachers' underlying ideas about argumentation. This was done by discussing the context, rationale and significance of this study. Lastly, I explained the importance of the study in South Africa by giving reasons why there is a lack of interest in argumentation in science classrooms. Lastly, I provided the intention, aims, driving research questions and the rationale of the study.

CHAPTER 2: Literature review and theoretical Framework

2.1 Introduction

In this chapter, I review literature which informed this study. This includes a theoretical framework, as well as literature reporting similar studies. The study is embedded within the constructivist theory of learning (Vygotsky, 1978). I draw on Toulmin's (1958) model of the pattern of an argument, as an analytic tool. The discussion looks at argumentation within the constructivist perspective, defines argumentation, its role in science education, the purpose of written arguments for learning science and lastly, the challenges with argumentation in science classrooms.

2.2 The role of social interaction in science learning

Vygotsky (1978) argues that learning occurs in social interactions and that these interactions have an effect on the mental development. Vygotsky's (1978) is a constructivist view of learning. Constructivists view learning on both the intrapersonal and interpersonal plane. This implies that, learning happens from the external environment and within the individuals' internal cognitive domain. Vygotsky (1978) suggests that learning involves internal arguments within individuals' mental structures. For example, these internal arguments can occur when an individual internalises knowledge claims made by the teacher or study materials. Therefore, meaningful learning happens with both internal as well as external arguments which occur through physical interactions with the environment.

Vygotsky's perspective is a constructivist approach to learning (Vygotsky, 1978). Constructivists view learning as an active social and cultural process. "Argumentation is both a means to develop a scientific culture and a normative outcome of the development of that culture" (Manz, 2014, p, 2). This means that everyday classroom practices in science classrooms include ways of engaging in an argument. The argument could either be internal or external.

The constructivist approach describes learning as a learner-centred activity. Learning should be centred on students who are working together to make sense of knowledge or the task at hand. As such, Lemke (1990, p.7) notes that "wherever we do science we take ways of talking, reasoning, observing, analysing and writing that we have learnt from our community and use them to construct findings and arguments that become part of science only when they become shared in that community". Hence, argumentation is an example of a constructivist approach which engages students in social interaction where they make sense of knowledge through the use of evidence to support their claims. Social interaction plays an important role in the process of personal construction of meaning (Vygotsky, 1978).

Argumentation is a core practice of science and has recently been advocated as an essential goal of science education (McNeill & Pimentel, 2010; Driver, Newton and Osborne, 2000) Science is a social entity. Driver *et al,* (2000) notes thus, it is essential to allow students to experience science through this manner of argumentation as scientist do when they present and justify new knowledge claims to the scientific community. As such, argumentation forms part of the most important part of engaging students in the social context with their own life and relevant community experiences which can lead to deeper understanding of science concepts, process, laws and theories (McNeill & Pimentel, 2010).

Argumentation is therefore a form of social interaction that promotes learning through formal or informal classroom talk or written tasks. For instance, Qhobela (2012) argues that "talking science particularly between peers in science classrooms must be made up of students that are being able to or being helped to argue a view point, as such science talk should probably be about an activity on describing and making an observation and reaching some inter-subjectivity"(p. 2). This means that argumentation structures include interactions through talking.

Argumentation is portrayed as a social process of constructing, supporting and critiquing claims for the purpose of developing shared knowledge (Driver *et al*, 2000), therefore it is believed to engage students by providing access to deeper understandings of scientific activity (Manz, 2014). Thus, scientists use the practice of argumentation to justify their scientific claims. New discoveries undergo argumentation amongst other scientists, and evidence is presented to support the claims. Likewise, argumentation is important in science classrooms, for helping students develop the ability to comprehend how scientific knowledge came to be known and why we believe in what we do as a scientific community (McNeill & Pimentel, 2010). However, the argumentation process is not automatic. It needs to be taught to students to know how to use existing scientific knowledge to support their claim. Argumentation can be, verbal or through written activities.

In summary, Driver *et al*, (2000) say that science is a social process in which scientist's continuously refine and revise knowledge based on evidence. Therefore, science can be learnt through activities that allow students to interact and share ideas, especially to understand the science norms and values that are upheld by the scientific community. This implies that, students get a chance to learn through talking which shifts authority of knowledge from the teacher to students (Manz, 2014).

2.3 Defining Argumentation

Research shows that argumentation studies in science education have increased over the years (Sampson & Clark, 2008; Jimenez-Aleixandre, Bugallo Rodriguez & Duschl, 2000; Berland & McNeill, 2009). Argumentation is defined as the process of arguing or constructing an argument (Erduran, Simon & Osborne, 2004; Knight, McNeill, Corrigan & Barber, 2013). Students need to learn how claims are supported with evidence to present new discoveries to the scientific community, through arguments with logic reasoning (Sampson & Clark, 2008). Teaching argumentation is in accordance with science education goals, which aim to equip students with skills to 'reason about problems and issues, be it a practical, pragmatic, moral or theoretical issue' (Jimenez-Aleixandre *et al*, 2000, p.757).

There are few models that can be attributed to the use of argumentation in science classrooms. One of the models include TAP by Toulmin (1958) that was later adopted by Erduran *et al*,(2004) to suit science classroom contexts. There is another model Contiguity Argumentation Theory (CAT) (Ogunniyi, 2007a). The theory is focused on how distinctly different or conflicting thoughts, such as the scientific and Indigenous Knowledge System (IKS). This theory describes a dialogical framework and the changing aspects involved in determining the clashes that usually arise when two or more competing thought systems are considered together in this case science vs IKS. A battle arises when a cognizing individual is exposed to different understanding to the existing one in the mind. CAT suggest that when science and IKS are contrasted, it may end in some sort of 'dialogue' to find some important form of co-existence.Toulmin (1958) developed a model to describe the structure of a good law argument, which later came to be known as Toulmin's Argument Pattern (TAP). TAP is my theoretical framework as it focuses on arguments that are justified by linking them with data on which clams are based and not CAT as it focuses on contradictions of IKS and science knowledge. According to Toulmin (1958), an argument consist of six interrelated concepts namely; data, claim, warrants, backings, qualifiers and rebuttals. These concepts are defined as follows; *'Data* is the facts or evidence used to prove the argument. *Claim* is the statement being argued (a thesis). *Warrants* are the general hypothetical (and often implicit) logical statements that serve as bridges between the claim and the data. *Qualifiers* are the statements that limit the strength of the argument or statements that propose the conditions under which the argument is true. *Rebuttals* are statements indicating circumstances when the general argument does not hold true. *Backings* are the statements that serve to support the warrants (i.e., arguments that don't necessarily prove the main point being argued, but which do prove the warrants are true' (Msimanga & Lelliott, 2002, p.196).

From Toulmin's model, Erduran, Simon and Osborne (2004) developed an analytical framework for assessing the quality of oral arguments in science lessons. The authors adapted TAP and formulated levels of argumentation between level 1 and 5. This framework classifies arguments into levels to rate the ability of an argument to be convincing. For example, the levels are classified as follows; *level 1* is a simple argument which consist of claim vs another claim. *Level 2* is an argument that is characterised by claim, data, warrants or backings. At *level 3* arguments consist of a series of claims, data, and warrants with weak rebuttals, while at *level 4* the argument consists of claim, data, warrants, backings and identifiable rebuttal and lastly, at *level 5* arguments consist of several claims, counter-claims, data, warrants, backings and more than one rebuttal (Erduran *et al*, 2004).

2.4 The role of Argumentation in Science Education

Argumentation is one of the core practices of the science discipline and has recently been advocated, as an essential goal of science education (McNeill & Pimentel, 2010; Driver, Newton & Osborne, 2000). The processes of constructing a scientific argument give students a chance to speak and think about the norms of scientific knowledge. "Argumentation is a structural element of language in science, which is an essential coy in both doing science and communicating scientific claims" (Jimenez-Aleixandre, Bugallo-Rodriguez & Duschl, 2000, p.758). Argumentation can shift student's conceptual understanding as they talk about scientific claims and theories to justify why a claim can or cannot be scientifically valid.

Argumentation does not only build students' ability to talk about science concepts, but to be better able to write scientifically valid arguments. The importance of argumentation seems to lie in the chances for students to discuss their ideas and engage in scientific knowledge construction with the teacher and fellow students. Argumentation is embedded in science as the central practice to generate an understanding of how science functions (Osborne *et al*, 2001). Science knowledge is generated through the use of argumentation to convince the scientific community with the latest scientific claims. Hence, Diwu (2010) defined argumentation as a premise on deductive-inductive form of reasoning. It provides students with a choice to attend to any doubt to knowledge claims during classroom discussions.

It is crucial that students understand how to assess validity and reliability of data when constructing arguments. One of the objectives of science education is to develop students who can engage in scientific inquiry, which is the generation and justification of knowledge claims, beliefs and actions to understand the nature of science (Sampson & Clark, 2008). As such, argumentation is encouraged as an important part of engaging students with social issues for example, socio-scientific issues and relevant community experiences which can lead to deeper understanding of science concepts, process, laws and theories (McNeill & Pimentel, 2010).

Thus, the process of argumentation is based on the ability to generate persuasive arguments (Jimenez-Aleixandre *et al*, 2000; Sampson & Clark, 2008). This is why students need argumentation skills in order to deal with any valid disbelief about knowledge claims (McNeill & Pimentel, 2010). However, students need to be given guidance to engage in the practice of scientific argumentation practice for example, through debates and other writing frames such as, laboratory reports (Berland & McNeill, 2009).

2.5 Written arguments for conceptual understanding

Many studies, both nationally and internationally focus on classroom practice between teachers and students on oral rather than written arguments. In such studies, argumentation is seen as both a teaching strategy and a research tool (Otulaji, Cameron & Msimanga, 2011). International studies on argumentation include those done in the UK, for example, Simon, Erduran and Osborne (2006), Sampson and Clark (2008), McNeill and Pimentel (2010) and Osborne, Erduran, Simon and Monk (2001) as well as the USA by Berland and McNeill (2009). There are fewer studies done in South Africa for example, Msimanga and Lelliott (2012); Webb William and Meiring, (2008); Diwu (2010) and Lubben, Sadeck, Scholtz, and Braund (2010).

Very little research has been done on written arguments. The link between understanding and writing is asserted by Aydeniz & Gurcay (2013) as they note that argumentation can assist develop enhanced conceptual understanding of the scientific concepts covered by the school curriculum. Written arguments play a crucial role in learning science as students write they "must make inferences about the data prior to being able to construct the claim" (Knight *et al*, 2013, p.5). In addition, it is important to note that Lemke (1990) argue that "reading and writing skills are related, but reading is primarily receptive, while writing is primarily productive" (p.6).

Written argumentation practice relies on students' ability to think critically. However, students are not always afforded the chance to engage in argumentation and to learn how to construct convincing arguments verbally. Thus, it is even more difficult for students to communicate their arguments in writing (Lubben *et al*, 2010). Meanwhile, teachers' ability to implement argumentation in their science classrooms depends on their own understanding of argumentation. Scholtz, Braund, Hodges, Koopman and Lubben (2008) note that teachers need to be involved in the process of critical discussions and assessment. Therefore, helping them to be aware of their own views can motivate them to fully understand the characteristics of argumentation. Thus, Kuhn (2010) argues that the expansion of argumentation abilities warrants pedagogical investment. This implies that much still needs to be done with teaching practices teachers poses.

There is a difference between oral arguments and written arguments. Oral arguments are often whole class or small group discussions, while written arguments could or are often an individual task. Oral arguments tend to be collaborative works were students participate to contribute to the main argument, because oral arguments often give all students a chance to contribute to the argument. Hence, the way one analyses oral arguments would be different to written arguments (Kelly & Takao, 2002).

But, when written arguments are done individually I believe students struggle as they have to filter their thinking by selecting the important facts to write. Often students have not been tutored the structure of an argument and thus, struggle to produce a good argument. Besides, Laurinen and Marttunen (2007) argue that for learning, the practice of writing arguments is more effective than oral arguments.

Furthermore, writing scientific arguments can be challenging for non-English speakers or second language speakers in South African context. Considering the fact that most students in South African schools are learning science in a second additional language would not make it easy for them to express their ideas when writing arguments. And again, science is a language in its own right which is not English in isolation. Thus, I believe English language and science language both affect how students are able to write arguments.

According to Laurinen and Marttunen (2007) "when students are in fact learning by arguing their retrieval processes are directed toward the memory engrams of written texts" (p. 233). This means that argumentation is a process of thinking that uses existing memory of written texts. Arguing is a skill that develops students' analytical skills thus, when students' write arguments they recall and reflect on their thoughts. Hence, by writing arguments students get a chance to also use formal written language when they justify their claims and opinions. Unfortunately, Kelly and Takao (2002) found that, students are generally better at identifying stronger written arguments than being able to write detailed reasoning for their choice.

Laurinen and Marttunen (2007) states that written arguments can always move students' creativity along a spectrum of spoken and written language. I believe in order to develop students' critical thinking both writing and oral argumentative skills are important in science learning. However, research reveals that students struggle to write arguments for different reasons. For instance, written arguments play a crucial role in learning science as students write they “must make inferences about the data prior to being able to construct the claim” (Knight, McNeill, Corrigan & Barber, 2013,p. 5). This means that students make use of pre-existing information to write arguments.

Students also need to be taught how to write arguments at a higher level. Written arguments play a critical role in learning science. It is crucial that students engage in the writing activity at times rather than in oral discussions all the time because analyses of students’ scripts provide insights on how they understand content (Kelly & Takao, 2002). The role of argumentation instruction should be to emphasise the development of students’ conceptual understanding of scientific concepts rather than the end goal that emphasise the rhetorical structure of an argument (Cavagnetto & Hand, 2012).

In conclusion, science education aims to produce students who can engage in science practices that include doing, talking and writing science. Argumentation practice requires both verbal and writing skills as such; argumentation is a special kind of science talk. Argumentation is fundamental to scientific understanding. Research on written arguments is under researched in South Africa. Students are not taught the skills to write scientific justification to their claims. McNeill (2011) conducted research on argumentation and found that elementary students are able to write scientific arguments yet, they need support to apply this practice to new and more complex contexts and content area, and hence argumentation skills are not dependent on elementary or high school level.

2.6 Challenges with Argumentation

Many students in South Africa have not, and are not taught skills to construct and write scientifically accurate justifications for their claims (Diwu, 2010). Another challenge is that most South African students’ literacy levels are so low, that they cannot effectively communicate their understanding of science concepts (Lubben *et al*, 2010). As a result, students struggle to articulate their arguments either by verbal or written texts. While, Msimanga and Lelliott (2012) also argue that argumentation in itself can assist students make sense of science concepts.

Cavagnetto and Hand (2012) argue that although argumentation is thought to be a positive skill to improve learning similarly, to inquiry argumentation has potential to become a teaching strategy. Unfortunately, over the broad body of research, there is still no “valid and reliable instruments to measure comprehensive, effective and scalable classroom tools and assessments for argumentation” (Knight, McNeill, Corrigan & Barber, 2013, p. 1). As such, argumentation is undefined and therefore ends up being underutilized in teaching and learning contexts.

One could also ask whether argumentation is feasible in South African school contexts. It is clear that we have many students who do not speak English and yet it is the Language of Learning and Teaching (LOLT); this could be one of our challenges. Furthermore, argumentation research in South Africa is still new and a challenge to develop in schools (Webb *et al,* 2008: Lubben *et al*, 2010; Diwu, 2010). The reason is that most teachers are affirmed to the traditional ways of teaching science which are teacher-centred e.g. chalk and board, while argumentation is learner-centred teaching and learning strategy. However, studies done so far cannot provide numbers that demonstrate that argumentation has increased student achievement. Thus, there is case to be made for studies like mine which begin to show learning through argumentation.

Furthermore, Qhobela (2012) notes that the challenge associated with argumentation, is teachers Pedagogical Knowledge (PK) as argumentation practice changes the traditional ways of teaching and learning that both the teachers and students are used to. PK is a teacher's special kind of knowledge that is posed about '*general knowledge of teaching'*. Besides that, argumentation as a tool does not require a school to have resources, but the necessary teaching skills on how to include it in a lesson. Furthermore, Castellas, Cervero and Konstantinidou (2011) argue that student's ability to argue is influenced by features of the particular task given to students, their pre-existing ideas, personal interpretations of the task and their science content knowledge.

In addition, student challenges include the lack of the skills to provide evidence for their argument, lack of understanding of the difference between data and evidence; hence interchanging the use of the two in an argument (Sampson *et al*, 2013). For example, when students write their lab reports they struggle to interpret their data from their observations as evidence. In this case, data means the results that students obtain during an experiment, because most often students shift the findings to coincide with their ideas and tend to avoid any other findings (Sampson *et al*, 2013). Other students use inadequate data to make general conclusions and they struggle to defend their arguments (Sampson *et al*, 2013). When writing lab reports little argument is done to question the data obtained as science is seen as absolute truth.

The challenges with students' written argument are that they struggle to filter their thought to make an argument. Students often write arguments that are narrow and do not have the appropriate skills to provide counter-arguments. Thus, my study aims to study the nature of these students written arguments and how they are able to construct written arguments.

2.7 Summary

In this chapter, I have shown how I drew on argumentation literature to frame my study. I have also looked at studies which show how argumentation has been used in research both locally and abroad. Argumentation is an interesting concept to research in science education contexts as it is implicated in various curriculums as being important for students learning. Students should be able to acquire and engage in argumentation skills during classroom interactions by using the science knowledge to debate knowledge claims.

The key goal of science education is to achieve a state where students are able to engage in arguments within a social process of knowledge construction. By so doing, students must be able to support their claims with relevant evidence and provide reasoning that draws from their everyday knowledge to conceptualise scientific knowledge. Science classrooms aim to produce students who can engage in science practice which includes doing, talking and writing science. According to research, students however struggle with this practice and thus, need additional instruction.

Argumentation has also been accredited as a feasible strategy of teaching and learning that requires either written or spoken arguments to consolidate students' prior knowledge and assist them to understand science at a higher level. Argumentation as a potential teaching and learning tool will require changes from the traditional way of doings things in science classrooms.

Involving teachers in the process of critical discussions, assessment and leading them to be aware of their own views on argumentation is the first step towards the improvement and development of their practice of argumentation in science classrooms. Students need to be taught the skills to use scientific concepts to support their claims. The classroom practice should be that, which allows flexibility to students input on contents of a lesson. Not only does arguing about science concepts help understanding, it aids mental thoughts about the scientific knowledge to be developed conceptually. Students need to be taught the skills to argue from their practical investigations and through to their classroom practice of learning, in class activities either through writing or talking.

If students develop complex argumentation skills, it would be beneficial to enable them to evaluate claims and data, which is essential in order to make decisions in everyday life to whether an argument is valid or not. Argumentation skills are seen as a means to negotiate knowledge claims. Like most research findings above, studies confirmed the importance of argumentation, as a teaching and learning tool in science classrooms.

Written arguments are particularly difficult for students because lack skills on how to construct them. Students are often untutored on how to write a valid scientific argument. The structure of a written argument has not been taught to the students, how to include a claim, data, warrants, backing and rebuttals when writing a good argument. Thus, my study aimed to understand students' struggles with written arguments. In the next chapter I will discuss the methodology and design of my study.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter seeks to describe and explain the research design and methodology of my study. I will show how the paradigm that informed the research links to the instruments, data its analysis and interpretation.

As discussed in Chapters 1 and 2, my research aimed to address students' and teachers' understandings of science arguments and the nature of students written arguments. The main purpose was to see if students understood how to construct a relevant argument through written responses. Furthermore, I wanted to know if students are able to support their claims with scientific evidence and show their reasoning on a written task. The research questions guiding this study are:

i. What are students' understandings of argumentation as a tool for science learning?

ii. What are teachers' understandings of argumentation as a tool for science teaching?

iii. What is the nature of student's written scientific arguments?

As discussed in the literature review, I took a socio-cultural view of learning, which notes that learning occurs through social interaction. Learning is viewed as a cultural process in a cultural discourse (Vygotsky, 1978). Vygotsky notes that learning is mediated through social interaction. Therefore, learning can happen with assistance from peers or the teacher. A teacher serves as a bridge between knowledge and students, as students make meaning cognitively. It is important to note that learning takes place through both internal and external arguments. Driver, Newton and Osborne (2000) argue that science is a social process in which scientists' debate knowledge claims and continuously refine and revise knowledge based on evidence hence, argumentation skills are crucial part of social interaction.

This belief underpins this research project to help find out how students interact with their teachers in science classrooms during classroom talk. Argumentation is one form of classroom talk that students and teachers utilize at different levels depending on the topic of the lesson. Argumentation can also be observed from verbal or written responses to a task. Hence, my research aimed to address the understanding of science classroom talk through the tool of argumentation from students' and teachers' understanding. In addition, this research was also assessing the student's responses to the short Multiple Choice Question task, which revealed the nature of their written arguments.

3.2 Research design

Hatch (2002) argues that each research is guided by what we call a paradigm. A paradigm is a body of knowledge that is characterised by a set of beliefs or theory about "how the world is ordered, what we may know about it, and how we may know it" (Hatch, 2002, p.11). For this study, I used a qualitative approach which focused on the descriptions of how students and teachers experience argumentation in science classrooms.

Thus, my research paradigm is interpretivist. The ‘interpretivist’ paradigm views the nature of reality as “knower and known are inseparable, research is value bound, logic leads to generalization, induction, qualitative analysis” (Johnson & Onwuegbuzie, 2004, p.16). The data was based on teachers and students own categories of meaning from their own understanding of “argumentation’’. Inductive analysis of data was implemented to interpret in detail scenarios as they are situated and embedded in a local context of the participants (Johnson & Onwuegbuzie, 2004). Thus, inductive analysis was applied to determine how participants understood the construct in this case “argumentation” as a teaching and learning tool.

3.3 Data Collection Instruments

The research instruments were questionnaires, interviews and one MCQ task item. The major research instrument of the study was the questionnaires to explore students understanding of argumentation in science learning. Piloting the questionnaire was very important therefore, this was done immediately after creating the suitable layout of the questionnaire. Ten students from NS1 (first year course for student teachers) were required to complete the questionnaire at the piloting phase. Piloting revealed errors on sentence constructions.

The advantage of using the questionnaires and interviews was to produce descriptive and opinion-related data about students’ and teachers’ understanding of science talk through argumentation. The questionnaires was a good way of collecting data and were also easy to give out and less time consuming in that it took a participant only 20- 30 minutes to complete a questionnaire and less than 20 minutes to audiotape each teacher’s interview. To make the questionnaire easy to fill, I made sure that the wording was not too long and the questions were clear, explicit and straight forward. This was informed by observations from the piloting of the instrument. I self-administered all the research instruments in schools.

The structure of the questionnaire included both open and close ended questions. Osborne *et al*, (2001) assert that the use of open-ended question in a questionnaire is the best way to evaluate students written argumentation skills. Open ended questions allowed the participants to give responses that are not narrow. The participants get a chance to answer in any way they want to, unlike when restricted by close answer that are indicated on the questionnaire. The questionnaire also collected data from their response to the MCQ question.

The interview data gathered from respective teachers had provided collaborative data, for answering research question on teachers’ understanding of argumentation for teaching. Opie (2004) and Bell (2010) note that there are three types of interviews, namely unstructured, structured and semi-structured. I used a semi-structured interview format to interview physical science teachers on their understanding of argumentation for teaching science in classrooms. Although I asked follow up questions, the semi-structured format had a core set of short directed questions that had provided a manner to analyse and code. The purpose of the interviews was to capture differences or similarities in teachers’ views of argumentation.

According to Cohen and Manion (1985) interviews can provide an opportunity for asking questions to the interviewer clearer than a questionnaire would. This implies that it was easier to get teachers' thinking, beliefs and understanding of argumentation in more detail than on questionnaire, since I had an opportunity to ask a follow up and clarifying questions in the interviews. The trick with interviews was that I needed to prepare them thoroughly. Interviews were audiotaped and later, transcribed for analysis. Audiotapes helped me to play back the audio and retrieve the data collected during the interview as accurately as possible.

3.4 Sampling and Ethical Considerations

Data was collected from Grade 11 science students in two high schools. The reason for choosing Grade 11 is that they have been exposed to the Physical Science classroom context in Grade 10, so I assume that they have a good background of concepts from both Physical Science in Grade 10 and Natural Sciences in Grade 8 and 9.Therefore, I assumed students should at least have minimum ability to understand how to talk about science through argumentation in class. On the contrary, Berland and McNeill (2009) argue that their research revealed that neither age nor class of students limit their ability to include some type of evidence and reasoning to support their claims in argumentation activities. However, the authors do not deny that tutored students on argumentation tend to have a stronger understanding of content than untutored students. I worked with untutored students, so I chose a higher grade level for this study.

It was very important for me to make all my assumptions about the Grade 11 students clearly known; hence I have done so in the paragraph above. Assumptions are some of the pre-existing ideas that I had about the students that I choose to work with. The MCQ that I gave the students to complete in my questionnaire was based on the assumption that students already have an idea about the law of the conservation of mass from previous Grades and that students were proficient in English as a language of instruction so they could be able to read and write in English.

A total of 79 students were requested to complete the questionnaire and the attached MCQ task item at the end of the questionnaire. The interviews were done with the two respective teachers at these two high schools. Both are male teachers, Mr B holds an MEd in Science Education and Mr G has a B.Sc. in Chemistry. Both schools are fairly well resourced with laboratory equipment and a computer centre.

The schools are situated in the northern suburbs of Johannesburg and only a few kilometres from the university which made it very easy to access and collect data. Also, I did my second year undergraduate teaching experience in one of the schools in 2011 and therefore had a friendly relationship with the school and staff.

My sampling rationale was based on the scope of a Masters Research project registered for full time and that can only be completed within six to eight months after the research proposal was accepted around June. Therefore, one cannot take up a huge sample than to work with two schools that gave me a sample of 79 students who completed the questionnaires. Time was a very important fact to consider in order to interpret and analyse the data thoroughly and to write a research report.

Although students and teachers were not paid to participate in the study, I believe they will benefit from the findings of the study. The findings will inform both teachers and students what they understand by argumentation for teaching and learning of science. Wits ethics clearance and GDE permission were obtained. These required me to comply with certain ethics standards, when conducting the research such that teachers and students were not exploited in any way. The data is currently stored in a password protected laptop, and the hard copies are under lock and the key at Wits University. No one gets to interact with the data except me and my supervisor. After writing the research report, the data will be stored for a period of three to five years and then destroyed. This information was communicated to teachers, students and parents in the consent forms. (Appendix C, D, E, F)

Before collecting data, the students were given information sheet and consent forms for them and their parents or guardian to sign. Some students forgot to ask their parents to sign so I had to go back to the schools four to five times until I had a sufficient number for an access sample of seventy nine.

3.5 Data Analysis

Teacher interviews and Section A of the student questionnaire, that consisted of closed and open questions were transcribed and analysed using frequencies and themes that emerged. This form of analysis is termed inductive analysis, according to Hatch (2002). Inductive data analysis is a search for patterns of meaning in data, so that general responses about a phenomenon under investigation can be made. Inductive analysis is different to deductive analysis, as deductive analysis is an approach that uses pre-existing analytic codes to interpret data.

The written MCQ item was analysed using Erduran *et al*, (2004) analytical framework as described in the literature review. This analytic tool uses a deductive analysis (Table 3.1) because it imposed levels at which arguments were evaluated. The use of the MCQ task item at the end of the questionnaire was relevant to explore the nature of arguments students were able to construct. Below is the MCQ task item which was attached to the questionnaires.

Section B (MCQ task)

This section is analyzing how you argue a scientific statement and how you support your written scientific response.

Please answer the following question:

A 5 gram sample of solid iodine is placed in a tube and the tube is sealed close after all the air is removed. The tube and the iodine together weigh 20 grams.

If the tube is then heated until all the iodine is evaporated and the tube is filled with iodine gas. Will the weight after heating be.........?

Circle the correct answer:

a. Less than 19 grams
b. 19 grams
c. 20 grams
d. 21 grams
e. More than 21 grams

Explain/argue your answer in detail:

Written responses were analysed using the following framework:

Table 3-1: Table of Analytical Framework used for assessing the quality of arguments

Level 1	Level 1 argumentation consists of arguments that are a simple claim versus a Counter-claim or a claim versus a claim.

Level 2	Level 2 argumentation has arguments consisting of claims with data, warrants, or Backings but does not contain any rebuttals.
Level 3	Level 3 argumentation has arguments with a series of claims or counter-claims With data, warrants, or backings with the occasional weak rebuttal.
Level 4	Level 4 argumentation shows arguments with a claim with a clearly identifiable Rebuttal. Such an argument may have several claims and counter-claims.
Level 5	Level 5 argumentation displays an extended argument with more than one Rebuttal.

(Adapted from Erduran *et al*, 2004)

This table was used to interpret and classify students written arguments according to levels. The levels would indicate what the written argument consisted of in terms of the presence of claim, data, warrants, backing or rebuttals.

However, it was not easy to use Erduran *et al*, (2004) analytic framework, as it is normally used to analyse oral arguments and not written arguments. Also as with other analyses the challenge was to define a claim, data, backing, warrants, and rebuttals. For example, my identification differed from my supervisor's. My supervisor and I then decided to involve four more academics that are familiar with the concept of argumentation in science. Their responses to two written arguments were compared to those of mine and my supervisor's. The selection of the claim, data, backing, warrants and rebuttals within those written arguments were different. In the end, my supervisor and I had to discuss and come to a consensus. The validation tool is attached, Appendix I.

3.6 Rigour: validity and reliability

Bell (2010) argues that sometimes the number of participants needed, depends on the amount of time one has to collect data. The number of students who completed the questionnaire was more than 75 and I believe this number is big enough for data consistency. In a qualitative study, it is important to make sure that one reports on results that are true. This meant that my findings had to be an honest reflection of what I had obtained from the research instruments. Six academics assisted to validate the analytic framework and to find consensus in identifying a claim, data, warrants or rebuttals on a written argument. This helped to enhance the validity of my data analysis and findings.

3.7 Limitations

The MCQ task item was not sufficiently open, meaning that it did not allow students to explore their argumentation writing skills. The question was a pure science topic and not a socio-scientific topic. Socio-scientific topics make it easier for students to engage in arguments. For example, question like do you think the state should permit the construction of a nuclear power station. A question like this would make students argue better than a pure science question.

It is also possible that the MCQ task item was a problem in terms of the English language. Most students called me to clarify what the task actually required them to do. Students did not know what it meant to support their chosen answer. The sentence construction of the task was also a challenge for students to understand was happening to the iodine solid when it was heated in the test tube. When the iodine was heated it evaporated to fill up the space within the closed test tube. Some students associated the evaporation, to mean that the iodine gas escaped the test tube, not considering the fact that the test tube was closed.

3.8 Summary

In this chapter I have explained what, why and how my research methodologies (tools of collecting and analysing data) were relevant for answering the research questions. The research took a qualitative approach which was focused on the descriptions of how students and teachers experienced argumentation in science classrooms.

The focus of the research was on understanding of argumentation by two teachers and their Grade 11 students' perceptions of argumentation as a teaching and learning tool and at what level the written arguments occur. The next chapter will show findings from the responses of the students and teachers to the research instruments described above. The themes and frequency tables are used to present the data and interpretations to answer the research questions of this study.

CHAPTER 4: DISCUSSION OF RESULTS

4.1 Introduction

In this chapter I discuss my data analysis and present my results. The data analysed was drawn from the questionnaire and the interviews on students' and teachers' understanding of argumentation. I also present some findings on the nature of students' written arguments. Argumentation was analysed as both a teaching strategy and a learning tool.

The results presented below are drawn from data collected in Grade 11 science classrooms from two different schools in the Northern part of Johannesburg. The interviews were conducted with the teachers of the two respective classes. The questionnaire was analysed so that information can be extracted about how students' understand argumentation and to determine the nature of their written arguments. Teacher interviews gave me qualitative data about how they understand argumentation and its role in science teaching. A total of 79 questionnaires were completed by 51 students from Mr B's class and 28 students from Mr G.

4.2 Findings on students understanding of argumentation:

To make sense of the responses to the questions gathered from the questionnaires, I grouped these responses into three main groups namely; questions on the value of science classroom talk, questions on students' understanding of argumentation and questions on how to promote argumentation.

4.2.1 Questions on the value of science classroom talk:

I present the data according to the questions that I asked.

The first question was to see if students talk about science in class, which was *do you talk about science concepts (that you're being taught) in class.* Seventy one students said they do talk about science in their classroom and only eight students said they do not talk. This question was asked to establish whether students engaged in any form of verbal communication when learning science. Conceptual understanding in science can be investigated best by understanding how we talk and write science (Lemke, 1990).

When they were asked who they talk to about science concepts, students gave a variety of answers as seen in the next table. The table is constructed according to how often the name occurred in the analysis of the questionnaires. Hence, I used frequencies to count how often the person had been mentioned.

Table 4-2 Frequencies of people who students talk to about science concepts

	Girls High	Boys High	Total frequency
Classmate	16	32	48
Friends(peers)	10	18	28
Family	6	5	11
Teacher	10	23	33
Other	3	2	5
No responses	-	3	3
Total	45	83	128

Here students indicate that they talk mostly with their *classmates* about science concepts, with a total of 48 out of 128 frequencies indicating that. The next highest frequencies were that students talked to their *teacher* which has a frequency of 33 and their *peers* with a frequency of 28. A few students said that they talk to *family* about science, while some talk to *'other'* people. A follow up interview would have helped me determine who the 'others' are that they talk to. Overall students do talk to other people about science in and out of the classroom. Lemke (1990) argues that learning science is always led and informed by talking science, to ourselves and with others; as such it was important to know who the students actually talked science with.

When asked how often they *talk about scientific concepts taught in the classroom*, students had the following to say.

Table 4-3 Ranks at which students say they talked in science classroom

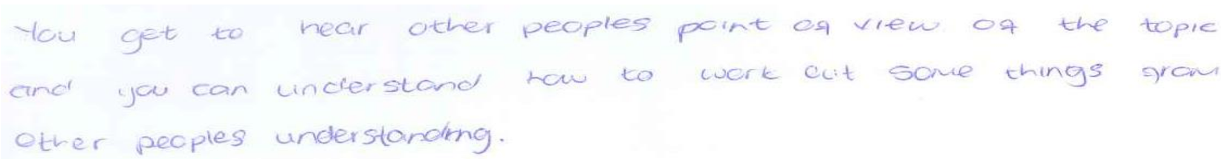
	Very often	Often	Sometimes	Less often	Not at all	No response
Girls High	2	7	16	2	-	1
Boys High	4	19	23	5	-	-
Totals out of 79	***8***	***33***	***49***	***9***	**-**	***1***

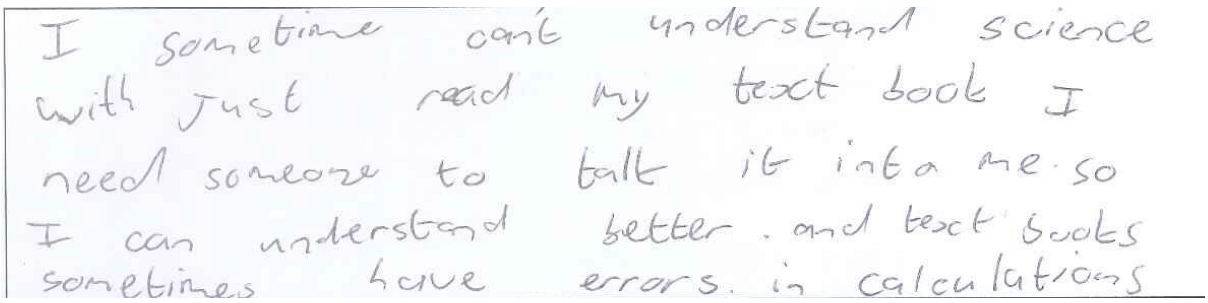
The responses to this question were given on a Likert scale from "very often" to "not at all". These information, indicate that in both schools, a total of 49 students talk only *'sometimes'* about the scientific concepts. While, the second highest is 33 students who agree that they '*often'* talk about science. So, although in answer to the first questions, students said they do talk in class, it seems that they feel they do not talk often enough.

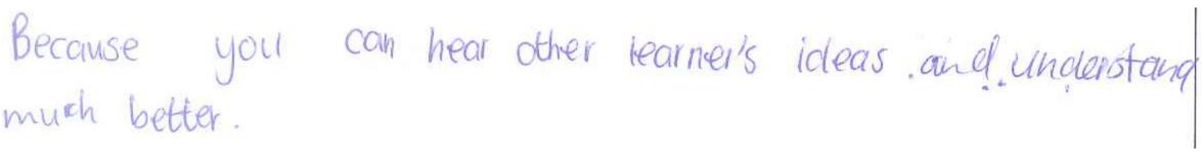
When students were asked if the *talk they had was an open ended or closed ended talk*, they seemed to struggle to understand the difference, until I told them the difference. It is not surprising that the students did not know the difference because these are terms used by teachers and researchers. I threw the question in just to see if students do pick up the difference. In this question I wanted to extract the type of talk that dominated in those science classrooms. In a sense that I wanted to find out if the talk that did occur was often open or close ended. From the data 53 out of 79 students noted that the talk they had was mostly open ended, while 25 said it is a closed talk. This type of question was important to establish the contextual talk that occurred in those two science classrooms.

Students *were asked if one can learn science better from talking science in the classroom*. 64 out of 79 students say that one can learn science better from talking in the science classroom, while 15 other students say no. The students were asked this question as I wanted to get their opinions about whether they value the effect of talking in science classroom and if they thought the talk do help them learn science better. I made an assumption that within the discussions that occurred, some level of argumentation about science concepts does arise, and through that students get to learn more scientific knowledge.

Students then gave reasons to why they say that one can learn science better from talking in the classroom as follows below:


You get to hear other peoples point of view of the topic and you can understand how to work out some things from other peoples understanding.


I sometime can't understand science with just read my text book I need someone to talk it into me. so I can understand better. and text books sometimes have errors. in calculations


Because you can hear other learner's ideas and understand much better.


Discussions allow better understanding because its verbal

you get clearly understand when you talk because you can understand when you are wrong.

Because one gets to learn more where she gets different opinions from different people.

By talking, it opens up a whole lot of ideas and theories to question.

You remember beter when you talk but when you just write you sometimes ~~writh~~ write with no understanding

Students quoted above gave different reasons, for why they think talking in class is important to help them understand science better in the classroom. These findings shows that most students value to effect of talking science and how they belief it will help them learn science better. In short, students notes that talking helps as they remember concepts better, get to understand different opinions from fellow students and they learn better because they are discussing ideas.

Students seem to value their peers' ideas and they view talk as both a window to peers' thinking and a tool to aid their own understanding of concepts. These findings are important for teachers to be informed about how students value the talk that occurs in the classroom. Teachers can then decide whether or not to incorporate the characteristics of argumentation driven lesson within the talk. This would help to engage students to argue scientific concepts for further conceptual understanding, as verbal scientific arguments are embedded in talking science.

Students were also asked to give examples of how science talk is encouraged in science classrooms learning, below are some of the responses:

> *'By making more practical's and expos for learners and by also changing the system of learning from textbooks and using more technical advanced technology such as tablets'*
>
> *'By scientific argument and by experiment and by experiments'*
>
> *'In a science talk, it may lead to a debate which may encourage more learners to listen so they can be part of the argument /debate. I may also encourage the teacher to teach and give his opinion'*
>
> *'Through experiments and practical's and if the teacher showed interest and potential in the lesson. And treat every learner like we equal'*

'Talking more and having interesting argument s in class encourages us learners to take part in class'

'Starting more scientific arguments in class and prove laws'

' science talk can be encouraged in science classrooms only if learner cooperate and listen attentively when the teacher is speaking or discussing or doing a practical in class about a concept'

'Starting scientific arguments in class and asking children to bring proof about the class scientific argument'

'Starting more scientific arguments and asking the learners to prove theories'

'it can be encouraged in such a way that the person who is talking should know what he is talking about and he should be sure that he is correct and has proof about his work'

'Creating scientific debate competitions'

'if only we can get example that have similar concepts but are not really scientifically like things that we go through in our everyday lives'

The above quotes are students' suggestions on how science talk can be encouraged in science classrooms for learning purposes. These quotes are a random sample of what some students think will support them learn science better through talking. Students are aware of the strategies such as, debates, everyday examples of science concepts, talk using proofs and experiments that they can be used to learn science thorough talking. From this data one can make means to observe and investigate lessons over a period of time to see if they lead to any form of science arguments.

The students were also asked if *the talk they have in class leads to a scientific argument and* ***most*** answered "yes" to that question. Fifty four students said yes and 25 students said no. This question was meant to investigate whether they felt that the talk that happened in the science classroom was useful for developing '*scientific argument'*. While asking this question I made the assumption that students knew what a '*scientific argument*' is. Lemke (1990) argues that talking science is an illustration of every scientific argument we make in all our reasoning as we do science.

It is important to note that 'when talking one presents a justified claim in response to a question or listens and respond to the claim someone else is making' (Knight, McNeill, Corrigan & Barber, 2013, p. 5). These authors argue that talking is embedded within the principles of thoughts requiring internal and external arguments. However, I wanted to use this question to build up to the next one which would show me if they really knew what a scientific argument is. The majority said their talk led to scientific argument. Now the second question shall help us see if the students did understand what a scientific argument was.

4.2.2 Questions on students understanding of argumentation:

The next question was to ask students *what is a good scientific argument* and this was an open ended question allowing students to write down their answers. I then categorised their answers into three groups. In order to classify if the student had an idea or not I looked for specific words in their definition. The words include facts, evidence, support, proof etc. Most students seemed to have a good idea of what a scientific argument is, as 55 had an idea, 19 hands no idea and the remaining 5 out of 79 did not respond to this question. However, students gave general ideas about what a good argument is and not what a good scientific argument is. For example, let us look at some of their written definitions below:

I)

Its when learners argue about a certain thing and ~~they~~ both their opinions are right.

ii)

It is an argument that has a problem and facts to support it and justify the argument.

iii)

a good scientific argument is an argument whereby the person arguing against a certain science question both have facts to prove a certain point and also has enough information and also solutions

iv)

It is when the learners agree or disagree about the topic given and the class tries to find a conclusion of the topic.

Some students did seem to know what an argument is. For example, these definitions quoted above show that the students are aware of what a good argument is. Similarly, the two definitions below show a fair understanding of what a scientific argument is as, the students made use of the wording like '*different solutions'* and '*scientific reasoning'*. These are reasonable definitions which demonstrate adequate understanding of a good '*scientific argument'*.

v)

A good scientific argument is when there are different solutions to a case and there are strong points to argue against or with those solutions, giving scientific reasoning.

vi)

A good scientific argument is reasoning your arguments / Statements with a scientific reason.

These examples of what a '*good scientific argument'* is are just a general way of defining a good scientific argument from the students understanding and perceptions. I accepted these because they have some of the elements that define a 'good argument' even though they lack further add-ons to a good 'scientific argument'. Also, for this level of students, who are untutored in argumentation, this is a good start. Research finding reveals that students need more instruction to construct scientific arguments as, they poses very little argumentation skill (Schen, 2013).

In summary, this question helped me to get an understanding of students' perceptions of what makes a good scientific argument. It is adequate from the students' responses that they are not blank about what would really make a good scientific argument. This was important to investigate in the research as part of the journey to understand how students would engage in their written arguments on section B. Their definitions were an important finding, that indeed students from both high schools are aware of what a good scientific argument should consist of. I looked forward to seeing how they write their arguments later.

I now want to highlight some of the incorrect or incomplete definitions of 'scientific argument': Here are some of the incorrect or incomplete definitions of 'scientific argument':

> *'An argument that gives information to people'*

> *'A good scientific argument is based on what you have learnt and what you know about that particular topic'*

> *'Talking in a scientific way'*

> *'Way by you finds the solution of the scientific answer'*

Often teachers (and researchers) focus on the correct answer. It is important to look at incorrect answers in order to understand learners' struggles and knowledge gaps about scientific arguments. The teacher can then use these as resources in teaching the topic in future. Some of these student responses show that there should be something about science but they are not sure what. So these are incorrect definitions because they are not clear.

As a follow up to students' understanding of what a scientific argument is, I also wanted to extract their ideas about questions that they think can help them engage in scientific argument. I asked them *which questions would make you talk/argue in the science classroom.* Students' responses were interesting as they demonstrated that they were aware of the questions that can stimulate an argument. Here are some examples:

> *' the questions that may require a lot of research and that may require one to maybe use some real life examples to get to the solution'*

> *'Questions that require us to think really deep'*

> *'What is the difference between a normal gas and ideal gas?'*

> *'Questions as to why light or sound waves impact on people'*

'Can sound waves travel without a medium?'

'Why does water freeze on the surface of the ocean but its liquid underneath?'

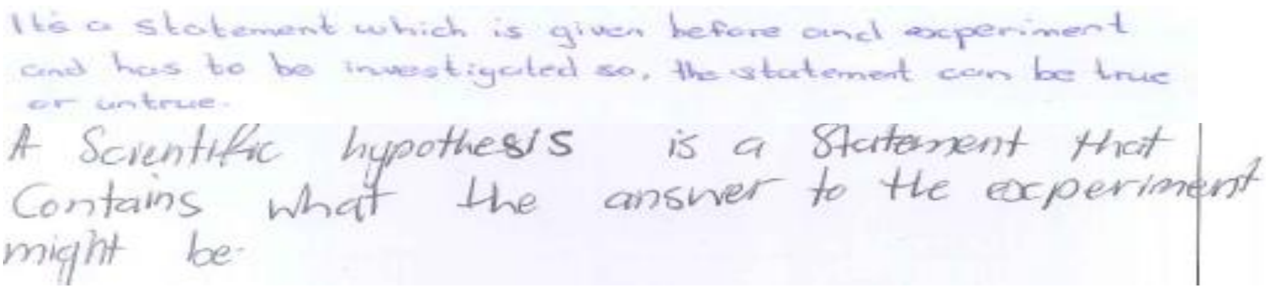
'How can you improve on how to get your answer?'

'Questions that involves theories that need to prove'

From these findings students gave adequate statements about what could assist in making them talk or argue about science concepts in the classroom**.** For example, they said questions that starts with words like, why, how and what. These types of responses showed that some students are aware of typical questions that would make or lead them to talk in class.

In order to deepen students' thinking about scientific arguments, I asked them some questions that link argument construction directly to science learning that they are familiar with. For example, I asked them whether they understood *what a scientific hypothesis is.* A scientific claim is a logical explanation of a phenomenon which is yet to be proven otherwise (Bless, Higson-Smith & Kagee, 2006). Data indicates that about 50 students are able to define a scientific hypothesis, while 23 students are unable to define a scientific hypothesis. The criteria I used to categorise whether the students had an idea or not was based on the definition of a scientific hypothesis. Therefore, if we want students to be able to engage in scientific arguments it is important that they are able to distinguish between scientifically correct hypotheses and scientifically correct statements. Just because an argument is scientific does not always mean that it is a correct scientific argument (Bless, Higson-Smith & Kagee, 2006). In these findings at least more than a half of the total students are able to define a scientific hypothesis.

Below are some of the correct explanations:



It's a statement which is given before and experiment and has to be investigated so, the statement can be true or untrue.

A Scientific hypothesis is a Statement that Contains what the answer to the experiment might be.

A prediction of the results based on theory.

Above quotes are some of the correct definitions of a scientific hypothesis and it is important that students think it is an intelligence guess that is informed by pre-existing scientific ideas. It is then proved correct or incorrect during an experiment.

Here are some of the incorrect explanations:

A conclusion or proven fact about a particular experiment.

A scientific hypothesis is the answer you got on the experiment.

a scientific hypothesis is sort of a conclusion of an experiment carried out.

When you look at the above quotes, one can see that students get the definition of a scientific hypothesis while others do not. It is easy for students to think a hypothesis is a conclusion of an experiment while that is actually an incorrect definition.

Furthermore, students were asked to *differentiate between scientific claims from a scientific hypothesis*. I categorised the student responses as correct or incorrect depending on whether they could make a clear distinction between a scientific claim and scientific hypothesis.

Table 4-4 Number of students who got the difference correct or not

	Correct response	Incorrect response	No responses
Girls High School	17	10	1
Boys High School	17	24	10
Totals Sum	***34***	***34***	***11***

It was an essential part of the study to ask students to differentiate between a scientific claim and a scientific hypothesis. This was significant to investigate, since students can only conceptually engage in scientific arguments to develop their scientific knowledge, if they can clearly differentiate between a scientific claim and a scientific hypothesis. Students can learn a lot or be hindered to understand science if they are not aware of the difference between the two when engaging in a scientific argument.

In the above analysis it was found that there were about 50% of the students' understanding the correct difference and 50% had incorrect explanation. This data helps us understand that students are mostly not aware of the difference between the two concepts and this could affect the way they use scientific claims and hypothesis to argue their ideas in the science classroom.

4.2.3 Questions on how to promote argumentation:

In order to see if students understand the role of evidence in constructing these arguments I then asked the question, *how would you convince your teacher or classmate about your ideas in class?*

I.

By proving my statement correct and by quoting from the text book or the teacher.

talk about it in class, in front of the students Make notes which will help me out to proof my point. Make examples in our daily lives.

By explaining the idea so that they can see things from my point of view.

By participating in class, in that way your classmates and teacher will see the enthusiasm you have and listen to your ideas.
- give examples
- diagram

By giving scientific facts base on what I have learned in class or read from the internet

State the Certain facts involving the idea

probably by having a diagram or example about that particular work.

By talking about it and giving them reasons to be convinced. Or by doing an experiment to demonstrate.

These quotes pasted above from the questionnaires are the students' direct responses on how they think they would convince their teacher and fellow students about their ideas in the science classroom. Students stated different views on what they would do to convince the teacher and the classmates. It was interesting that some students said they will conduct an experiment to demonstrate their ideas, while research done in South Africa by Lubben *et al*,

(2010) noted that very few students are able to access resources and set up experiment to test out and argue their view point.

In order to get where students get their evidence to support their claim this question was asked, *where do you get the information that you use to support your scientific ideas* and Table 4.4 is a summary of students' responses.

Table 4-5 Resources that student uses to support their arguments.

	Girls High School (frequency)	Boys High School (frequency)	Total Sum (Frequencies)
Textbooks	23	44	67
Internet	20	33	53
Teacher	5	6	11
Television	6	2	8
Others (friends, lessons, general knowledge, media, classmates, experiments, other people)	8	18	26

The data above shows a similarity in both schools about textbooks and the internet being the leading sources of information that students use to get information to support their ideas in the classroom. This finding was similar to the one in my Honours research were the textbook and the internet are leading as sources of information. The recurrence of this observation suggests that students do rely on these two resources for information to support their scientific claims in the science classroom. It was important to ask the students this question because in order to help students to engage in science arguments we need to know where they gather the information they use to support their claims/statements. This finding is also interesting for South Africa because learner reading skills are persistently low. If students believe that the textbook and internet are useful sources, teachers can design activities that require students to read in order to find the scientific information to complete their homework, for example. This can also help develop students' reading skills even at this high level at high school.

After obtaining students' ideas about classroom talk and argumentation, I needed to also investigate their teachers' understanding of argumentation as a teaching tool. This would help me to determine if they shared the same understandings of argumentation and its role in the teaching and learning of science.

4.3 Teacher understanding of argumentation as a teaching tool

In this section, an analysis of teachers' understanding of argumentation as a tool for teaching is presented. This was in answer to my second research question which reads thus, *what are teachers' understanding of argumentation for teaching science.* This question aimed to find teachers' views that might explain whether and how teachers understood argumentation as a strategy for teaching science. This is an inductive analysis of interviews with two teachers whose students formed the sample responding to my other two other research questions. According to Hatch (2002) inductive data analysis is a search for patterns of meaning in data, so that general responses about a phenomenon under investigation can be made. The interviews were audio-recorded and transcribed. For anonymity the teachers are code named Mr B and Mr G respectively.

I conducted a thematic analysis of the data to find patterned meaning to answer the research question. Thematic analysis is a form of analysis that is used on qualitative research to 'identifying, analysing and reporting patterns within data (Creswell & Plano Clark, 2011). Patterns that emerge are the ones that bring out themes that can be used to organise and describe data in more detail. From the interviews, these **four** themes emerged *definition of science argument*, *the value of evidence vs. opinions*, *the significance of discussions and debates* and *arguments expose misconceptions*.

Theme 1: definition of science argument

Mr G defined a good science argument to be

> *'An argument that involves learners talking about scientific facts to support their arguments, not talking in general about things'*

Mr B defined a good science argument as

> *'One in which someone has evidence about a certain or theory, to base his argument, unlike own views without bases or theory or findings'*

These definitions of an argument are very similar than to each other. This implies that both teachers have same perspectives and thoughts about what a good argument is. They both value the use of facts or evidence as an important part of a good science argument. These teachers' understanding of a science argument is important for how they will use arguments to teach science. Thus, from their definitions one can see that they both said the same thought in different ways.

Theme 2: the value of evidence vs opinions

Table 4-6 Comparison of Mr G and Mr B understands of argumentation as summarised from the whole interviews.

Mr G's understanding of a good science argument	**Mr B's understanding of a good science argument**
Scientific facts to support the argument	Has evidence to support

discussion	discussion
opinion	opinions

Mr G and Mr B understood the argument as a way of providing *proofs or evidence*, which requires *supporting facts*. For instance, if one is arguing they need to provide theory or a concept to back up their argument. Both teachers have the same understanding of argumentation; it is just that they are saying it in different words. If they share the same understanding of the word argument, it means they have a similar academic understanding of the word argumentation. For example, in science an *argument* can be a point used as *evidence* to demonstrate that something is true (Kuhn, 2010)

While both teachers, mention *opinions* as part of an argument they are clearly stating that a good argument does not require personal opinions it needs facts, for example Mr B said that certain concepts or theory are needed to base an argument.

Theme 3: the significance of discussions and debates

Mr B and Mr G also think that a *discussion* is part of argumentation. This might be because they understand argumentation as a process where two or more people discuss contrary views. Since, arguments provide students with a choice to access any doubt to knowledge claims during classroom discussions (Diwu, 2010).

Mr G said that some topics do lead to an argument, while topics do not since the topics are clear and straight forward. The assumption that the teacher makes here is that if a topic is clear and straight forward, it will not lead to a scientific argument. However, Mr G said that the reason why lessons do not lead to an argument is because students tend to use their everyday experiences and personal opinions instead of scientific knowledge. So the understanding of an argument according to Mr G is embedded within scientific knowledge and not personal experiences. Therefore personal experiences makes the topics not be arguable.

The limitation of the interviews was that I did not find information as to how teachers understood the structure of a good argument. And, from the interviews one cannot observe how teachers engage students in an argument. However, Mr B said he would encourage science arguments in his class by;

> *'Telling the learners to go investigate a particular topic to come and discuss it in the classroom for feedback'*

Mr B implies that if students are given enough time to go and make research it could be a way to encourage them to engage them in arguments. It was important to note that teachers are aware of means to make students engage in science arguments. This is an important aspect as research reveals that teachers do not know of means to encourage students to engage in arguments in science classrooms (Lubben *et al*, 2010). From this finding, it would have been useful to have observed how the teachers actually conducts and manages those arguments after students have researched information prior the arguments.

These teachers told me that their students get information from media sources such as the internet through googling as well as watching learning channels on television, but this is what I already knew from analysing the students' questionnaire responses. However it is crucial that teachers are aware of the sources of information their students relies on for science content knowledge.

However, both teachers make notes that the talk they often engage in, with their students during teaching does not often necessarily lead to a scientific argument. These was evident as to why argumentation is not used as a teaching tool/strategy by teachers. Mr G admits that it's only *sometimes* were the talk actually leads to a scientific argument as;

> '*Most of the time the learners use their experiences and personal opinions when asked scientific things'*

On contrast, Mr B said;

> *'Some topics they do, others are clear and straight forward, and does not lead to an argument'*

These comments indicate that argument lessons are purposeful and as such, they need to be planned and managed accordingly. It is clear that argumentation as a teaching strategy still needs to be developed and trained to teachers to enable them to acquire argumentation skills for teaching science. An assumption is that not all learners should or can be taught via argumentation as a teaching tool/strategy.

Theme 4: arguments expose misconceptions

Both teachers said they believe that students can learn science better from arguing in class as this will assist them (teachers) in solving and discussing their 'misconceptions'. For example Mr B said that;

> '*Yeah, at least when they discuss and argue or give own opinions, as a teacher I am able to see their misconceptions. As A teacher I will be able to re-explain and give more evidence, by working on their misconceptions*'.

In similar comments Mr G, said that;

> *'When students talk, it helps them in solving their own misconceptions and getting second opinions to various issues'*

So both teachers believe that arguments about science concepts enable them to see students' misconceptions and this is because student's gave out opinions that often reveal their misconceptions. Misconceptions are a crucial part of science teaching and learning as they can inform the teacher about students' pre-conceived ideas. Thus, it was interesting to see that both teachers value arguments or even classroom talk as a tool to help expose students' misconceptions. A lot of studies have identified the impact of misconceptions in science education, for example Thompson (2006) citing Martin *et al*, (2002) notes that misconceptions in science are said to be ideas that give incorrect understanding of such ideas, objects or events, and these are referred to as misconceptions which are constructed by individual's experiences. Von Glaserfeld (1990) notes that misconceptions are mental images about how an individual perceives a phenomenon and they are very hard to eliminate and thus, requires teaching strategies that focus on conceptual change.

The other finding from the interviews was that Mr G said that his students can write convincing arguments, in addition he said;

> *'Provided that they read more, yes I believe my students can write convincing arguments'*

On contrary, Mr B admitted that he does not have faith in his students' ability to write convincing arguments as he is quoted saying that;

> *'Not many can do that; they are not positioned to present their own arguments'*

In this section on teachers' understanding of argumentation for teaching science, it implies that these two teachers are aware of what science arguments are, but Mr B, made it clear that his students are not in a position to be able to write good arguments. While, Mr G said yes his student can write convincing arguments considered that they read more. Even, though both teachers demonstrated some level of understanding towards argumentation practice for science teaching and learning.

In the context of this research on argumentation, it implies that more interventions need to be done to support or develop teachers' confidence to teach their students how to write convincing arguments in science classrooms. It is clear from the teachers' interviews that more research still need to be done to observe how teachers and students actually engage in argumentation practice during science lessons.

In summary, these two interviews reveal that teachers' understanding of argumentation are on a general notion of arguments not necessarily the idea of using argumentation structure as a teaching tool in science classrooms per se. Even though these teachers are not blank about the argumentation a lot still needs to be applied to develop their skills to use argumentation as a teaching strategy.

I then wanted to investigate whether the teachers' understanding could be correlated with their students' understanding of the role of argumentation. Thus, the table below summarises key ideas that students prompt from both schools.

Table 4-7 Comparison of key words that appeared frequent in Mr B and Mr G's students understanding of argumentation

Mr B students understanding of a good science argument	Mr G students understanding of a good science argument
Evidence, facts	Evidence, facts
opinions	Opinions
Learning science	Information to people
Open ended talk	Different hypothesis/ideas

Debate	Different solution
Lots of solutions in the talk	Open minded in intellectual manner
Bring different ideas	Debate

From what students mentioned three frequent concepts they used to define a good science argument was the use of *evidence and facts*, *debate* and source of information (*for learning of science).*

Students often mentioned that a good science argument should consist of *evidence and facts***,** debate and be some form of learning scientific knowledge. I assume students repeatedly mentioned those three ideas because in a classroom students would expect an argument to consist if facts that would be used to support their claims. Teachers would normally expect students to give facts to support their statement when they are arguing a point.

Students also think that a *debate* in the classroom is characterised by an argument thus a good science argument would be executed through a debate. Students mentioned a debate many times as they think a good science argument should being a debate like form. Interestingly students think that a good argument will be seen as a verbal exchange of ideas. In addition, Driver e*t al*, (2000) propose that science is a social process in which scientist's debate knowledge claims and constantly improve and revise knowledge based on evidence.

Last but not least, students often mentioned that a good science argument should be used to transfer or be a *source of information* to other students. It is important to note that Vygotsky (1978) noted that learning is both an internal and external arguments. Internal arguments happen in the brain and external arguments happen verbally. In this case, students view good science arguments as a form source of knowledge that will disrupt internal knowledge. So I assume that learners do believe that one needs to learn something from a good science argument. In everyday life arguments often give out new knowledge to the audience. That's why students said that good science argument must help other pupil learn science knowledge. This implies that students value science arguments as they teach them science.

The thematic analysis above answers my research question number which reads as, *what are teachers' understandings of argumentation as a tool for science teaching?* In the research data it was found that teachers' understanding of argumentation was classified into four themes which are; *definition of science argument*, *the value of evidence vs opinions*, *the significance of discussions and debates* and *arguments expose misconceptions* outlined above to summarise the ideas that teachers have about argumentation for teaching science. It was also evident that the teachers' understanding of argumentation was similar to those ideas of their respective students. Both teachers and students define an argument as discussions that one needs to provide facts as supporting evidence to their debates. Even, though these two teachers are not blank about the role of argumentation for science teaching and learning, a lot still needs to be done to develop their skills to use argumentation as a teaching strategy.

After obtaining teachers' and students' ideas about the role of argumentation, I then wanted to see if students could actually construct written arguments which the third research question is analysed below.

4.4 Student construction of written arguments:

This section analyzed how students argued and supported their written scientific arguments. The analysis was based on the Toulmin's Argumentation Pattern, TAP and on the levels of argumentation, both of which were introduced in Chapter 2. The task that students completed was a multiple choice question that required them to support their selected answer. A common difficulty in students' responses to assessment questions is students' lack of relevant evidence to support their claim or choice of answers (Schen, 2013). This is understandable for students who are untutored in argumentation. Osborne *et al*, (2001) observed that it is important for students to be taught the skills to argue in all science activities, either through writing or talking. Written arguments play a crucial role in learning science because as students write they make use of the information that they already know. Hence, this might reveal their prior knowledge about that concept.

4.4.1 The task and the expected answer

The following multiple choice task was assigned to the students within the questionnaire for them to complete.

Section B (MCQ task)

This section is analyzing how you argue a scientific statement and how you support your written scientific response.

Please answer the following question:

A 5 gram sample of solid iodine is placed in a tube and the tube is sealed close after all the air is removed. The tube and the iodine together weigh 20 grams.

If the tube is then heated until all the iodine is evaporated and the tube is filled with iodine gas. Will the weight after heating be.........?

Circle the correct answer:

a. Less than 19 grams

b. 19 grams

c. 20 grams

d. 21 grams

e. More than 21 grams

Explain/argue your answer in detail:

Option C was the expected correct answer and learners were expected to write a justification for their choice of C or any other option they chose.

A model answers for option C:

Claim- the mass will remain the same after the burning of the test tube.

Evidence (data) – the tube is sealed, so the iodine gas cannot escape the test tube

Backing- the iodine substance is still the same in gaseous form because the test tube was extracted of air that might consist of other elements; as such nothing has reacted with iodine.

Warrant- the fact that the test tube is closed means no iodine gas particles would escape the closed system. And the law of the conversation of mass states that matter cannot be created or destroyed but can be transferred from one form to the next in a closed system

Rebuttals- the mass could be less only if the tube was open or leaking, evaporation into the vacuum could have occurred. Again, the mass could have been more if the air in the test tube was not extracted, other elements would have reacted with the iodine as well.

Of a total no of 79 students 76 of them completed the task and 3 did not complete the task and their choices were as follows:

Table 4-8 Counts of students' choices

	A	B	**C***	D	E	(DID NOT RESPOND)
Girls High School	14	1	**13**	0	0	0
Boys High School	33	0	**11**	1	3	3
Totals out of 79 students	47	1	**24**	1	3	3

**Note that option C is the correct answer.*

Only 24 out of 76 students got the answer correct, while 3 students did not respond to the task at all. This means that only 32% of the students were able to select the correct answer while the remaining 62% of the students got it wrong. The responses did not depend on gender. A total of 47 students selected option A, because they have a mistaken belief that when a solid substance turns into gas in a closed system the mass of the substance decreases.

The following section is the analysis of the nature of students' written scientific argument.

A sample of explanations for the correct answer were analysed to determine the level of argument. The argument levels were observed using the TAP analytical framework which was explained in chapter 2. I must admit that this analytical framework from literature has been used to often analyse oral arguments than written arguments. Attached below is the table that summarises the five levels of arguments according to Erduran *et al*, (2004):

Table 4-9 Erduran **et al, (2004) Analytical Framework**

Level 1	Level 1 argumentation consists of arguments that are a simple claim versus a Counter-claim or a claim versus a claim.

Level 2	Level 2 argumentation has arguments consisting of claims with data, warrants, or Backings but does not contain any rebuttals.
Level 3	Level 3 argumentation has arguments with a series of claims or counter-claims With data, warrants, or backings with the occasional weak rebuttal.
Level 4	Level 4 argumentation shows arguments with a claim with a clearly identifiable Rebuttal. Such an argument may have several claims and counter-claims.
Level 5	Level 5 argumentation displays an extended argument with more than one rebuttal.

(Adapted from: Erduran *et al*, 2004)

It is a challenge to identify what a claim, warrant, backing and rebuttal is from an argument. Thus, I had to get six people including myself and my supervisor to analyse two arguments. The aim was to try and validate the means of identifying a claim, warrants, backings etc. within an argument. It was an eye opener to see that there was a range of variation in how each of us identified the various components of an argument. The validation from these six people has been attached, Appendix G. In the end, I had a discussion with my supervisor to consolidate that for other arguments. Here is an example of how we then agreed on some of the components of an argument:

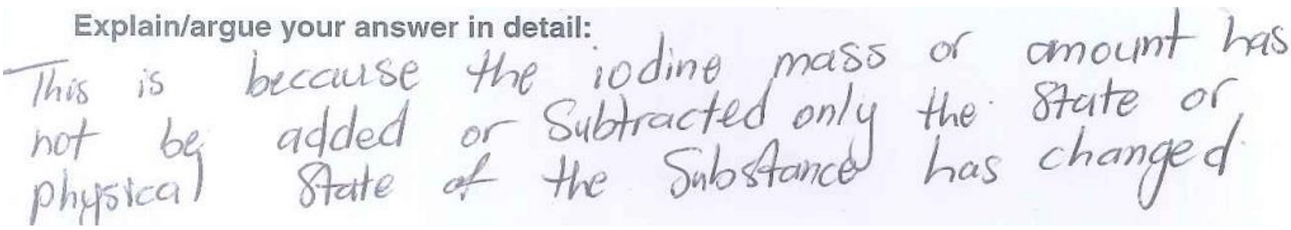
From my model answer for option C given above, I defined:

A claim as the mass will remain the same after the burning of the test tube. (Alternatively, the claim could be the choice of option C);

Evidence (data) as the tube is sealed, so the iodine gas cannot escape the test tube (alternatively, the data could be that the mass remains the same. This is based on the understanding that data is what learners can observe and in this case the observation is either that the test tube is sealed or that the mass remains at 20g)

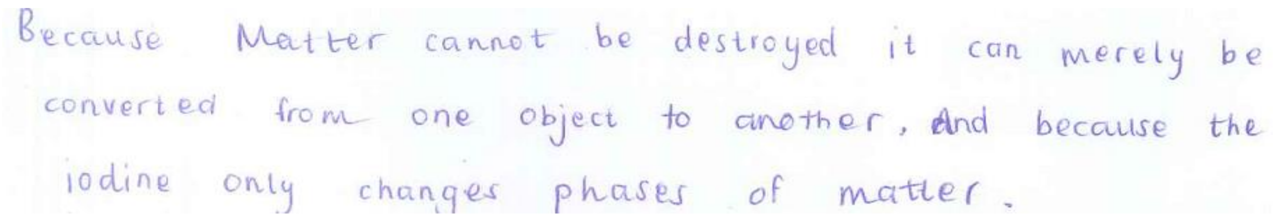
A sample of explanations for the correct answer were analysed to determine the level of argument. The argument levels were observed using the TAP analytical framework which was explained in chapter 2. Attached below is the table that summarises the five levels of arguments according to Erduran *et al*, (2004):

The following correct evidence from students written scientific arguments were given:



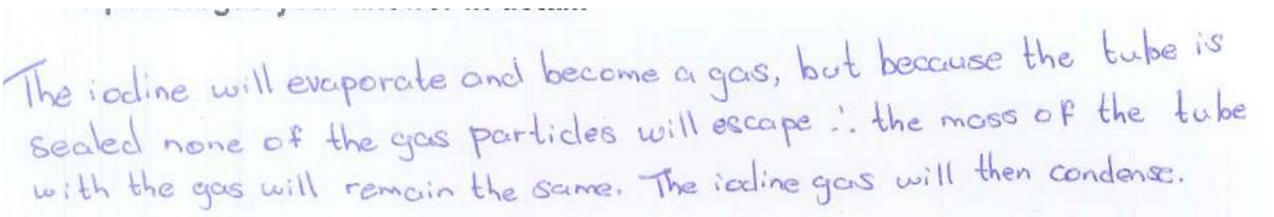
Explain/argue your answer in detail:
This is because the iodine mass or amount has not be added or Subtracted only the State or physical State of the Substance has changed

This argument above consist of a claim which is the fact that the student chose *option C*, that the mass will remain the same after heating the test tube. The data to serve as evidence is the fact that the student says that ‘‘*the iodine mass or amount has not been added or subtracted*”. The warrant that the student brings forth is that “*only the physical state of the substance has changed*”. This argument is at level 2 of Erduran *et al*, (2004) analytical framework for analysing arguments.



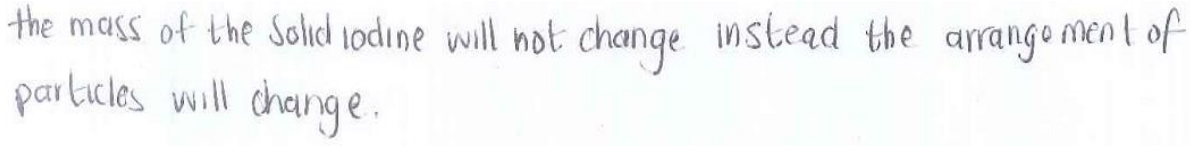
Because Matter cannot be destroyed it can merely be converted from one object to another, And because the iodine only changes phases of matter.

Looking at the argument above, one could classify it as level 2 argument according to the TAP adapted for analysing scientific arguments. This is a level 2 argument since the argument consists of a claim, data and warrant. The claim is that the mass will remain the same, the student selected option C on the MCQ. The data is that *‘the iodine only changes phases of matter”.* The warrant for this argument is that *“matter cannot be destroyed it can merely be converted from one object to another”*. This argument lacks a rebuttal that should state the conditions under which this argument does not hold true. As such, this argument falls under level 2 on the analytic tool above. This is a scientific argument as the student used scientific knowledge e.g. ‘*the law of conservation of matter’* to build the argument which is scientifically grounded.

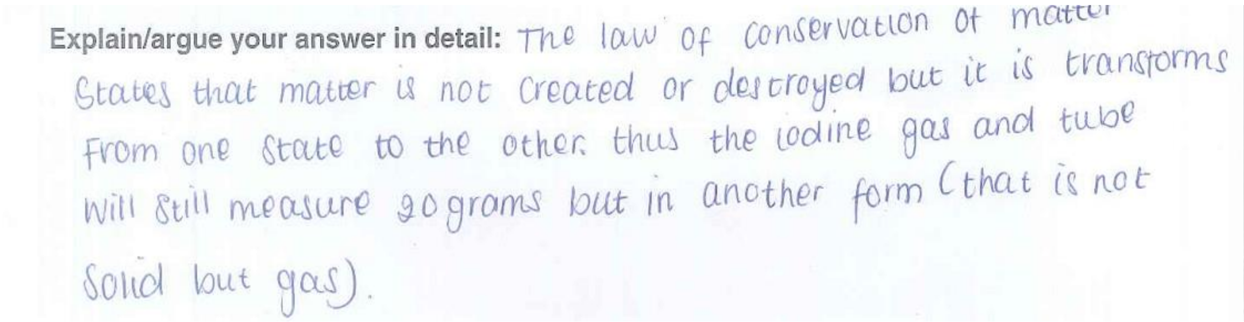


The iodine will evaporate and become a gas, but because the tube is sealed none of the gas particles will escape ∴ the moss of the tube with the gas will remain the same. The iodine gas will then condense.

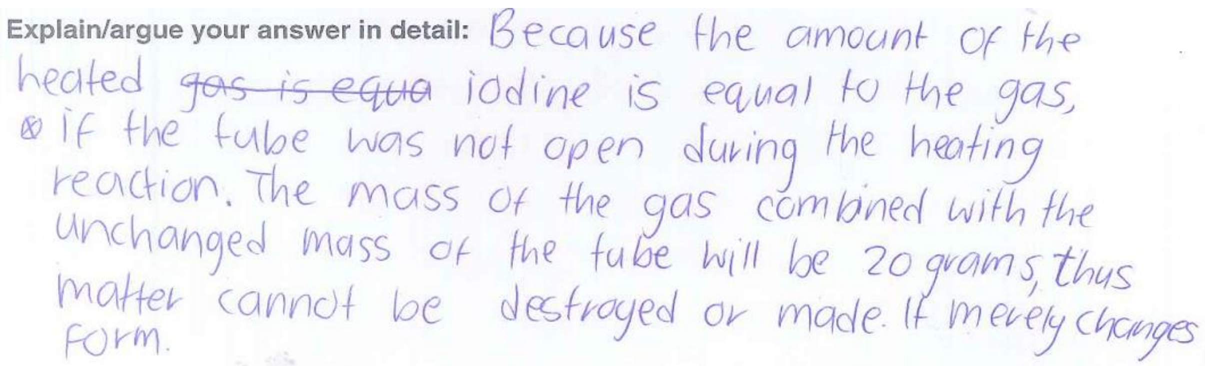
The claim for this argument is that fact that the students chose option C, which means the mass will remain the same after heating the test tube. The data is that ‘*because the tube is sealed none of the gas particles will escape*‘. The warrant is that ‘*the iodine gas will then condense*’. To support that claim the student gave backing as evidence that ‘*the mass of the tube with the gas will remain the same’*. This backing actually supports the warrant above. This argument consists of a weak rebuttal which provides us with the circumstances when the claim cannot hold true e.g. the tube is sealed none of the gas particles will escape. The above argument is at level 3. The argument is none scientific but it demonstrate the level at which the students understood the question and the argument is logic and accurate.


the mass of the Solid iodine will not change instead the arrangement of particles will change.

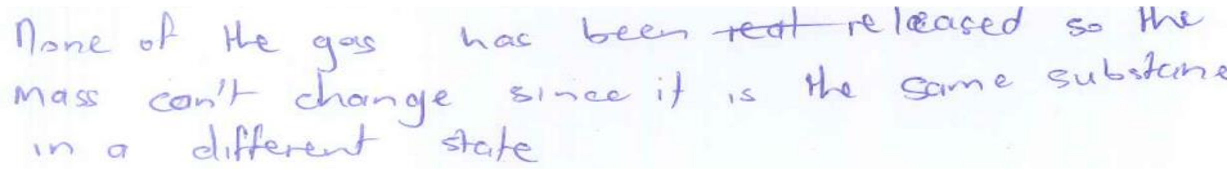
This is a level 2 argument above, since the students'claim is the selection of option C, which the mass will remain the same. As such the students' data to serve as evidence is that '*the mass of the solid iodine will not change'* and the information which gave us the facts towards the warrant is that *'the arrangement of particles will change'*. There are no rebuttals are placed forth for this argument, but the argument is without scientific jargon/ terminology perhaps the term *'particles'*, but this argument above is non-scientific but accurate.


Explain/argue your answer in detail: The law of conservation of matter States that matter is not created or destroyed but it is transforms From one state to the other. thus the iodine gas and tube will still measure 20 grams but in another form (that is not Solid but gas).

The argument above shows a claim that is the students' selection of option C, which means that the iodine mass "*will still measure 20 grams*". The data that gives us evidence for this argument is that "*the iodine gas and tube will still measure 20 grams but in another form (that is not solid but another form)"* and this claim is supported by the warrant which reads thus, *"he law of conversation of matter states that matter is not created or destroyed but it is transforms from one state to the other". This argument is scientifically based and it's a level 2 since, there is no rebuttal to the claim.*


Explain/argue your answer in detail: Because the amount of the heated ~~gas is equa~~ iodine is equal to the gas, if the tube was not open during the heating reaction. The mass of the gas combined with the unchanged mass of the tube will be 20 grams, thus matter cannot be destroyed or made. It merely changes Form.

This argument is at level 2, the claim is the selection of option C, '*The mass of the gas combined with the unchanged mass of the tube will be 20 grams'* while the data that provides evidence for this claim is that *'because the amount of the heated iodine is equal to the gas*", the backing which proposes the condition under which this argument is true is that *"if the tube was not open during the heating reaction'* the students further added this warrant that reads thus *"matter cannot be destroyed or made it merely changes form"* this was to provide a logical statement to support the data provided for the claim. However, there is no rebuttal in this argument. This is a scientific argument as the facts used to support this argument are scientifically based.

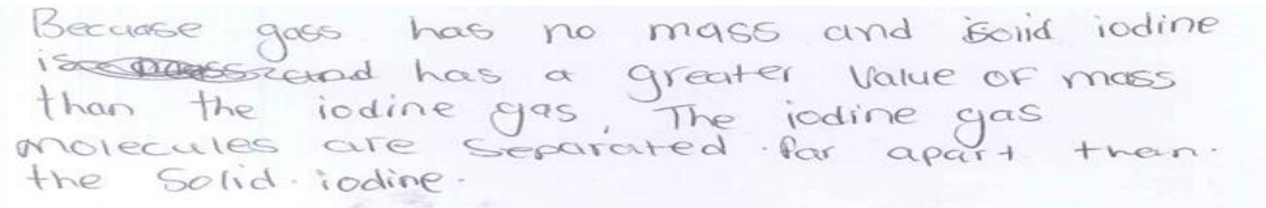

None of the gas has been released so the mass can't change since it is the same substance in a different state

The argument above is at level 2, because the student's claim the selection of option C, which indicated that the mass will remain the same. The data that serves as a fact for this argument is that '*none of the gas has been released so the mass can't change'* while the claim is warranted by saying that iodine is '*the same substance in a different state'.* This is a simple accurate argument, however the student did not provide rebuttals for this argument, hence it falls under level 2 of Erduran *et al*, (2004) analytic framework.

After analysing students' written arguments, one can summarise frequencies of the students' levels of arguments. Students are able to construct arguments at level 1, 2 and level 3, however a great number of 19 out of 20 students can argue at level 2. Students can provide a claim and data which will serve as evidence for the claim but then again the statements do not often reflect the accurate demands of adequate demands of level 2 arguments.

Since, we can see in most arguments quoted above students provide little warrants which should be linking statements to support the claim using data. This data confirms previous research that states that students can only argue science at minimum level and this is due to how much they know about that particular concept in this case (conservation of matter) and if weather the argument is pure science or a socio-scientific arguments (Erduran *at al*, 2004). The argument levels were observed to be spread between levels 1 and level 2 of the TAP analytical framework.

I then analysed some of the incorrect arguments to demonstrate the nature of the evidence used:


Because gas has no mass and solid iodine is [illegible] has a greater value of mass than the iodine gas, The iodine gas molecules are separated far apart than the solid iodine.

The argument above is an incorrect answer, which the students' claim is option A, which means that the mass will be less than 19 grams. The students' data is that "gas *has no mass"*. The warrant that the student used to give logic for the claim is that '*the iodine gas molecules are separated far apart than the solid iodine*'. The students' warrant or the logical statement used to bridge the claim and the data is that *'solid iodine has a greater value of mass than the iodine gases.* This argument is at level 2 but it is scientifically incorrect justification.

'It is less than 19 grams because a solid weighs more than a gas. Therefore it will be less as the tube is now filled with gas and the solid has evaporated'

The above argument has a claim that it's option a, meaning the mass is less than 19 grams. This student supports the claim with data noting that '*a solid weighs more than a gas'*. The warrant is that there '*will be less as the tube is now filled with gas and the solid has evaporated*'. The backing is now that both the tube and the iodine gas shall be 'less than 19 grams'. This argument is at level 2.

'This is because when iodine is heated and evaporated, its particles move further away from each other. This results into a decrease in weight and mass. Other evaporated particles get into the air'

The student claim is that the mass will be less than 19 grams, option A. The data to serve as evidence for this argument is that '*when iodine is heated and evaporated this results into a decrease in weight and mass*'. And this student warrant this claim by noting that the' *iodine particles move further away from each other and other evaporated particles get into the air'.* I think the student argued this because she did not understand the question were it stated that the test tube was closed hence; the student thinks the iodine gas will escape into the vacuum. This argument is at level 2.

'It will be less than 19 grams, because the heated iodine will evaporate as a gaseous state, meaning the mass of the iodine has decreased'

The students' claim is that the mass will be less than 19 grams, option A. the data for the argument is that the '*heated iodine evaporated meaning the mass of the iodine has decreased'* this implies that the student thinks that the gaseous state of an element decreases its mass. The backing is because the '*iodine evaporates in a gaseous state*'. Thus the warrant for the claim and the data is that 'the *mass will be less than 19 grams*' this argument is at level 2.

'When a substance is heated, the intermolecular/ particle forces are broken meaning that the particles will move further apart when substance is in a gaseous state. This then causes the substance to weigh less than it did before due to weaker bonds in between particles'

The student claims that mass will be less than 19 grams. Then the data for this argument is that 'when *a substance is heated the bonds are broken causing the substance to weigh less'* and the evidence for this data is that '*after heating the particles will move further apart when the substance is in a gaseous state*' the logical backing to bind the claim and the data is that '*after heating a substance the weaker bonds in between particles causes the substance to weigh less*'. This argument is at level 2.

'the solid iodine together with the tube has 20 grams, so if the tube is now filled with iodine gas it will weigh less than the solid iodine with the tube , because of the properties of gas and because gas is less dense than solid'

The students' claim that the mass will be less than 19 grams. The data is that the '*gas is less dense than solid, thus the iodine will weigh less as a gas than when it's solid'* the student supports the argument by warranting that the *'properties of iodine as a gas are different to those of iodine as a solid thus the gas will weigh less than solid iodine'*. The backing is that '*if the tube is filled with the iodine gas then the weigh will be less*'. The argument is at level 2.

When we look at the above incorrect arguments, we notice that levels through which the arguments are is probably at level 2 and these are scientifically incorrect justifications. The structure of an argument includes the knowledge of stating the claim, data, backings, warrants and rebuttals. As such, students' levels of arguments must link to content understanding and not only to the rhetorical structure of an argument (Cavagnetto & Hand, 2012).

These finding above shows that students have used what literature would commonly refer to as 'misconceptions' to support their claims. 'Misconceptions' according to von Glasersfeld (1995) refers to a cognitive version of reality that is shaped by the brain and understanding. In addition, misconceptions are said to be pre-concluded ideas, non-scientific beliefs, naïve beliefs, mixed conceptions or conceptual misunderstanding (Thompson, 2006).

Students argue that when a solid substance changes its phase to gas it will have different amount of mass compared to when the substance was in solid phase. I would like to assume that, this perception comes from students' everyday observations of water in gaseous phase and assume that its mass decrease as in gas phase unlike if it would be in solid phase (ice). However, in this regard students need to refer to the concept of the law of conservation of mass which states that matter can change form, but the total amount of mass will remain the same in a closed system.

There is a link between understanding and writing which is an enhanced conceptual thinking of scientific concepts. Argumentation skills also rely on students who can have subject matter knowledge which is authentic and can be used to contextualize their intellectual skills (Kuhn, 2010).

This section above looked at the nature of students' written scientific arguments. This was to answer the third research question which is, '*what is the nature of student's written scientific arguments*'. The findings are similar to previous "studies show that students can only be able to write simple arguments with claims and evidence, even though they struggle with evidence choice, using reasoning to connect evidence to claim and addressing alternative explanations" (Schen, 2013). These finding reveal that students cannot construct scientifically accurate arguments, as they pose misconceptions on the concept of the law of conservation of mass. Only 20 out of 79 students managed to select the correct scientific answer. However, they cannot write arguments that are beyond level 3.

4.5 Summary

To summarise this whole chapter, I outline main findings within each research question. Firstly, to answer the research question one that said; *what are students' understanding of* *argumentation for science learning*, findings indicate that students value science classroom talk and they link talking as part of argumentation practice. Students can also define arguments even though half of the students did not relate the definition to science but overall they have an idea of what is a scientific argument. Lastly, students are aware of the benefits of talking in class could help them argue science concepts and thus, have ideas such as debates and discussions about science can promote science arguments.

Secondly, to answer the second research question on; *what are teachers' understanding of argumentation for science teaching;* four themes were extracted from the inductive analysis of the interviews. From the interviews, these four themes emerged *definition of science argument*, *the value of evidence vs. opinions*, *the significance of discussions and debates* and *arguments expose misconceptions*. In short, teachers showed that they had a similar definition of a science argument and they valued that a good science argument must have scientific facts and theory or laws to support it. Both teachers valued the fact that a good argument must be based on evidence and not on opinions. Most importantly they said that students can execute arguments through classroom discussions and debates. Lastly, these teachers value arguments as they said they help expose students' misconceptions on science phenomenon and thus the teacher would then are able to re-explain to their students.

And lastly, to answer the third research question on; '*what is the nature of student's written scientific arguments*', there were 24 students who selected the correct scientific answer, which was option C. However, the main finding is that only a few students could construct scientifically accurate written arguments. The remaining 56 students posed a misconception on the law of conservation of mass when writing arguments. Most students think that when a substance is in a gaseous form its mass is less than when it was a solid in a closed system. Only 24 out of 76 students were able to write the correct scientific answer, as 3 students did not respond to the task. However, they could not write arguments that were beyond level 3.

Most arguments even the incorrect arguments where at level 1 and 2, which means they had provided only the claim, data and /or evidence and some weak warrants. All arguments had no rebuttals. The lack of rebuttals could be attributed to the nature of the task which was rather closed ended. I could have opened the question by asking subtly; that the learners show for example, what would happen if the test tube was open. However, this could also give away the importance of this characteristic of a closed system. This for me was a lesson in terms of thinking through the limitations of the task for future research. The following chapter will summarise the findings in more detail.

CHAPTER 5: SUMMARY OF FINDINGS AND CONCLUSION

5.1 Introduction

The previous chapter discussed outcomes of the research on *science talk; exploring students' and teachers' understanding of argumentation in Grade 11 science classrooms*, thus this chapter seeks to summarise the findings. To do this, it will provide brief findings and some conclusions drawn from the data interpreted. Furthermore, this chapter will outline recommendations, implications and limitations of this study.

In what follows below, is the summary of the results outlined through the use on three research questions that guided this study.

5.2 Research findings:

5.5.1 What are students' understandings of argumentation as a tool for science learning?

The questionnaire had various questions that were used to analyse what students' understood as argumentation as a tool for learning science. I gathered the responses into three main groups namely; *questions on the value of science classroom talk*, *questions on students' understanding of argumentation* and *questions on how to promote argumentation.*

Questions on the value of science classroom talk:

Research findings indicated that 71 out of 79 students said that they do talk in class and mostly talk with their classmates more often than their teacher. From the data 53 students noted that the talk they had was mostly open ended, while 25 said it is a closed talk. However, it was difficult for the students to differentiate between a close ended and open ended talk, until they asked me to clarify. 64 out of 71 students say that one can learn science better from talking in the science classroom, while 15 other students say no. Students were also asked if *the talk they have in class lead to a scientific argument,* 54 out of 71 students agreed that the talk they had in the classroom lead to a 'scientific argument'.

Questions on students' understanding of argumentation:

When analysing the students' definition of what they understood to be a good scientific argument, 70% demonstrated the ability to understand what constitute a good scientific argument, however they also included general thoughts of defining an argument and not necessarily a '*scientific argument*'. It was not easy to classify various definitions as entirely incorrect or correct as those thoughts had some of the elements that define a 'good argument' even though they lack further attachments to a 'good argument' which reads thus, a good realistic argument includes the knowledge of stating the claim, evidence, backings, warrants, qualifiers and rebuttals (Toulmin, 1958). Though, evidence revealed that students were aware of what a good scientific argument should consist of.

Questions on how to promote argumentation:

From the responses to the question '*how would you convince your teacher and fellow students about your ideas*', two students noted that they would conduct an experiment to convince both the teacher and their fellow students their ideas despite the fact that, research done in South Africa by Lubben *et al*, (2010) noted that only few portions of students are able to access resources and set up experiment to test out and argue their view point.

Scientific claim is a logical explanation of a phenomenon which yet to be proven otherwise, whiles a *scientific hypothesis* is a statement that is constructed using informed existing scientific knowledge reasoning and is yet to be proven right or wrong in a practical experiment (Bless, Higson-Smith & Kagee,2006) . Students are mostly not aware of the difference between a scientific claim and a scientific hypothesis and this could affect the way they use scientific claims and hypothesis to argue their ideas in the science classroom. The study reveals evidence that 50% of students can and 50% of the remaining cannot differentiate between the two. This was important to investigate as students can only conceptually engage in scientific arguments to develop their scientific knowledge if they can differentiate between a scientific claim and a scientific hypothesis. However, at least more than a half of the students were able to define a scientific hypothesis.

A total of 64 out of 79 students indicated that yes, one can learn science better from talking in the science classroom. I wanted to get students' opinions about whether they value the impact of talking in science classroom and if they thought the talk does help them learn science better with an assumption that they would say that, argumentation is part of the discussion in those talks about science concepts. The aim was to use this finding to enlighten teachers to incorporate the characteristics of arguments when talking during lessons to promote conceptual understanding.

5.1.2 What are teachers' understandings of argumentation as a tool for science teaching?

From the interviews, these four themes emerged *definition of science argument, the value of evidence vs. opinions, the significance of discussions and debates* and *arguments expose misconception.*

Definition of science argument:

The teachers' definitions of a science argument were very similar. This implied that they both have the same perspectives of what will make a good science argument. In both their definitions they included the importance of using science facts as evidence to support an argument.

The value of evidence vs. opinions:

When I analysed the rest of the interviews I realised that both teachers valued the use of theories and laws as evidence to support claims and thus, eliminated the use of opinions as a base to support statements. Both teachers showed noted that in order for a science argument to be a good one, it will require an individual to use proofs to convince to the next person that their claim is valid.

The significance of discussions and debates:

Both teachers demonstrated that they value discussions as an important part to execute science arguments. They also mentioned debates as a vital way to enable students to engage in science arguments. These might be because these teachers see arguments that need to occur between two or more people. One teacher said that the reason why lessons do not lead to a scientific argument is because students tend to use their everyday experiences and personal opinions instead of scientific knowledge. So an understanding of a science argument is embedded within scientific knowledge and not personal experiences. Therefore personal experiences makes the topics not be arguable. However, both teachers make note that the talk they often engage in, with their students during teaching does not often necessarily lead to a scientific argument. These was evident as to why argumentation is not used as a teaching tool/strategy by teachers.

Arguments expose misconception:

So both teachers believe that arguments about science concepts enable them to see students' misconceptions and this is because students give out opinions that often reveal their misconceptions. Thus, it was interesting to see that both teachers value arguments or even classroom talk as a tool to help expose students' misconceptions. Research identified misconceptions are a crucial part of science teaching and learning as they can be used by the teacher to identify students' pre-conceived ideas.

In summary, it is evident that both teachers are aware of what science argument should consist of, however they might not be clear on how to articulate them in their classroom learning and teaching tool. As such, teachers will need to be trained on how to incorporate argumentation in their science classrooms.

5.1.3 What is the nature of student's written scientific arguments?

On this third research question, the study revealed three main results drawn on students' written arguments. *Firstly*, the study showed that out of 79 students only 20 were able to select the correct answer on the MCQ task, while the remaining 59 selected an incorrect answer. *Secondly*, students were able to construct arguments at level 1 between level 2 and very little on level 3. However, a great number of students argued at level 2.

Level 2 arguments are those that consist of a claim, data or evidence and a little bit of warrants, but nothing more than that. Students struggled to construct arguments which were beyond level 3. However, even some scientifically incorrect arguments, stood at level 2 and those were scientifically incorrect justifications. Students provided a claim and evidence for their argument; however it did not often reflect the accurate demands of a level 2 argument structures according to Erduran *et al*, (2004) analytic framework.

And *thirdly*, evidence revealed that students cannot construct scientifically accurate arguments, as they have misconception on the law of conservation of mass. This finding is similar to the one, I found in my honours research in 2014. Students think that when a solid substance turns into gas, in a closed system its mass is lesser than when it was a solid.

Literature notes that students' ability to argue depends on their understanding of the concept (Simon *et al*, 2002; Lubben *et al*, 2010). It was important to note that students' levels of argument linked to their understanding of content, more than the rhetoric structure of an argument. In summary, this finding above concur to the statement were, Schen (2013) argue that when students supported their claims they often lacked the ability to use specific relevant evidence, because they lack correct content knowledge.

5.2 Limitations of the research:

TAP Analytical Framework:

It was a challenge to select what made a claim, data or evidence, backing, warrant or even a qualifier in the students' written arguments. The fact is that the TAP analytic framework from the literature it is used to analyse whole class oral arguments in most cases. So it was a challenge to adapt it to fit analysing written arguments. Thus, my supervisor and I found that were did not agree on how I selected what constitute as a claim or other components mentioned above. She then suggested that I choose two arguments to give to four more academics to analyse and compare and discuss with her a consensus approach to identify those components in a written argument. To do so, I tabulated the responses from all six academics including myself and my supervisor in order to construct a validation of the TAP framework to work with in my analysis.

Research instrument: The MCQ task

The MCQ task used words that are not the same as those ones used in everyday classroom science context e.g. the term test tube can be altered as some classrooms they refer to it as glass tube. The sentence construction could have been problematic and the uses of the word 'evaporate', when referring to the iodine gas that filled the closed test tube. Students might have been distracted by the word 'evaporate' to mean the gas escaped. The word 'weigh' was incorrect as it should have been the word 'mass'. Weight is a force that an object is experiencing due to gravity and mass.

Interviews:

Inductive analysis was a challenge because it was not easy to extract themes when working with small sample of two teachers. The transcripts of these teachers were very challenging to interpret and draw themes. The challenge is brought by the fact that most questions were open ended rather than closed.

5.3 Implication(s) and recommendations

From the research finding, students are aware of what a scientific argument is, however they cannot construct scientific arguments because they lack the correct content knowledge. Students need to be taught how to construct arguments at a higher level, as an argument is said to be fundamental to scientific understanding (Osborne *et al*, 2001). Students have a misconception on the law of conservation of mass; they think a gas has less mass in a close system than when it was a solid.

Different teaching strategies need to be employed to help students develop conceptual understanding. Students have the ability to engage in scientific arguments only if they could be taught the skills to argue. Teachers need to be trained on how to introduce argumentation in students' writing tasks. Further studies need to research argumentation in science classrooms to investigate the nature of oral vs written arguments to understand which one is best for teaching and learning of science. There is a need to create an intervention to train teachers how to incorporate argumentation in their lessons and how to help students construct valid written arguments. Teachers must also teach students how to argue, they also need to understand open and closed questions and open and closed talk.

5.4 Reflections and Conclusions

Argumentation is a definitive practice of science and, as such, science classrooms should be grounded in such practices. Argumentation practice requires both verbal and writing skills. Students need to be taught how to construct arguments at a higher level and also the structure of a scientific argument. How students can construct arguments that has a claim, data, warrants, backings, qualifiers' and rebuttals. Students have the potential to engage in scientific arguments if only they could be tutored the skills to argue. Teachers need to be trained on how to implement argumentation driven lessons in science classrooms.

REFERENCE LIST

Aydeniz, M., & Gurcay, D. (2013). Assessing quality of pre-service physics teachers

Bell, J. (2010). *Doing your research project*. England: Open University Press.

Berland, L. K., & McNeil K.L. (2009). Using a learning progression to inform scientific Argumentation in talk and writing. Paper presented at the *Learning Progression in Science (LeaPs). Conference*, Iowa City, IA.

Bless, C., Higson-Smith, C., & Kagee, A. (2006). *Fundamentals of social Research Methods: An African perspective.* Juta & Co Ltd. Cape Town. SA

Castellas, M., Cervero, J. M., & Konstantinidou, A. (2011). Study of the interrelationship between students' arguments and features of tasks in science classes. *Discourse and argumentation in Science Education.*

Cavagnetto, A. R. (2010). Argument to Foster Scientific Literacy: A review of Argument Interventions in K-12 Science Contexts. *Review of Educational Research, 80, (3),* 336-371

Cavagnetto, A., & Hand, B. (2012). The Importance of Embedding Argument Within Science Classrooms. In M.S. Khine (Ed). *Perspectives on Scientific Argumentation*. Springer Science+ Media, B.V. 39-53

Cohen, L., & Manion, L. (1985). *Research methods in education*. Bristol. England

Creswell, J. W., & Plano Clark, V.L. (2011). *Designing and Conducting Mixed Methods Research*. SAGE Publications. Inc

Department of Education. (2011). CAPS Document Physical Science Grade 10-12. South Africa

Diwu. C. (2010). Effects of a dialogical Argumentation Instructional Model on Grade 10 Learners' Conception of Fermentation. *PRESA Occasional Papers, 36*. University of Cape Town. SA.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the Norms of Scientific Argumentation in Classrooms. *Science Education (84)*. 287-312.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education. 88(6)*, 915-933.

Hatch, J.A. (2002). *Doing qualitative research in education settings*. New York: SUNY Press. Chapter 1. Pp.11-20

Jimenez-Aleixandre, M.P, Bugallo-Rodriguez. A., & Duschl, R.A. (2000). "Doing the Lesson" Or "Doing Science". Argument in High School Genetics. *Science Education*. *84*. 757-792

Johnson, R.B., & Onwuegbuzie, A.J. (2004). Mixed methods research: a research whose time has come. *Educational Researcher, 33*(7), 14-26

Kelly, G.J., & Takao, A. (2002). Epistemic Level in Argumentation: An Analysis of University Oceanography Students' Use of Evidence in Writing. *Science Education, 86,* 314-342

Knight, A, M., McNeill, K.L., Corrigan, S. & Barber, J. (2013). *Student assessments for reading and writing scientific arguments.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Kuhn, D. (2010). Teaching and Learning Science as Argument. *Science Education*, *94*. 810-824.

Laurinen, L.I., & Marttunen, M.J. (2007). Written Argumenta and collaborative speech acts in practising the argumentative power of language through chat debates. *Computer and Composition, 24*. 230-246

Lemke, J. L. (1990). *Talking Science:* language, learning and values. Norwood, NJ: Aldex

Lubben, F., Sadeck, M., Scholtz, Z., & Braund, M. (2010). Gauging Students' Untutored Ability in A South African case study. *International Journal of Science Education 32(16).* 2143-2166

Manz, E. (2014). Representing student argumentation as functionally emergent from scientific activity. *Review of Educational Research.* Published online,

Marttunen, M. (1992). Commenting on Written Arguments as a Part OF Argumentation Skills- comparison between students engaged in traditional vs online study. *Scandavian Journal of Educational Research, 36*(4). 289-302

in an inquiry laboratory task. *Science Education International, 24(3),* 254-281.

McNeill, K.L. (2011). Elementary students' views of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of research in Science Teaching. 7 (48),* 793-823

McNeill, K.L., & Pimentel, D, S. (2010). Scientific Discourse in Three Urban classrooms: The Role of the Teacher in Engaging High School Students in Argumentation. *Science Education. 94*. 203-229

Msimanga, A., & Lelliott, A. (2002). Making sense of science: Argumentation for meaning- Making in a teacher-led whole class discussion. Marang Centre for Maths and Science Education, Wits School of Education, Johannesburg, South AfricaOgunniyi, M.B. (2007a). Teachers' stances and practical arguments regarding a science-indigenous knowledge curriculum: Part 1. *International Journal of Science Education*, 29(8), 963-986.

Opie, C. (2004).*Doing educational research*. London: Sage Publications

Osborne, J., Erduran, S., Simon, S., & Monk. M. (2001). Enhancing the quality of argument in School science. *School Science Review. 82* (301). 63-70

Qhobela, M. (2012). Using Argumentation as a Strategy of Promotion of Talking Science in a Physics Classroom: What Are Some of the Challenges? *US-China Education Review B (2).* 163-172 .National University of Lesotho, Roma, Lesotho.

Reznitskaya, A., Anderson, R. C., McNurlen, B., Nguyen-Jahiel, K., Archodidou, A., & Kim, S. (2001). Influence of Oral Discussion on Written Argument. *Discourse Processes*, *32*(2-3), 155–175.

Sampson, V., & Clark, D. B. (2008). Assessment of the Ways Students Generate Arguments in Science Education: Current Perspectives and Recommendations for Future Directions. *Science Education*. *92*, 447-472

Schen, M. (2013). A comparison of biology majors written arguments across the curriculum. *Journal of Biological Education. 47 (4),* 224-231

Scholtz, Z., Braund, M., Hodges, M., Koopman, R., & Lubben, F. (2008). South African teacher's ability to argue: The emergence of inclusive argumentation. *International Journal of Education Development*, *28,* 21-34

Simon, S., Erduran, S., & Osborne, J. (2002). Enhancing the quality of argumentation in

School Science. *Paper presented at the Annual Meeting of the National Association for Research in Science Teaching*. New Orleans. USA

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to Teach Argumentation: Research and development in the science classroom. *International Journal of Science Education. 28,* (2-3). 235-260.

Thompson, F. (2006). An exploration of common student misconceptions in science. *International Education Journal.* 7(4). 553-559

Toulmin, S. (1958). The uses of Argument. Nueva York: Cambridge University Press.

von Glasersfeld, E. (1995). A constructivist approach to teaching. In L. Steffe & J. Gale (Eds.). (1995). *Constructivism in education*, (pp.3-16). New Jersey: Lawrence Erlbaum Associates, Inc.

Vygotsky, L. S. (1978). *Mind and Society: The Development of higher mental processes*. Cambridge., MA: Harvard University Press.

Webb, P., Williams, Y., & Meiring, L. (2008). Concept cartoons and writing frames: Developing argumentation in South African science classrooms? *African Journal of Research in Science Mathematics and Technology Education, 12* (1), 5 -18

LIST OF APPENDIXES

Appendix A- Questionnaire sample

QUESTIONNAIRE FOR STUDENTS

Section A

This section requires your comments about how you engage in science talk in the science classrooms and your understanding of a scientific argument as a tool for learning science.

1. Do you **talk** about (science concepts that you're being taught) in class?

Yes		No	

2. If yes, with **whom** do you talk to about those concepts?

3. **How often** do you talk about scientific concepts taught in the classroom?

Very often		often		Sometimes		Less often		Not at all	

4. Is it an **open ended** talk or a **closed ended** talk? Give reason

5. Does the talk **lead** to a scientific argument?

Yes		No	

6. **What** is a good scientific argument?

7. Which science **topics** are you likely to argue, in the science classrooms?

Matter and materials	
Waves, sound & light	
Chemical change	
Chemical systems	
Electricity and magnetism	
mechanics	

8. Which **type of questions would make you** talk in the classroom?

9. **How** would you convince your teacher or classmate about your idea in class?

10. **Where** do you get the **information that you use** to support your scientific ideas?

11. What do you understand to be a scientific hypothesis?

12. How does a scientific claim **differ** from a scientific hypothesis?

13. Can one **learn** science better from talking in the classroom?

Yes		No	

14. Explain your answer to question 13

15. How can science talk be **encouraged** in science classrooms?

Section B (Written Argument)

This section is analyzing how you argue a scientific statement and how you support your written scientific response.

Please answer the following question:

A 5 gram sample of solid iodine is placed in a tube and the tube is sealed close after all the air is removed. The tube and the iodine together weigh 20 grams.

If the tube is then heated until all the iodine is evaporated and the tube is filled with iodine gas. Will the weight after heating be………?

Circle the correct answer

a. Less than 19 grams
b. 19 grams
c. 20 grams
d. 21 grams e
e. More than 21 grams

Explain/argue your answer in detail:

Adapted from Prof. Rollnick M. (lecture notes)

Thank You Very Much for Your Response!

Appendix B- interview schedule

INTERVIEW SCHEDULE FOR TEACHERS

1. Do you talk about science concepts as your teaching with your students in class?

----

2. How often do you and your students talk about scientific concepts you're teaching during a lesson?

Very often		Often		Sometimes		Less often		Not at all	

3. Is it an open ended talk or a close ended talk? Give reasons

----

----

4. According to you, what is a good scientific argument?

----

5. Does the talk you have when teaching lead to a scientific argument?

----

6. Which science topics are likely to prompt a scientific argument in the classroom with your students?

----

7. Which type of questions would typically make you and your students argue in the classroom about science concepts?

----

8. How do your students convince you and other students about their arguments?

----

9. Where do you think your students get the information to support their scientific arguments?

----

10. Do you believe students can learn science better from talking in the classroom? Give reasons

----

----

11. Do you think your students can write convincing scientific arguments?

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12. How can science arguments be encouraged in your science classroom?

THE END! Thank you

Appendix C- Information sheet for the students

INFORMATION SHEET FOR LEARNERS

University of the Witwatersrand

Private Bag 3

Wits 2050

Johannesburg

South Africa

August 2015

Dear Learner

My name is Maletsau Mphahlele and I am M.Sc. in Science Education student in the School of Education at the University of the Witwatersrand. I am doing research project on classroom talk in science classrooms through argumentation.

My study involves the use of a questionnaire to try and understand how students understand and engage in the practice of science classroom talk. I am interested in both the scientific argument and the written responses on one MCQ test. The purpose of this research project is to encourage students to talk in science classroom about scientific concepts in order to improve learning using argumentation. I am asking permission from you to complete a questionnaire and one MCQ task at the end of the questionnaire.

Remember, this is not for marks and it is voluntary, which means that you don't have to do it. Also, if you decide halfway through that you prefer to stop, this is completely your choice and will not affect you negatively in any way. You are not required to write you name on the questionnaire, even if you did, I will not be using your own name or your school name, but I will make one up so no one can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3-5 years after I have completed my project.

Your parents have also been assigned an information sheet and consent form, but at the end of the day it is your decision to participate in the study. The participation is voluntary. The anonymity and confidentiality of all responses will be ensured. All participants will have the right to withdraw at any time during the study without any penalties.

My contact details are as follow: Cell ***0766595725***; e-mail: ***458154@students.wits.ac.za*****.**

Address: No 7 Esselen Street, Esselen Residence, Hillbrow, 2001

I look forward to working with you!

Thank you in advance

Maletsau Mphahlele

Appendix D- Students consent forms

Learner Consent Form

Please fill in the reply slip below if you agree to participate in my study called: Science talk: exploring students and teachers understanding of argumentation in Grade 11 science classrooms.

My name is: _________________________

Permission for questionnaire

I agree to fill in a questionnaire for this study. YES/NO

Permission for test within the questionnaire

I agree to fill in a MCQ task for this study. YES/NO

Informed Consent

I understand that:

- my name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date____________________________

Appendix E- Information sheet for parents

INFORMATION SHEET PARENTS

University of the Witwatersrand

Private Bag 3

Wits 2050

Johannesburg

South Africa.

Dear Parent/Guardian

My name is Maletsau Mphahlele and I am a M.Sc. in Science Education student in the School of Education at the University of the Witwatersrand. I am doing research project on talk in science classrooms through argumentation practice. I write this letter to ask your permission for your child to take part in my research questionnaire and a single MCQ test within the questionnaire.

My study involves the use of the questionnaire to try and understand how often students are engaged in the practice of science classroom talk. This talk could be in a form of a scientific argument or through the written responses on the classroom tasks. The purpose of this research project is to encourage students to talk in science classroom about scientific concepts in order to improve learning opportunity.

The reason why I have chosen your child's class is because I believe that they have done physical sciences in the previous Grade 10. The assumption is that Grade 11s are familiar with some basic science concepts and how to talk about them. I am asking permission for your child to be part of the study by completing the questionnaire and the MCQ task that will take up to 20 minutes max.

Your child will **not** be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw her/his permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your child's name and identity will be kept confidential at all times as she/he will not be asked to write his/her name on the questionnaire. His/her individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3-5 years after completion of the project.

Please let me know if you require any further information. My phone no: 0766595725 and my email: 458154@students.wits.ac.za. Address: No 7 Esselen Street

Esselen Residence

Hillbrow

Thank you very much for your help.

Yours sincerely,

Maletsau Mphahlele

Appendix F- Parents' consent

Parent's Consent Form

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called Science talk: Exploring teachers and learners understanding of argumentation in Grade 11 science classrooms.

I, ________________________ the parent of ________________________

Permission for questionnaire

I agree that my child fill in a question and answer sheet or write a test for this study.
YES/NO

Permission for MCQ test within the questionnaire

I agree that my child fill in MCQ task for this study. YES/NO

Informed Consent

I understand that:

- my child's name and information will be kept confidential and safe and that my name and the name of my child's school will not be revealed.
- he/she does not have to answer every question and can withdraw from the study at any time.
- he/she can ask not be audiotaped, photographed and/or videotape
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date____________________________

Appendix G- Gauteng Department of Education Research approval letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no: D2016 / 131
enquiries: Diane Buntting 011 843 6503

GDE RESEARCH APPROVAL LETTER

Date:	**22 July 2015**
Validity of Research Approval:	**22 July 2015 to 2 October 2015**
Name of Researcher:	**Mphahlele M.J.**
Address of Researcher:	**No 7 Esselen Street; Esselen Residence; Hillbrow; 2001**
Telephone / Fax Number/s:	**076 659 5725**
Email address:	**458154@students.wits.ac.za**
Research Topic:	**Science talk: Exploring students and teachers understanding of argumentation in Grade 11 Science classrooms.**
Number and type of schools:	**TWO Secondary Schools**
District/s/HO	**Johannesburg North**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted. However participation is VOLUNTARY.

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter;
2. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB);

2015/07/23

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix H- Wits University Ethics Approval Letter

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

12 June 2015

Student Number: 458154

Protocol Number: 2015ECE015M

Dear Maletsau Mphahlele

Application for ethics clearance: Master of Science

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

Science talk: exploring students and teachers understanding of argumentation in Grade 11

science classrooms

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

cc Supervisor

Appendix I – The TAP validation tool

Explain/argue your answer in detail:
This is because the iodine mass or amount has not be added or Subtracted only the State or physical State of the Substance has changed

	Myself	Dr A Msimanga	Tshiamiso	Nomzamo	Wiseman	Aviwe
Data	Only state or physical state of the substance changed	The iodine mass or amount has not been added or changed	Amount has not been added or subtracted	Iodine mass or amount has been added or subtracted	-	-
Claim	The iodine mass or amount has not been added or changed	Option C, the mass will remain the same	-	-	Physical state of the substance has changed	-
Warrants	-	Only the physical state of the substance has changed	Physical state of the substance has changed	The state or physical state of the substance has changed	The iodine mass or amount has not been added or subtracted	If a substance undergoes phase change that means the substance will also change
Qualifiers	-	-	-	-	The iodine mass or amount has not been added or subtracted	-
Rebuttals	-	-	-	-	If iodine mass or amount has been added or subtracted	-
Backings	-	-	-	-	-	-

Because Matter cannot be destroyed it can merely be converted from one object to another, And because the iodine only changes phases of matter.

	Myself	Dr A Msimanga	Tshiamiso	Nomzamo	Wiseman	Aviwe
Data	The iodine only changes phases of matter	Only changes phases of matter	Only iodine changes phase	The iodine only changes phase of matter	Matter cannot be destroyed	Iodine was undergoing phase change
Claim	Matter cannot be destroyed it can only be converted from one object to another	Option C, the mass will remain the same	Matter cannot be destroyed it can merely be converted from one form to another	Matter cannot be destroyed it can merely be converted from one form to another	Iodine only changes phases of matter	Matter cannot be created or destroyed
Warrants	-	Matter cannot be destroyed	-	Matter cannot be destroyed it can merely be converted from one form to another	-	-
Qualifiers	-	-	-	-	Matter cannot be destroyed , iodine only changed phases of matter	-
Rebuttals	-	-	-	-	-	-

Backings	-	-	-	-	-	-