A Research Report Submitted to the School of Science of the University of the Witwatersrand, Johannesburg, South Africa in partial fulfilment of the Masters of Science 2018

Protocol Number: 2017ECE021M

Introducing Grade 10 and Grade 11 Learners to Scientific Argumentation.

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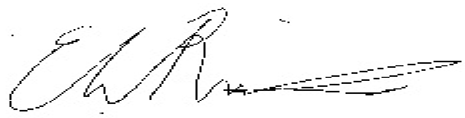
Declaration

This research is entirely my own and has not been previously submitted as a research report, dissertation or thesis at any other university.



University of the Witwatersrand

31 January 2019

Abstract

This report draws on Vygotsky socio-cultural and argumentation literature. The key findings of the study is that Grade 10 and 11 learners with sustained practice and support, can learn argumentation. A growing body of empirical evidence shows that the ability to engage in disciplinary specific way of thinking, talking, evaluating and articulating scientific concepts leads to development of argumentation skills (Asterham and Schwarz, 2007; Sampson and Clark, 2009; Kuhn, 1991). In light of an increasing number of what is called "progressed learners" in South African schools and in view of their poor Grade 12 academic achievements, the study sought to examine instructional strategies that can help such learners to engage more conceptually and hence help improve their performance in science. The report analyses transcripts of two Grade 11 lessons in a township school in Gauteng, South Africa, one in Physics and the other in Chemistry. An analysis of these lessons reveals the following: Firstly, learners found it easy to articulate their claims but struggled to understand the use of evidence to support these claims. The first finding is unsurprising as it has been shown from other studies locally in South Africa and abroad. Secondly, when learners began to understand the role of evidence in their arguments they were able to pick up some argumentation skills albeit at a very low level. That is, learners began to critique their peers' arguments although in the process, revealed their own misconceptions. As in other literature this finding suggests that a sound content knowledge is a prerequisite for argumentation. The implications of this finding are that South African teacher development programs can improve students' conceptual understanding through helping teachers to use teaching strategies that embed argument construction and justification in science.

Acknowledgement

1. I would like to thank my supervisor: Dr. A. Msimanga for her invaluable guidance and feedback throughout the compilation of this study.
2. I am also grateful to the participants –learners at my school-, their parents and/or guardians for their consents.
3. My grateful thanks towards the principal, staff of the school and the Gauteng Department of Education for allowing me the permission to use the school where this study was conducted.
4. Thanks to my family members for their support.
5. Last and not least important, my sincere gratitude to the support group.

Chapter 1

1.0. Introduction

Since the dawn of democracy in South Africa in 1994 and during its dark apartheid era, black township schools have been haunted by a substantial number of school leaving learners obtaining poor matric results, especially in Mathematics and Physical Sciences. The current state of South African science education woes can probably be attributed to, among several factors, the prevalent traditional instructional approach that renders learners to be passive recipients of science content knowledge. It is on this basis that I introduced and adopted argumentation as an instructional tool to foster learners' understanding of science practice and hence science content knowledge, and undertook to introduce it to my Grade 11 learners as a learning tool. Argumentation has the potential of bringing to the fore disparate perspectives on the school task under study, thus 'direct [learners] at exploring and perhaps resolving this disagreement' Chin and Clarke, 2013).

1.1. Social construction of knowledge

This study is an attempt to situate scientific argumentation practices in school science classrooms, a call made by South African National Curriculum Statement Grade R-12 (Department of Education, 2011). One of the goals of South African science curriculum is the promotion of learners' scientific inquiry skills and understanding of the nature of science. Scientific inquiry is a knowledge-building process in which explanations are developed to make sense of data and then presented to a community of peers for critique, debate and revision (Sampson and Clark, 2008). This goal, relates closely to the principle of "active and critical learning, encouraging an active and critical approach to learning rather than rote and uncritical learning of given truths" as cited in the South African Curriculum and Assessment Policy Statement (CAPS) document. (Department of Education 2012, p.8). Sampson and Grooms (2009), aptly captured this goal when they asserted, "a major goal of the science curriculum is for students to develop an understanding of the scientific view of the world and to be able to use scientific reasoning when a situation requires it" (p.66). One of the strategies for developing these critical thinking and active learning approaches in science is argumentation. Literature abounds on the role of argumentation in science teaching and learning both locally and internationally.

Argumentation is an epistemic practice at the heart of scientific enterprise or practice. Epistemic practices are discipline-specific ways of proposing, justifying and evaluating, knowledge claims (Aydeniz and Bilican, 2016). Ford (2010) explains aspects of argument, construction and critique which are key to scientific sense making and are central epistemic practices. Thus, the rote learning that is prevalent in many science classrooms negate the social aspect of scientific enterprise. Such practices are a misrepresentation of science and the nature of science, (Driver, Newton and Osborne, 2000). Argument is the umbrella under which all reasoning lies (Kuhn, 2011), and it is the rational-process of restructuring thoughts in a way that is in agreement with the evidence provided (Driver et al., 2000). Driver et al. (2000) argue that science is a discipline committed to epistemological models that marshal conceptually framed evidences that do not predominantly rely on observation alone, rather on reliability and validity.

1.2. Rationale and Research Question

Previously disadvantaged schools have the challenge of learner performance in science resulting in very low success rate in Grade 12. This is compounded by the problem of growing number of learners termed ‘progressed and at risk learners’. Progressed learners are those that are allowed to advance to the next grade even though their grades are below minimum pass requirements. Whereas learners at risk are those obtaining marks far below 50% (30%-49%) in a particular subject. It is the policy of the Department of Basic Education not to retain a learner in a grade if her/his marks are (1-2) % below elementary achievement of 30%. The assumption is that with the correct intervention in the next grade the learner’s academic performance will improve. However, many teachers minimally utilize argumentation as a teaching strategy, probably due to limited time stance for such interventions. In light of this, the researcher (myself) focussed on instructional strategy that will improve learners’ conceptual understanding (understanding of content), hence I shifted from traditional way of teaching to the one that allowed learners to be in dialogue with each other and myself in the communication of the curriculum.

Evolving understanding of knowledge and its development has led to an emphasis on argument and argumentation in science education (Cavagnetto and Hand, 2012; Duschl and Osborne, 2002), which is seen as an innovative shift from teaching science as an inquiry to teaching science as a practice (Osborne, 2012). Argumentation as a central scientific practice enhances student learning because foremost, scientists engage in argumentation to develop and improve scientific knowledge (Aufschnaiter, Erduran, Osborne and Simon, 2008). Secondly, for the public to make informed decisions about scientific reports that contain contested claims, it requires adeptness in evaluating evidence brought forward for contesting claims (Simon, Osborne, and Erduran, 2003). Finally, students' learning of science is enhanced by argumentation. Participating in argumentation requires articulating and justifying one's claims Driver et al., 2000).

Although argumentation research globally is growing, argumentation related studies in the South African context are at their early stages especially at school level (example, Braund et al., 2007; Scholtz et al., 2006). A lot of argumentation studies done in South Africa have been mainly with teachers and not with learners. There are emerging studies on learners' argumentation (example Lubben, Sadeck, Scholtz and Braund, 2010; Msimanga and Lelliot, 2010). The study by Lubben et al (2010), is of particular interest to me because they were working with untutored learners and targeted argumentation assessment. My study although furthering Lubben's et al (2010) study, differs from the Lubben in two respects in terms of its participants. Firstly, Lubben et al (2010) study was working with untutored learners, whereas my study was with learners' argumentation after they were taught argumentation techniques and criteria used to evaluate arguments.

Secondly, the teacher involved in Lubben's et al. (2010) study was untutored, whereas in my study I was the teacher and have studied argumentation. I was exposed to argumentation and its importance as a Masters student, and most importantly, I conducted argumentation lesson after the completion of the curriculum section involving concepts learners are to argue about. Teaching learners the simplified structure of arguments- that is the claim, evidence and rationale components- help them, firstly, construct arguments in terms of how the argument's component relate with each other. Secondly, I designed my tasks to stimulate arguments on prescribed topics. This allowed peers and the teacher to refute and refine their interpretations of a scientific idea. It is during the critiquing process that the participants are afforded an opportunity to consider their viewpoints in relations to peers' viewpoints thus thinking about their thoughts on the matter under discussion (Mason and Santi, 1994).

Argumentation expertise gained by learners from participating in this study will be beneficial to learners not only in overcoming challenges they encounter in answering end of the year examinations, but also and probably most importantly in their later years of study in Universities. It is the researcher's belief that to comprehend concepts, one should engage on a social plane with peers and more knowledgeable adults on epistemological aspects of the subject matter. The profound understanding of scientific principles is, in Driver et al. (2000) words, being able to give an account of 'what the concept is, how it is related to other concepts, why it is important to know it, and how it came to be known'. Extant researches and literature advocate a shift from instructional strategies that promote rote learning of knowledge towards inquiry-driven scientific argumentation as the latter is seen to foster critical reasoning. School science curricula- internationally and locally- demand not only the memorization of concepts, but also calls upon justifying these knowledge claims through a clear exposition of mathematical, verbal and graphical representation of concepts.

The study sought to address **the broad question**: What is the nature of learner engagement after being introduced to argumentation and how does it facilitate learner conceptual understanding of science?

1.3 Sub-questions:

1. What is the nature of learner arguments as they engage with peers in small group?
2. What is the nature of learners' (written and displayed) arguments when reporting to the whole class?
3. What is the nature of learner arguments during whole class interaction on the chemistry topic?

The term "nature" in this report denotes the overarching, essential feature of learners' assertions, questions and/or refutations as they are in dialogue with the scientific idea or explanations to impose meaning to material being learnt. An adequate engagement with a scientific explanation speaks to a thorough addressing of the idea's ontological-aspect 'what we know about an idea', causal-dimension 'why the idea happens as perceived by the observer' and the epistemic-question 'and how we know the idea' (Osborne and Patterson, 2000). In a nutshell, the term "nature" in this report means how learners' arguments and, counter-arguments when in dialogue with an idea and peers address the afore-listed aspects of scientific explanations. An adequate address of these features of a scientific explanation is an indication of their understanding of a concept under scrutiny.

1.4. Theoretical Framework

The study draws on Vygotsky Socio-Cultural and Argumentation Theories. These theories of learning are chosen firstly, because of their emphasis on the social contexts' role in the shaping of learners' reasoning. Secondly, on the realization that scientific community relies on argumentation to construct, articulate and persuade others of the validity of their account of phenomena. Vygotsky's perspective on effective learning posits that: learning is the product of personal interactions in social contexts and of internalization of this socially constructed knowledge (cf. Mason and Santi, 1994; Brown and Palincsar, 1984)). Reasoning in children is mainly manifested in the externalized form of discussing and arguing with others. Social settings such as groups arguing, provide social support, shared expertise, and role models, whereas the teacher provides expert scaffolding-zones of proximal proximity. The zone of proximal development points us to two aspects of the state of the learner or child. "Actual developmental level" aspect is what the learner can do without assistance, it is useful as departure point for later development. This actual developmental level is inwardly oriented, therefore individual. The "potential developmental level" is what is not yet mastered but is about to mature. This level is not yet interiorized; its mastery lies in participation with others who have already mastered the level. It is outwardly oriented on a social plane. What is Vygotskian account of the social plane's role on learning and to what extent is it compatible to argumentation theory's overarching aim of fostering critical thinking skills to participants?

The argumentation theory literature characterize learning science as an argument and scientific knowledge as evidence based. Argumentation as conceptualization started with Toulmin (1964) outside the classroom setting. Argumentation was adapted for use in the classroom in United Kingdom (UK) by Erduran et al. (2004) and in the United States of America (USA) by Berland and Reiser (2009), Sampson (2008). Argumentation in this study is defined as the process of arguing- "a process of reasoning that requires a scientist to make a justified claim about the world. In response, other scientists attempt to identify the claim's weaknesses and limitations" (NRC, 2011). Driver, et al. (2000) distinguish between rhetoric and dialogical arguments in terms of their purposes. Rhetoric argument is one-sided in which a person provide evidence and construct an argument for his audience in support of a particular claim with the purpose of persuading the audience of the plausibility and intelligibility of the claim. Dialogical argument involves examination of different perspectives in an effort of reaching an agreement "on acceptable claims," Driver et al. (2000) elucidated. Dialogical and rhetoric arguments can be in written forms or they can be verbal within the consensual epistemological norms and models. Dialogical argumentation require one to show how an alternative claim's evidence is a misrepresentation of established scientific theory. Scientific practice has three distinct phases of activity, that is, hypothesis generation (construction of explanations), experimentation (investigation), and evidence evaluation (argumentation) (Osborne, 2014).

Critical thinking skill is a technique that can be nurtured through constant engagement with social contexts that not only demand the exact recall of meaning of concepts, but also calling upon discipline-specific way of framing-theory-bound way of articulating- knowledge claims. Argumentation is indispensable towards supporting learners in coordinating theory and evidence (Sampson and Clark, 2009). Instructional strategies targeted towards fostering critical thinking are mainly concerned with the teaching of scientific practice. Scientific practice has three distinct phases of activity, that is, hypothesis generation (construction of explanations), experimentation (investigation), and evidence evaluation (argumentation) (Osborne, 2014). Expertise in argumentation is the culmination of partaking in a social settings that call on one to make conjectures from theoretically interpreted data, and rationalization of evidence provided.

Driver et al. (2000) on the epistemological aspect of science wrote, "[…] to know" science is a statement that one knows not only *what* a phenomena is, but also *how* it relates to other events and *why* it is important, and *how* this particular view of the world came to be. Knowing any of these aspects in isolation misses the point" (p. 297). Emphasis on the original text. Let us interpret the afore-cited quotation. Knowing in science goes way far beyond knowledge of what a concept means, it entails how the concept relates to other concepts within a discipline. How it finds meaning within a constellation of other concepts, as well as how it magnifies the meanings of other concepts within the discipline. The relation between abstract constructs in science is used to explain observable phenomena in terms of the relationship and consonance between abstract scientific concepts and the observation of the world these concepts elucidate. The plausibility and credibility of scientific claims lie in the rigorous evaluation of the production method to assure quality, validity, reliability and relevance. It is the best tentative, justifiable description of phenomena in the absence of an irrefutable alternative perspective. How this particular view became the official version of the entire scientific community lies in its robust explanatory and predictive powers. Expertise in scientific argumentation adequately addresses fostering critical thinking. This is the epistemological-“individual’s general understanding of knowledge and knowing”- assumption this study brings into scientific classrooms with argumentation as a tool to their realization, Kuhn (1998, p.19).

1.5. Organization of the research report

Chapter 1-this chapter- outlines how argumentation as process of knowledge construction is played out in a social arena in which knowledge claims are critiqued, as means to their refinement.

Chapter 2 of this report is the literature review on argumentation. It is within this chapter where the social dimension of the scientific knowledge construction will be discussed. I will be arguing that argumentation is central to and it is the epistemic practice of scientists. I will while arguing for the centrality of argumentation in the construction and sense making of scientific knowledge point to how competency in the art of arguing fosters critical thinking skills and hence improves the quality and fulfilment of lives of participants. I will outline the challenges inherent in the teaching and implementation of argumentation in science classrooms. The types of activities compatible to the promotion of argumentation skills among learners will be discussed as well as teachers’ and learners’ roles outlined during critiquing of peers’ claims. Finally the theoretical framework that underpins the report will be brought to the fore.

Chapter 3 of the report will shed light on the context of the study, methodology and the research instruments used as well the justification for their choice. Lastly I will discuss the ethical consideration and how the secrecy of participants’ identity are assured.

Chapter 4 is the analysis and discussion of the findings. The final chapter, chapter 5 will outline summary of the findings, and recommendations on instructional approaches that are most likely to foster critical thinking skills.

Chapter 2 Literature review and theoretical framework

2.0. Introduction

This section deals with literature on the main aspects of my study. First I review literature on the centrality of argumentation in scientists' practice of knowledge production and appraisal. I proceed to explain how the social interaction is the context for argumentation, where scientific knowledge claims are refined and evaluated in the social space on the basis of the evidence ability to shed light on the credibility of the claim, as well as how it relates to other claims and counter claims. In line with other researchers, this chapter shows how the infusion of argumentation in science classrooms directly addresses science curricula overarching goal, which is, fostering of critical thinking (cf. Kuhn, 2010; Ford, 2008; Engel & Conant, 2002; Brown, 1997). I finally discuss the theories that frame my study, that is, Vygotskian socio-cultural and argumentation perspectives on learning.

2.1. Scientific approach to knowledge construction

A scientific state of mind can be defined in relation to the culture of evaluation of arguments constructed for the knowledge claims. The distinct nature of scientific state of mind is to regard peers' constructed explanation of ideas as assertions. Assertions are belief states which can be evaluated and compared according to criteria of argument and evidence (Kuhn, 1999). Assertions are adequately justified by first, making distinction between an assertion and an external evidence bearing on it, and secondly by forging correspondence between an assertion and an evidence (Kuhn, 1999). Evaluation of evidence is staged in a social setting with its distinctive culture. Brown (1997), defined culture as the way of life and thought that we construct, negotiate, institutionalize, and finally (after it's all settled) end calling 'reality' to comfort ourselves (p.399). The phrase "after it's all settled' refers to the comparison and evaluation of disparate belief states according to the criteria of evaluation of evidence. It is after this refinement process of peer review that an idea assumes a superior authority over an alternative belief states and is proclaimed a scientific knowledge (Forman and Ford, 2013). What epistemological criteria are to be satisfied for an idea to assume a 'superior authority' over others? According to Sampson and Clark (2008), scientific inquiry is a knowledge-building process in which explanations are developed to make sense of data and then presented to a community of peers for critique, debate and revision. The critique process is the consideration of the strength of an argument in relation to the refutations levelled against it. “Based on the earlier work of Leitao (2003), Nussbaum and Schraw (2007) proposed the concept of argument-counterargument integration, in which the strength of an argument is the function of how well a conclusion accounts for counterargument by refuting, discounting or accepting the counterarguments or proposing a creative solution that eliminates possible objections” Nussbaum (2018, p.350). In conclusion, collaborative discourse and argumentation are indispensable knowledge-construction and meaning-making process within the large scientific community

2.2. Social construction and refinement of knowledge

Scientific knowledge is a product of dialogic argumentation whose ultimate goal is the “critical examination and evaluation … [of the] transformation of evidence into explanation” Duschl (2008, p. 159). Central to this critical examination and evaluation of knowledge claims that give rise to scientific explanation, according to Ford (2010), is the dynamic interplay of positing and critiquing of knowledge claims. The dual process of construction and critique of knowledge claims, according to Ford (2010) is a scientific view of phenomena that is distinctively different from a non-scientific approach which relates claims to experience (p.208). It is probably against this background that Duschl (2008) asserted, scientific knowledge claims include information about theory (what knowledge is important), method (what strategies of obtaining and analysing data are appropriate), and goals (what outcomes are sought and how can we determine if the outcome has been attained). It is through engagement in this kind of scientific discourse and practice of knowledge refinement- argumentation-that learners will make sense of scientific knowledge. This refinement process –to borrow Vygotsky’s phrase- first appears between people as an inter-psychological [social] category, and then within a child as an intra-psychological [individual] category. The question that begs the answer in regard to the transmission and/or transference of knowledge from a social setting to an individual’s internalization is: *In what way(s) is being engaged in argumentation and collaborative discourses-on a social plane- foster individuals’ concept learning or understanding?*

Argumentation intertwines a number of social and cognitive processes considered to promote concept learning (Asterhan and Schwarz, 2007). The social processes that interact with participants’ thought processes are classroom activities that invoke argumentation about contradicting views. Argumentation learning tasks help learners “cooperate in solving a particular problem to which a number of solutions are proposed" (p. 626). It is the social process of seeking solutions to a problem that exposes participants to "a multiplicity of ideas and encourages the exploration of the validity of each other's ideas" (p. 626). Examination of the validity of peers' ideas triggers participants' numerous cognitive processes, such as focussing on a question, distinguishing relevant and irrelevant information, asking clarifying questions, judging the credibility of sources of information and using deductive and inductive reasoning (Kilby, 2004)**.** In summary, Nussbaum (2008) illustrated that, it is through involvement in critical collaborative discourse and collaborative argumentation that learners can learn to construct elaborate explanation, reconstruct their prior-knowledge, thus strengthen and preserve learning and understanding of content (p.354).

2.2.1. Argumentation in Science Education

Kuhn (2010) argues that the goal of science education is attainable to the extent of a creation of a well-articulated and empirically supported model that identifies the essential characteristic and skills paramount to partake in science (p.810). The call for the explicit infusion of argumentation skills in science education curricula is premised on the belief that science 'as a way of knowing' is grounded in argumentation. Argumentation or 'art of arguing' is bounded in and framed within complex multifaceted norms, criteria and standards that can be subsumed as 'shared way of knowing' which is now known as scientific approach to knowledge (cf. Ford 2008; Kuhn, 2010). Thus Kuhn (2010) points out that, central to science as an enterprise that persuade others to its perspectives of the world is being adept in the construction, defending and critiquing of others' arguments.

2.2.2. What is an argument and how does adeptness in it foster critical reasoning?

An argument is an assertion with accompanying justification. An argument entails 'juxtaposition of two opposing assertions of two people in a dialogue, [where] each offers justification for his or her views in addition each rebuts the other views by means of a counterargument' (Kuhn, 1991). It is an activity in which interlocutors attempt to decrease or increase the acceptability of one or more ideas by reasoning (Asterhan and Schwarz, 2009). Two types of argument become apparent, namely rhetorical argument and dialogic argument. A rhetoric argument is one-sided or monologic, it is one in which a speaker marshal evidence and construct an argument to his audience (Driver, Newton and Osborne, 1997). Dialogic argument is a multidirectional form in which two or more people "articulate reasons for a particular claim, to attempt to persuade or convince their peers, to express doubts, to ask questions, to relate alternative views, and to point out what is not known" Driver et al. (1997, p.291). Argumentation in educational settings assumes a dialectical and collaborative form because its goal is not only to resolve disagreements among participants' positions, but it is also a process of refining positions jointly (Chin and Clarke, 2013). Competency in argumentative reasoning requires the ability to reflect on one's thinking as an object (Kuhn, 1991). It is by means of this second order reflective ability that one can come to think about, evaluate, and hence be in a position to justify these beliefs, (p. 12).

2.3. Role of argumentation

Berland and Reiser (2010) regards argumentation as a dialogue that entails three overlapping goals, that is, "*making sense* of phenomenon under study (i.e., constructing claims and explanations [from relevant data]), *articulating* those understandings ([constructing and] presenting arguments), and *persuading* others of their ideas (critiquing and evaluating counter-ideas while defending [one's] own" (p.192). Emphasis in the original document. Making sense of an idea occurs when data is transformed into explanations (Sampson and Clark, 2008).

A scientific explanation is an account of how or why something happens. Instead of simply identifying that a phenomenon occurred, scientists try to explain phenomenon by determining how or why they occurred and conditions and consequences of the observed event (McNeill, Lizotte, Krajcik and Marx, 2006). Asterham and Schwarz (2009) delineate argumentation and explanation development as two complementary and yet different epistemic actions that reflect different (socio-) cognitive processes each of which are beneficial in different tasks. The purpose of an explanation-driven discourse is to promote incremental change (Asterham and Schwarz, 2009), as well to provide an account of how and why a phenomenon occurs (McNeil 2011). Asterham and Schwarz (2009) argue that, explanation alone without generating an argument in its favour, may not suffice to effect radical reorganization of conceptual knowledge-understanding. According to Nussbaum (2008), argumentation is an indispensable educational tool that can:

> [instrumental in] stimulating deeper learning (O'Donnell and King, 1998), […] encourage students to generate relationships among concepts and with prior knowledge (Wittrock, 1992), […] help students to become attuned to more conceptual relationships and constrains (Greeno and van de Sande, 2007), [help students] to identify and repair flaws in their mental models (deLeeuw and Chi, 2003), and to consider and adopt alternative conceptions (Reiser et al 2001) (p.352).

This is a complex process of searching, transforming, interpreting, questioning and evaluating appropriate data (Sampson and Clark, 2008). Expertise in the selection and use of appropriate data to support one's argument and attend to counter-arguments, is the function of understanding the goals of inquiry. Proponents of argumentation argue that classroom instructions that provide students with the opportunities to practice argumentation skills, will most likely fosters critical thinking skills (Sampson and Clark, 2008).

At the heart of critical thinking is the ability to weigh the pros and cons of a concept. Critical thinking among others, is awareness of what the concepts speaks to as well as misconceptions associated with it. It is the understanding of how an idea relates to and coheres with other accepted concepts within the domain as well as how evidence bearing on it is 'distinct and relates' to it (Kuhn's 1998). Critical thinking is awareness and understanding of one's own mental processes-metacognition (Kuhn 1998). It is through the evolution of metacognition that people develop the ability to coordinate existing understanding with new evidence, that is, metacognition skills (Kuhn, 1998).

Metacognition is a term representing the notion of thinking about one's thought. In refining the term Mason & Santi (1994) wrote, 'the essential aspect of metacognition is the ability to think explicitly about a theory one holds rather than merely thinking with that theory' (cf. Kuhn, Amsel, and O'Loughlin 1988). This means that classroom activities that embed learners in arguments about scientific ideas and conceptions they hold, foster their metacognition thus impacting on their conceptual growth and change (Mason and Santi, 1994). As Brown (1997) has pointed out, collaborative way of life and thought in the classroom promotes 'agency and reflection' in children towards the discovery of deep principle of the domain and to develop flexible learning of wide applicability. Agency is taking control of one's mental activity, whereas reflection refers to making sense of what you learn, understanding it (Brown, 1997). Metacognition skills are fostered in a collaboration arena where an evidence is not only examined in respect of how distinct is it to the claim it purports to justify but also in how it relates to a claim (Kuhn 1991).

The intellectual demand to carry this dual cognitive actions (of constructing and critiquing arguments) fosters metacognitive skills. Thinking carefully and well about the reasons one puts forward for proclaimed claims, entails looking at ways these reasons might be wrong. The critical evaluation of a knowledge claim speaks directly to how refined and appropriate are the methods of data collection, analysis and therefore, the substituent conclusion that emerges from the process. Said differently it is the examination of how it outsmarts existing counterarguments in respect of enhancement of our understanding of the idea in question, as well as the extent the knowledge claim finds wide applicability within the domain. Metacognitive skills are in essence, the ultimate educational goals and adeptness in argumentation has been identified as an indispensable process for fostering critical skills in the classroom. The questions that arises is, what are intellectual challenges entailed in the construction and evaluation of a scientific argument and explanation? Phrased differently or broadly, the question is: What skills are essential to be critically engaged in scientific inquiry?

In their review of literature on how students engage in scientific argumentation, Sampson and Clark (2008) identify challenges students encounter when generating scientific arguments. These students' struggles are in respect to data usage in generating explanations and evidence to claims. In regard to making sense of a phenomenon based on data, students often do not seek out data that can help test their ideas. Students also rely on personal views rather than use available data. In some cases students may use data to draw conclusions, but not appropriate data. Furthermore, students fail to attend to patterns in data, and are bias to ignore or distort data that threaten strongly held ideas (Sampson and Clark, 2008).

Scientific inquiry as a knowledge-building process, entails expertise in transforming data to scientific explanation and construction of an argument for the explanation to be presented to a community of peers for critique, debate and revision (Sampson and Clark, 2008).The strength of an argument is in terms of how well it accounts for counterarguments by refuting, discounting or proposing a creative solution that eliminates possible objection (Nussbaum, 2008). In light of education researchers' within the argumentation strand findings and advocacy, it is imperative that learners' construction and understanding of what constitutes a scientific explanation should take the central stage in science classrooms.

As a direct response to help students and teachers to circumvent these afore-cited challenges in terms of students' data handling, McNeill et al. (2006), created an instructional model of scientific explanation that can be used in argumentation. It is an instructional model designed to "help students seek evidence and reasons for the ideas or knowledge claims" through explicitly stated prompts that are gradually faded as students become accustomed to its use and application (p.159). McNeill et al. (2006) explanation framework is comprised of the claim, evidence and reasoning components. The claim component is an assertion or a conclusion drawn from or based on interpreted data. The claim is the account of what the occurrence entails and it is often definitive of an occurrence. It addresses the 'what' aspect of a scientific explanation (cf. Driver et al., 2000). The evidence component is the complex part of "reasoning with available data" Cavagnetto and Hand (2012, p. 49). It is seeking appropriate data; reasoning with this appropriate data through attending to important patterns emerging from data to finally forge links in data "into coherent series" (p. 49). According to McNeill et al. (2006), evidence that adequately supports the claims is a function of "students' understanding of the content and the understanding of evidence can influence students' ability to provide evidence for a particular task" (p.156).

So far, I have described the role of argumentation in developing critical, reflective skills which can be subsumed under the term metacognition. These are skills that are essential to learn and partake in the scientific practice of collaborative argumentation.

Collaborative argumentation within the argumentation strand is regarded as a process within which participants improve their quality of reasoning about ideas. These are overarching, long term educational goals which can be attained through mastery of content knowledge. Collaborative argumentation is a vehicle to foster the quality of learners' reasoning about domain-specific knowledge with its distinct culture. Chinn and Clark (2013) referring to Andriesen (2006) and Schwarz (2009) wrote, a number of argumentation researchers distinguish between *learning to argue and arguing to learn* (p.321). According to Chinn and Clark (2013), *learning to argue* occurs when learners are learning the components of argumentation and how to engage effectively in argumentation. Arguing to learn occurs when learners engage in argumentation for the purpose of mastering the content about which they are arguing. In a nutshell, learning to argue is a mastery of argumentation skills which is a function of understating the two goals of argumentation (Kuhn and Udell, 2003). The two goals of argumentation are:

> According to Walton (1989), skilled argumentation has two goals. One is to secure commitments from the opponent that can be used to support one's own argument. The other is to undermine the opponent's position by identifying and challenging weaknesses in his or her argument (p.1246).

'Securing commitment from the opponent' means a profound understanding of the overarching tenets of an alternative perspective. This is the 'deep-level processing of the opponent's argument' and an essential starting point towards challenging its conclusion (Kuhn and Udell, 2003). In addition to articulating one's own argument as a reasoned account of data, it is imperative to construct a counterargument to illustrate disjunctions and contradictions of the opposite perspective. 'To undermine the opponent's position' is pointing out how the conclusion reached is a misinterpretation and distortion of available data it purports to clarify.

Arguing to learn on the other hand, is to jointly manage disagreement in a collaborative argumentation by attending to and evaluating others' evidence and reasons towards producing a refined position as an end goal of the discourse (Chinn and Clark, 2013). Managing disagreements entails:

> Working in the spirit of collaborative inquiry to develop the best solutions. When they [students] encounter new evidence and arguments, they adapt their ideas to new information and evidence rather than to simply dig in and keep trying to persuade others of their position. Persuasion may sometimes be a means to understanding the world, but the ultimate goal is to work together to develop understanding (example, Clark and Sampson, 2007, 2008); the ideal end and goals involve developing better ideas. (p.316).

2.3.1. How does 'attending to others' viewpoints' and elaborating one's position in a collaborative discourse foster learning of content knowledge?

Sampson and Clark (2008) in reviewing literature asserted that, collaborative argumentation has substantive learning benefits for individuals because they engage in *different types of cognitive processes.* (Cohen, 1994). Collaborative argumentation, they continued, provides individuals with the opportunity to engage with *different perspectives* (Linn and Eylon, 2006; Webb and Palincsar, 1996). These different perspectives require *discussion to resolve them* (Amigues, 1988; Phelps and Damon, 1989). Discussion of differing viewpoint *produce explanation* of one's thinking about a phenomenon (King, 1990; Webb, Troper and Fall, 1995). It also offers participants an occasion to *provide and receive critiques* (Linn and Eylon, 2006; Webb and Palincsar, 1996), observe the *strategies of others* (Azmitia, 1998) as well as an occasion to listen to *explanations of others* (Coleman, 1998; Hatano and Inagaki, 1991; Webb, 1995). Emphasis not in the original document.

To produce evidence from available data during collaborative argumentation enhances content learning (Sampson and Clark, 2008). We now need to examine how, for an example, being engaged in the *resolution of disagreements* through *construction* and *critiquing explanation* effect conceptual change.

According to Asterhan and Swartz (2009), a specific form of learning, namely *conceptual change* involves the changing of prior misconceived conceptual knowledge to correct knowledge. Although there is much debate in the educational literature on different types of conceptual change, it is not my aim to examine them in this report. Instead, drawing from Asterhan and Swartz (2009), I focus on two different types of change, namely:

> Some misconceptions may be locally repaired by replacement or correction of knowledge, or what has been referred to as *incremental* conceptual change. Others, however, have been found to be extremely resistant to instructional interventions and require *radical* conceptual change (Carey, 1985; de Leeuw and Chi, 2003), a substantive reorganization of knowledge structure. (p. 375).
>
> Emphasis in the original.

The central tenet of conceptual change is based on the notion "that pairing students with different initial conception or presenting collaborators with [… differing] conceptions they will experience *cognitive conflict*" (p. 375). Emphasis in the original.

Cognitive demand of constructing explanation to peers is found to (within the cognitive psychology strand) require deeper processing of concepts (Nussbaum, 2008). The process of processing information in construction of explanation has an "effect of [forging] links among concepts and with prior knowledge" (p.352). Drawing from both cognitive elaborative theory and argumentation theory, Nussbaum (2008) summarized the effect of constructing explanation on content learning as follows;

> [….] Students become attuned to more conceptual relationships and constrains (Greeno and van de Sande (2007), to identify and repair flaws in their mental models (deLeeuw and Chi, 2003), and consider and adopt alternative conception (Reiser et al. 2001). Of course, [these effects on learning

> is a function] rich and elaborate arguments and explanations, not superficial ones, for these effects to occur. (p.352).

The emergence or presence of disagreement in explanation amongst peers causes the explainer to consider connection between evidence and claim, thus refine as well as elaborate comprehensively (Chin and Clark 2013). The act of finding connection between claim and evidence entails not only drawing on past experience, consolidating prior knowledge and alternative ideas, it also enhances understanding as well as offering students an opportunity to learn from others and to believe in claims they are articulating (Chinn and Clark, 2013; von Afschnaiter et al. , 2007).

2.4. Theoretical framework

2.4.1. Vygotskian Socio-cultural and Argumentation Theories' Perspectives

In my early submission to this faculty I wrote, Piagetian cognitive theory was not entirely satisfactory on two accounts. Firstly, the sociocultural aspect of learning was beyond Piagetian cognitive theory, and secondly, the proposed learning process appeared as a direct interaction of the child with the environment (Koulin and Presseisen, 1995). The human mediators played no significant part in the child's learning process, Koulin and Presseisen (1995) wrote. Perhaps to compensate for the lack of the social, mediatory aspect in the Piagetian perspective, Vygotsky constructed his widely cited, overarching, all-encompassing theoretical framework. Vygotsky's widely published general genetic law of cultural development as it appears in Wertsch & Tulviste (1996, p. 86) posits that:

> Any function in the child's development appears twice, or on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an inter-psychological [social] category, and then within a child as an intra-psychological [individual] category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition…. Social relations or relations among people genetically underlie all higher functions and their relationships.

(Vygotsky, 1981b, p. 163)

According to Wertsch & Tulviste's (1996) interpretation of Vygotsky's law, intrapersonal functioning is viewed as derivative, as emerging through the mastery and internalization of social processes. An individual's mental developmental process is shaped by culturally mediated social activities the group subjects its members. According to Hamacheck (1995), "culture is the social medium in which children interact with more competent members of their social environment" (p.167). The child's internalization of social processes is not done individually, but it is possible within the child's culture. In Vygotskian theory, culturally driven or rather, socially mediated learning is primary and an impetus to individual internalization. According to Vygotsky (1978), higher mental function must be viewed as the product of socially mediated activity, Kozulin (1986) wrote. What is the nature of these inter-psychological (social) processes that Vygotsky attributes to shape the child's higher intra-psychological functions?

Werstch (1985), opined that "inter-psychological processes involve small groups of individuals engaged in social interactions and are explainable in terms of small-group dynamics and communicative practices" (p.60). Werstch's description of inter-psychological processes is akin to what modern psychologists call community of practice. Werstch (1985) argues that learning from Vygotskian perspective is not only through participation in the social grouping, but it is also possible because of the "…inherent connection between the two planes of functioning" (p. 61). Central to this inherently connected planes of functioning, is the internalization or mastery of the activities of the group's practices. Internalization in Werstch's (1985) terminology, is the process of gaining control over external sign forms.

Vygotsky's zone of proximal development provided researchers with a tool of understanding how this transition occurs (Zeuli, 1986). Vygotsky (1978) defines zone of proximal development as "…actual developmental level as determined by independent problem solving" and the higher level of "potential development as determined through problem solving under adult guidance or in collaboration with more capable peers". The zone of proximal development is used to assess children intellectual abilities as well as to plan teaching strategies aimed at improving children learning (Wertsch, 1985). The zone of proximal development speaks to inter-psychological and intra-psychological dimensions of this Vygotskian construct; Wertsch & Tulviste (1996) observed. The actual development of the child corresponds to intra-psychological dimension and potential development corresponds with the inter-psychological dimension of the child. The zone of proximal development points us to two aspects of the state of the learner or child. "Actual developmental level" aspect is what the learner can do without assistance, it is useful as departure point for later development. This actual developmental level is inwardly oriented, therefore individual. The "potential developmental level" is what is not yet mastered but is about to mature. This level is not yet interiorized; its mastery lies in participation with others who have already mastered the level. It is outwardly oriented on a social plane.

> According to Vygotsky, instruction in the zone of proximal development 'calls to life in the child, awakens and puts in motion an entire series of internal process of development. These processes are at the time possible only in the sphere of interaction with those surrounding the child and in collaboration with companions, but in the internal course of development they eventually become the internal property of the child.

Wertsch (1985, p.71).

I could have not summarized and shed light on the actual role of partaking in dialogic discourse better.

Egocentric speech helps people to plan and regulate their actions, which finds its roots in the earlier participation in verbal social interaction. The underlying theme throughout Vygotsky's theory can be summarized by this quote: Vygotsky (1979) in Wertsch & Tulviste (1992, p.549), "The social dimension of consciousness is primary in time and in fact. The individual dimension of consciousness is derivative and secondary" (p. 30). Argumentation theory is the refinement and the application of Vygotskian socio-cultural epistemological theory.

2.5. Conclusion

Drawing from Vygotskian socio-cultural theory, this study uses a classroom as a social context in which less capable members of the scientific practice are in constant dialogue with more capable peers, as they productively engage with scientific ideas in a discipline specific way.

Chapter 3: Research design and methodology

3.0. Introduction

In this chapter I describe my qualitative study's intention, using a case study methodology to find answers to the three research questions stated below. I then proceed to describe the sampling, research site and classroom activities. I also provide justification of how these classroom activities are tools towards fostering critical thinking skills. I illustrate learner engagement with and response to intellectual demands these activities pose. I also illustrate how the activities were meant to foster conceptual understanding. Data was analysed in terms of the following questions:

1. What is the nature of learner arguments as they engage with peers in small groups?
2. What is the nature of learners' (written and displayed) arguments when reporting to the whole class?
3. What is the nature of learner arguments during whole class interaction on the chemistry topic?

Finally, I will briefly explain the validity issues inherent in qualitative research, how I have dealt with ethical issues, ensured confidentiality and anonymity of participants and institutions.

3.1. Research design

This is a qualitative study using a case study methodology. The case is used to argue firstly, that understanding argumentation is important for learning (Kuhn, 1991; Ford, 2012). Scientific explanation-extensively used during the process of arguing- "answers three questions: what we know (ontological question), why it happens (the causal question), and how we know (the epistemic question)" (Osborne and Patterson 2010, p.631). Secondly, argumentation helps make theory distinct entity to the evidence. This is a complex process that can be developed in learners through engagement in specifically designed activities aimed towards fostering a special orientation to knowledge.

3.2. Sampling and description of research site

Data comprises transcripts of audiotapes of one class of twenty-four (24) Grade 11 learners' discussions during a Physics lesson on electricity and a Chemistry lesson on acids-bases. This data was collected in a secondary school located in a township school.

The school is considered as a 'priority school'. A 'priority school' is one whose programs are closely monitored by the Education Department's district office due to its low Grade 12 overall pass rate in relation to the provinces' percentage pass.

The school is located in Soweto, a low-to-middle income township of Gauteng province, South Africa. All the participants are classified as Black according to South Africa's constitution. The class has more or less equal numbers of boys and girls. The school's attendance is fairly high with a minimum drop-out level at higher grades.

The teacher

I am a male teacher with more than 10 years' experience of teaching Physical Sciences. I have been teaching Physical Sciences at this school for 5 years. I am currently completing my Master of Science degree and have been exposed to argumentation as a teaching strategy and a learning tool in the course of my studies. Thus, this study can be described as a tutored teacher with tutored learners. This means that I have been tutored in argumentation in my Masters studies and for this research I taught my learners about argumentation and thus they are tutored in argumentation.

3.3. Description of classroom activity

Prior to the activities meant for data collection the learners were introduced to the concept of argumentation. First I explained Toulmin's (1958) argument structure in very simple terms. I explained that an argument must have an assertion or statement or hypothesis or conclusion (claim). The claim must be supported by scientific evidence (what may be referred to as scientific facts or theories or laws). It is important to show how the evidence actually supports the claim. Learners were explicitly taught the following basic argument structures:

1. Claim (Conjecture, Explanation, Conclusion or Descriptive Statement). [What happened and why it happened?]

2. Evidence (Interpreted scientific data that defend or support claim). [What information or data or observations?]
3. Rationale (How evidence supports claim). Sampson and Gerbino (2010, p.428).

For the data collection activities the learners were placed in small groups and instructed to list concepts they find crucial to the understanding of the electricity topic which was recently completed in class. They were required to provide reasons for choosing that specific list of concepts and show how the reasons (the evidence) they provide support their claims. Secondly, learners were required to discuss how the listed concepts help them understand the specific science topic (justification of their choice of concepts and how they relate to the topic). The next task was a presentation of their arguments to the whole class. Other groups were expected to refute or critique the reporter's claim, evidence or rationale.

Learner small group discussions and presentations to the whole class were audiotaped throughout this exercise. In addition learners submitted their presentation written tasks to the researcher. Learners' written arguments structures as reflected on their presentation posters were evaluated using the claim, evidence, and rationale structure used by Sampson and Gerbino (2010) alongside Toulmin's (1958) analytical framework. Toulmin (1958) analytical framework was used to determine the logical orientation of learners' written arguments. Toulmin's (1958) core argument components, namely, "claim", "data', "warrant", "backing", "rebuttal" and "qualifier" are answers to different questions with different logical functions (Neilsen, 2013).

> **Data**-elements answers to "*What have you got to go on?*", **warrant**-element answer to "*How do you get from [from data to claim*]?", **backing-**elements answer to "*but why do you think that [the warrant is justified]*?, and **rebuttal**-elements answer to "*[what are the] circumstances in which the general authority would have to be set aside*?. (p. 376.) Emphasis not in the original document.

Sampson and Gerbino (2010) claim is an answer to Toulmin (1958) data-element, evidence corresponds with warrant-element, and rationale answers the backing-element. Sampson and Gerbino (2010) and McNeill et al., (2008) frameworks were developed as a more digestible version of Toulmin's (1958) argument structure to help develop critical thinking (Cavagnetto and Hand, 2012).

Berland and Reiser (2010) analytical framework in this report was used to analyse the nature of learners engagement with peers, the teacher and content matter in pursuit of consensus towards the resolution of groups' problem (Berland and Lee, 2012; Chin and Clark, 2013; Kuhn and Udell, 2003). In the next section I provide a detailed explanation of the task. Engaging progressed and at-risk learners with argumentation activity, resonated with Engle and Conant's (2002) four principle supportive of productive engagement. In respect of Engle and Conant's (2002) the first principle, argumentation activity problematized content. Mortimer, Scott and Aguiar's (2006) refine this principle, "problematizing content involves the teacher in encouraging student questions, proposals, and challenges rather than just expecting answers and assimilation of facts and procedures" (p. 607). The activity was also designed so as to allow shared authority among the teacher and students, allowing students "to be authors and producers of knowledge, with ownership over it, rather than mere consumers of it" (Engle and Conant, 2002, p. 404).The activity held learners accountable to each other providing human and textual resources to enhance their understanding of electricity concepts

3.4. The task

Step 1: Teacher-Exposition

The teacher briefly explain the main goal of the activity- activity hand-out attached in the **Appendix A. 2.** I explained how group's written argument would be graded, using the attached rubric - **Appendix A. 2; Table 2**.

Step 2: Learners identify and list central concepts.

In groups of four learners were required to identify central concepts essential towards understanding the topic that had already been taught. For purposes of this study identification of central concepts serves as the claim. The reasons provided to support their choice are the evidence. The groups' work was to be displayed so that it was visible to all in the classroom. Activity Duration: 50 minutes.

Step 3: Groups Presentation to the Whole Class

Groups present in turns and answered questions for clarification as well as respond to rebuttals from the audience.

Activity Duration: 60 minutes

- Presentation: 35 minutes
- Responses: 15minutes

All interaction was audio recorded and transcribed for analysis.

3.5. Data analysis

Data was analysed in respect of: learners' participation and their efforts to understand concepts to select and why they selected them, as well as supporting their explanation with appropriate evidence.

In respect of understanding of science content knowledge, learners' collaborative discourses was analysed using Berland and Reiser (2010) analytical framework of argumentation for sense-making, articulation and persuasion. According to Berland and Reiser (2010), students' scientific argumentative discourses for sense-making and persuasion contain the following five discourse characteristics:

- *construct* claims,
- *defend* […] own and other's claims,
- attend and respond to one another's claims and defence by *questioning* them,
- attend and respond to one another's claims and defence by *evaluating and critiquing* them, and
- *revise* their own and other's claims. (p.199). Emphasis in the original document.

Relating learners' discourses to the goals of making sense of the scientific idea, articulating these ideas to peers as well as persuading peers of one's ideas, Berland and Reiser (2010) devised the below diagram.

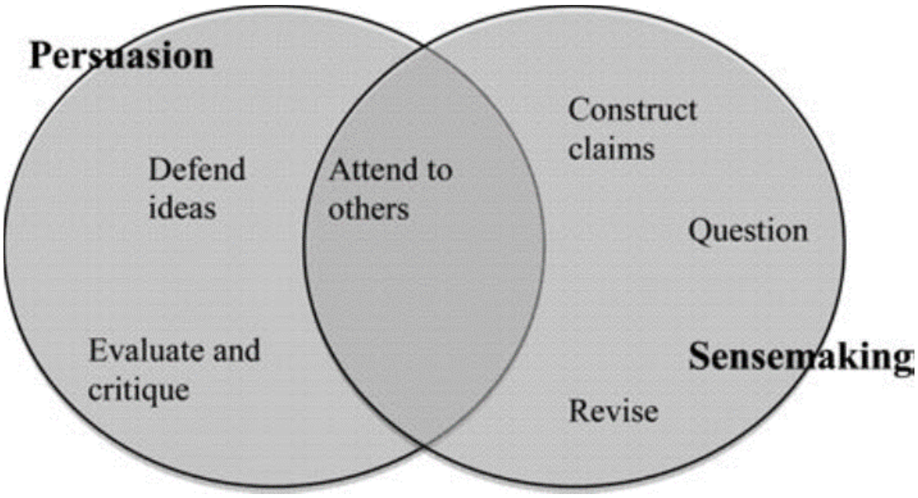


Figure 1. Relating the discourse moves to scientific argumentation to the goals of persuasion and sense-making (From Berland and Reiser, 2010).

Defending a claim against a refutation in a form of *questioning* the soundness of ones' evidence is in essence *persuading* the inquirer to critically see how your claim, evidence and rationale advance our sense of understanding an idea. In the process of constructing an explanation one is not only articulating the central tenets of one's position but one's objective is to point out flaws in others' evidences. The question that arises is precisely how does participating in collaborative discourses foster argumentation skills of juxtaposing; comparing; and resolving opposing positions? The second goal of promoting argumentation skills among learners as a tool to critically engage with content to enhance understanding is eloquently summarized by Kuhn (2015). In her words:

> The pair must attend to and examine the opposing pair's position with the aim of weakening it. They must also work to develop and uphold their own position in the face of parallel efforts of the opposing pair to weaken it. These dual objectives can only be met successfully if participants recognize the two different perspectives that exist, reflect on and gain understanding of each of them, and strive to coordinate them in a manner that fulfils the objectives of the activity (p.49).

3.6. Validity of this qualitative Research Design

According to Maxwell (1996), validity of description, explanation, interpretation and conclusion refers to the correctness and credibility of an account when tested in the real world it purports to explicate. It provides the strategies of nullifying the validity threat-a way you might be wrong- or alternative account or “rival hypotheses” (Maxwell 1996). The validity threat inherent in qualitative research is “making conclusion from data that fit researcher’s existing theory or preconceptions,” Maxwell (1996, p.90). One of the mechanisms of minimizing this validity threat inherent in qualitative research design is through my supervisor’s feedback of my explanation and interpretation of collected data.

3.7. Ethical considerations

Permission to conduct this study was obtained from the Ethics Committee of the University of the Witwatersrand, protocol number: **2017EC021M.**

On commencement of the study, I explained the purpose of my study to the learners and requested for their consent to participate in my study. I explained that activities in this study are not for marks. Learners were assured of the anonymity and confidentiality and told that their written arguments will be assigned codes and will not be identified by name in any presentation of my work. I also explained that the information that they gave me will not be shared but remain confidential and only be used for this particular research. Students were informed of their rights to withdraw their consent at any time if they so wish and that they will not be penalized in any way.

Fortunately, all my students agreed to participate in the study and they each completed and signed a consent form. Since the Grade 11 learners are minors, I obtained written permission from their parents or guardians to conduct this research with their children. I explained the purpose of the study as well as assured parents of the anonymity and confidentiality of the study’s sample. I sought the school’s principal and the Gauteng Department of Education’s permission to conduct this study. The purpose, methodology and data collection and analysing instruments were thoroughly explained to the institutions’ authorities. The below-listed ethics considerations were strictly adhered to.

3.7.1. How issues of confidentiality were addressed?

The information will only be used for my study and the project and will not be shared with anyone else outside of the project. Learners were coded so that they cannot be identified. I avoided descriptions that gave away the learner's identity.

3.7.2. Anonymity ensuring mechanism

Transcription used pseudonyms not real names of learners and a pseudonym will be used for the school as well. The school management in which the study was conducted were informed of their right to withdraw their permission at any time during this project without any penalty. The school's management team were informed that participants will not be paid for this study. The names of the research participants and identity of the school will be kept confidential at all times and in all academic writing about the study. I further stated that, the institute managers' individual privacy will be maintained in all published and written data resulting from the study.

3.7.3. Data storage

The data is stored in a password protected computer at Wits by my supervisors and external hard drive before and after transcription. The data will be destroyed in 3-5 years after completion of the study.

3.7.4. Conclusion

In conclusion, the extent to which learners' arguments, that is, assertions, questions and counter-arguments address the three aspects (ontological, causal and epistemic) of scientific explanation as advocated by Osborne and Patterson (2010) is an indication of having understood the learning material. In terms of the research's three sub-questions learners' arguments will be evaluated as outlined below:

3.7.4.1. What is the nature of learners' arguments as they engage in small groups?

The participation of progressed learners in group discussions was examined in terms of: Foremost, the relevance of their questions in pursuit of reaching consensus towards solving the group's problem. Secondly, their analysis and interpretation of data to construct explanations that not only articulate the group's position, but also nullify counter-explanations through being grounded in well-established scientific principles. And finally, in explicitly showing how the evidence they provided advances understanding of ideas discussed. This is evident when their claim, evidence and rationale do not contradict any of the disciplinary knowledge claim.

Examination of concepts learners choose and reasons they give for choosing these concepts.
The examination of chosen electricity concepts and Arrhenius acid-base theory concepts will involve the concepts' meaning as understood by experts in relation to learners' understanding of these concepts. It is in the analysis of learners' proposed reasons that I-researcher-was able to assess the extent of their understanding of these concepts.

3.7.4.2. What is the nature of learners' (written and displayed) arguments when reporting to the whole class?

Here I scrutinized learners' abilities to articulate arguments, as an indication of their understanding of the scientific knowledge. Learners' arguments were graded in terms of the quality of their arguments. The quality of arguments is determined by the logic and coherence of arguments' components. A logical argument is one that identifies and invoke appropriate scientific principles to support claims or a particular viewpoint in a collaborative discourse. Coherent argument is identifiable by the ability to relate claims, evidence and rationale to one another, as well as to correctly articulate the appropriate canonical scientific principles.

3.7.4.3. What is the nature of learners' arguments during whole class interaction in the chemistry topic?

It is at this point of analysis where fault and/or correctness of exposition and interpretation by learners is brought forward. The extent of learner correctness or faulty exposition and interpretation relies primarily on conceptual understanding. In addition to the accuracy and adequacy of contents of learners' arguments; focus was laid on their ability to persuade others of the validity and plausibility of their version of explanation.

Chapter 4 Analysis, results and discussion

4.0. Introduction

In this chapter I present my data analysis and the results as well as discuss the findings of my study. I commence the chapter by the brief outline of the central hypothesis the study advances about scientific argumentation.

4.1 The hypothesis the study advances

The process of embedding learners in a dialogic discourse of electricity and acids-bases concepts was aimed at allowing them to 'think about their thoughts' (Kuhn, 1989), about these concepts and hence enhance their conceptual understanding. In Ford's (2008) perspective, it is 'grasp of practice' which is acquisition of scientific 'duality state of mind', that is, making justified claims and construction of rationales that nullifies possible anticipated rebuttals. In Brown's (1997) terms, it is fostering communities of learners that "leads children to discover the deep principle of the domain and to develop flexible learning and inquiry strategies of wide applicability" (p.399). Argumentation in science classrooms problematizes content, it gives students authority, holds them accountable to others and to disciplinary norms, and provides relevant resources (Engle and Conant, 2002). Adeptness in argumentation calls upon identifying the central claim of an idea, it is in essence, being aware of 'what the idea is' and 'what it is not' and probably of greatest significance showing how it finds applicability to practical, real life situations.

Argumentation as a complex epistemic practice *problematizes learning materials* while shifting classroom *authority from the teacher towards the learner*, but holds learners *accountable to each other*, requires *adequate resources* to master. Engle and Conant's (2002) four principles that foster productive disciplinary engagement are outlined-by italicized words-in the above description of argumentation process. Analysis of learners' argumentative discourse in their designated groups allowed me to make observations that answer all three sub-question of this research study. Data was analysed in respect of the following questions:

1. What is the nature of learner arguments as they engage with peers in small group?
2. What is the nature of learners' (written and displayed) arguments when reporting to the whole class?

3. What is the nature of learner arguments during whole class interaction on the chemistry topic?

4.2. Analysis of learners' arguments as they engage with each other in small groups

4.2.1. The nature of learners' arguments

For learners to grasp the meaning of scientific concepts, articulate this understanding to peers, as well as persuading peers of their version of these concepts, they first have to reach a rational agreement about these ideas. Below is a transcript of learners' discussion to illustrate the argument role learners played in a group-work setting, as well as strategies they used to impose meaning to an interacted-upon material (Brown, 1997; Brown and Palincsar, 1986; Engle and Conant, 2002; and Berland and Reiser, 2010). In a group-work setting learners share responsibility for thinking about ideas (Brown and Palincsar, 1986). "The most common argument roles learners assume are those of: **executive**, who designs plans for action and suggests solutions; the **critic**, who questions premises and plans of others; the **didactic**, who constructs explanations and summarization; **record keeper**, who keeps track of what has passed; and the **conciliator**, who resolves conflicts," Brown and Palincsar, (1986, p.19). Emphasis in the original. Playing one or more of these roles allows one (and members of the group) to work on the problem to achieve the best possible solution, thus learn content knowledge by arguing for and against a particular position (Kuhn, 2015; Chin and Clark, 2013). Constructing and critiquing explanations subject participants to a variety of epistemic operations (Brown and Palincsar, 1986). Essential epistemic operations involve "referring to context, past knowledge, data or general principles, defining the problem, isolating important contributing variables, evaluating progress etcetera", Brown and Palincsar (1986, p.22).

Group 1's transcript

G1BL1 denotes Group 1 Boy Learner 1, **G1GL1** Group 1 Girl Learner 1. The first letter abbreviates 'Group' the number after it refers to the group number and the letter after the group number indicates the gender of the group member and the number after the participant's gender differentiates between members of the same gender in a group.

Participants	Verbatim utterance	Translation
1. <u>G1BL1:</u>	Guys re thoma ka potential difference. Concept 1 ya rona etla ba Potential Difference, equation ya rona ke $V = \frac{W}{Q}$ and definition ya rona tshwanetse re e "change" like e be easy for rona ho e understand definition and then we must also get a fact e re tlo e spanisa as an alternative explanation ya rona le diconcepts tse associated with potential difference".	Guys let us start with potential difference. Our concept 1 will be potential difference, whose equation is $V = \frac{W}{Q}$, and we need to change our definition in order to make it easy for us to understand the definition and then get a fact we will use as our alternative explanation. As well as concepts associated with potential difference.

Analysis:

<u>G1BL1</u> takes on the roles of an **executive and didactic** by suggesting that they rephrase an official definition of 'potential difference' in a manner that will also make concepts associated with it easy to retain and elaborate. Elaboration in this report does not only refer to the provision of a comprehensive, well-thought account of an idea, but it also means "generating relationships among concepts and with prior knowledge" Nussbaum (2008. p.352). Epistemic operation he employs to achieve the solution to group's problem is "referring to relevant data," namely, referring to the equation of the potential difference. His reference to the equation $\boldsymbol{V = \frac{W}{Q}}$ is an implicit, unstated suggestion that peers should "*refer to and identify important variables*" in constructing their argument. He further "*refers to context*" by reminding peers that while working together on a refined explanation of the idea 'potential difference', they should identify a common misconception associated with the term (refer to the task's instruction in the appendix section). In summary, according to Berland and Reiser (2010) analytical framework he is 'making sense' of the task instruction by suggesting the reorganization of the official definition of 'potential difference'. In terms of Toulmin's (1958) model of argument's core elements, he implicitly addresses the **data-element**. He implicitly answers the data-element question "*what do you got to go on?*" is we have an equation $\boldsymbol{V} = \frac{\boldsymbol{W}}{\boldsymbol{Q}}$ to work on to construct an explanation that adequately defines the potential difference.

2. **<u>G1GL1*</u>**: "And then ena? Translation: ["And then, what is this?"]

Analysis:

<u>G1GL1*</u> takes on a role of a **<u>record keeper</u>**, she enquires about the task's instruction, keeping track of what has passed (Brown and Palinscar, 1989). This is an on task question in that she is productively engaged with the problem (Kuhn, 2015), making sense of an idea through "attending to others'" contributions (Berland and Reiser, 2010). Epistemic operation she utilizes towards solving the group's problem is 'defining the problem', 'referring to the concept and data' (Brown and Palinscar, 1989). The task demanded that they not only proclaim their claim (about 'potential difference') and associated justification (Kuhn, 1991), but also critique an alternative explanation to the concept of 'potential difference'. **<u>G1GL1's*</u>** question is in reference to the alternative explanation to 'potential difference' which is written alongside the concept's definition.

3. **<u>G1BL1:</u>** Definition okay.
4. **<u>G1BL2:</u>** "Potential difference is work done per unit positive charge."
5. **<u>G1BL1:</u>** "Eng?" Translation: ["What?"]
6. **<u>G1BL2:</u>** "Work done per unit positive charge."
7. **<u>G1BL1:</u>** "Per unit positive charge? Wena ha o shebile definition ee e meana eng?" "Any definition ya potential difference?" Translation: [Per unit positive charge? When you consider this definition, what does it mean? Any definition of potential difference?]

Analysis:

Both **<u>G1BL1</u>** and **<u>G1BL2</u>** attend to **<u>G1GL1*</u>** initial question, Berland and Reiser (2010) categorizes "attending to others'" as entailing sense-making and persuasion. Attending to others satisfies these two goals of argumentation because it is an effort towards helping peers to contribute towards construction of explanations, conclusions or claims with understanding. **<u>G1BL2'</u>**s assume the role of a **<u>conciliator</u>** and **<u>didactic</u>**, who resolves an apparent conflict that may arise from holding different understanding of the same concept by taking the burden of explanation and summarization (Brown and Palincsar, 1986). Epistemic operations exhibited

[Type here]

in the utterances are ‘referring to context and data’; ‘defining the problem’ which are essential towards retention of content discussed (Brown and Palincsar, 1986). Participants’ retention of content is increased primarily by being productively engaged with the problem itself rather than being in a collaborative setting (Kuhn, 2015). Collaborative setting provides an audience that requires one to clarify, elaborate, justify, and resolve conflicts, thus catalyses one to critically think about relationships among concepts (Brown and Palinscar, 1986; Nussbaum, 2008; Kuhn, 2015). Reflecting on and being engaged with the problem itself and drawing on relevant data which is often made available by a collaborative settings, help the participants not only to retain, but also to assimilate and restructure knowledge when challenges arise (Brown and Palincsar, 1986; Kuhn, 2015).

Participants	**Verbatim utterance**	**Translation**
8. **G1GL1*:**	Energy transferred per unit charge.”	
9. **G1BL2:**	Okay.	
10. **G1BL1:**	So tshwantse re tsebe hore potential difference e mejarewa ka divolts right guys? So tshwantse re qave hore mono seka o bua. Like akare oitse potential difference is the work done per unit charge. Mona bare explainaela hore in the circuit charges is moved from high potential to a low potential. Electric energy is changes to heat, light and other energy forms. So, in a cell ne? Charge moves in a cell, in a cell, low to high and chemical energy is converted to electrical energy. Nkabe re checka	So, we need to know that potential difference is measured in volts, right guys? So we need to know that, like you are saying here, like you said ‘potential difference is the work done per unit charge. Here, it is said that ‘explain that in a circuit, charges [is] moved from high potential to low potential. Electric energy is changes to heat, light and other energy forms. So, in a cell, okay? Charges move(s) in a cell, in a cell, low to high, and chemical energy is converted to electrical energy. We need to

	mo handout eba re gaileng yona."	check from the hand-out given to us.]
11. G1GL1*:	I think Sir are re choosa.	I think the teacher says we should choose.
12. G1BL1:	Like akare re thotse explanation ya rona, so re tlo tlameha 1.2 ere 'give reasons for your preferred choice and rejection of an alternative explanation' and then ena ere; 'A battery supplies/produces charges that are simultaneously pushed and pulled at its terminals' So, alternative explanation e katlang ka yona ke e wenaa ke efeng? Explanation e wena o ka kgonang ho explaina potential difference in a proper way. You have to go back. So tshwanetse re e shebe re bona hore alternative explanation ke e feng ya rona.	We already found our explanation. We are supposed to, 1.2. says: 'give reasons for your preferred choice and rejection of an alternative explanation,' and then this says: 'A battery supplies/produces charges that are simultaneously pushed and pulled at its terminals' So, what is the alternative explanation that you can come up with? The explanation that you can be able to explain potential difference in a proper way. You have to go back, so we need to search and identify the group's alternative explanation.
13. G1BL2:	Inaudible	
14. G1GL2*:	Ke ye definition [inaudible], this: potential difference is equal to the work done to move a charge between A and B.	Here is the definition [inaudible], this: potential difference is equal to the work done to move a charge between A and B.
15. G1BL1:	Okay, ena ereng?	Okay, what does this say?
16. G1GL2*:	It is the energy transferred per coulomb across the components.	
17. G1BL1:	Unit? Definition ya teng e reng?	Unit? What does its definition say?
18. G1GL2*:	Ke ye definition.	Here is the definition.

19. <u>G1BL1:</u>	E reng?	What is it?
20. <u>G1GL2*:</u>	It is energy transferred per coulomb of a charge.	
21. <u>G1BL1:</u>	It is energy transferred per coulomb?	
22. G1GL2*:	Across the component.	
23. G1GL1*:	Ke definition eo?	Is that the definition?
24. G1BL1:	Ja	Yes it is.
25. G1BL1:	Re na le equation, definition tsei two, ya hao e reng definition?	We have two equations definitions, what does yours say?
26. G1GL1*:	The potential difference between two points in the electrical the electrical is work done per unit charge to move a charge from a point of lower potential to a one of [inaudible].	
27. G1BL1:	Tshwanetse re choose an equation easy for us hore re understand, like, nna ne ke nagana hore re nke this equation mo re tlo reng: '*<u>Work done per unit positive charge'</u>* Ke yon akera?	We must choose an equation hat I easy for us to understand. Like, I think this equations which says *<u>'Work done per unit positive charge'</u>*, as well as *<u>Energy transferred per coulomb across the component</u>*. That is it, is it not so?
28. G1GL1*:	Ke yona.	Yes it is.
29. G1BL1:	Okay eqution ya teng?	Okay what is its equation?
30. G1BL1:	Re tlamaile ho bua ka current.	We are [also] supposed to say something about the current.
31. G1BL3*:	Yoo! This!	This!
32. G1BL1:	Okay, okay, okay. Hence re kare mo potential difference…	Okay, okay, okay. Hence we can say here potential difference…
33. G1BL3*	Wa phapha.	You are forward.

[Type here]

34. G1BL1:	Okay, in your group make a choice-on a poster- of what is a refined/ better explanation of the concept. Better explanation, why renka e? And then 1.2, give reasons for your preferred choice and rejection of an alternative explanation. Why re nka alternative explanation?	Okay, in your group make a choice-on a poster- of what is a refined/ better explanation of the concept. Better explanation, why do we choose this? And then 1.2, give reasons for your preferred choice and rejection of an alternative explanation. Why do we take an alternative explanation?
35. G1BL2:	Mara ee! [Laughter].	But this one! [Laughter].
36. G1GL3*:	Hai! why nenga… [Inaudible].	No! Why don't you… [Inaudible].
37. G1BL1	Like equation ya rona e re: Give reasons for your preferred choice and rejection of an alternative explanation. Bafowethu! Reasons for rejection of an alternative explanation.	Our question goes as follows: Give reasons for your preferred choice and rejection of an alternative explanation. People! Reasons for rejection of an alternative explanation.
38. G1GL3*:	Lena he 'different points,' and thina se funa e 'potential difference.'	This speaks to 'different points,' and we are searching for 'potential difference.'
39. G1GL2:	I think re nke e, wa bona e thlalosa di 'different points'	I think we should take this one, because it explains 'different points.'
40. G1GL2*:	E feng?	Which one?
41. G1BL2:	E!	This one!
42. G1GL1*:	A charge moves from a point of low potential to a point of… [Speaker interrupted].	A charge moves from a point of low potential to a point of… [Speaker interrupted].
43. G1BL2:	To a point of high potential.	To a point of high potential.
44. G1BL1:	Give an alternative explanation of	Give an alternative explanation of

	the potential difference. 'A battery supplies or produces charges that are simultaneously pushed and pulled at its terminals.'	the potential difference. 'A battery supplies or produces charges that are simultaneously pushed and pulled at its terminals.'
45. G1BL2:	So shebang 'potential energy.'	So, search for 'potential energy.'
46. G1BL1:	Ra recorda guys. So if ee explanation yaka 'charges moves from a high point, akere that potential energy [inaudible] like battery go tshwana e le 'flat' are you aware? Okay in a circuit charges move from a high point to a low point and electrical energy is converted to heat, light and other energy forms. In a cell which is a battery, charges move from low to high potential. Energy is converted to electrical energy wa bona? The increase in electric potential provided by the cell is called the emf. Battery akere so o tla bona mo hore ke battery, nkabe e le circuit ne re tlo nka alternative explanation. Ho na nou a battery e tlo sala e le cell ne? So ee! Alternative explanation ya rona re tlo he nka like [inaudible] from here.	We are recording guys. So if this explanation: 'Charges moves from a high point, [so] that potential energy [inaudible] like battery. It is like it is flat, are you aware? Okay in a circuit charges move from a high point to a low point and electrical energy is converted to heat, light and other energy forms. In a cell which is a battery, charges move from low to high potential. Energy is converted to electrical energy, can you see that? The increase in electric potential provided by the cell is called the emf. You will see from here that this is a battery, could it had been a circuit we would take an alternative explanation. Now a battery relates to a cell, okay? So this one! Our alternative explanation will be taken from here].
47. G1GL1* and G1Gl2*	No! Hae!	No it cannot be.
48. G1BL1:	From low to high potential and	From low to high potential and

	chemical energy is converted into electrical energy. Battery e nale chemical energy, something like that, alternative explanation ya rona ke…	chemical energy is converted into electrical energy. The battery has chemical energy, something like that, our alternative explanation is…
49. G1GL1*:	For potential difference?	For potential difference?
50. G1BL1:	No, for potential difference ha re na ei one, re nale bo ma circuit.	No. We do not have oe [definition] for potential difference, we also have a circuit.
51. G1GL1:	[Question inaudible].	[Question inaudible].
52. G1BL1:	No, no, akere battery, potential energy ke battery, ke battery. A re sebediseng battery rona. Ha re no change if re ka kgona ho spanisa cell [inaudible] e tlo re explainela easy hore 'from low [inaudible] to high', mo ke vice versa ya cell le battery.Ya cell, ya circuit ke 'from high to low'. Ya circuit ke from 'low to high'	No, no, a battery, potential difference is the battery, it is the battery. Let us use the battery, we will not have to change [our definition] if can be able to use the cell [inaudible], we will explain it easy in terms of 'from low [inaudible] to high,' this is the opposite of the cell and the battery. For the cell, for the circuit it is 'from high to low.' Whereas for the circuit it is from 'low to high'
53. G1GL1* and G1GL2*	From low to high.	From low to high.
54. G1BL1:	And then chemical energy is being converted to electrical energy. Keye, so alternative explanation keye alternative explanation, and then mo batlo refa reason why re prefer and reject alternative explanation. And mo ke mo	And then chemical energy is being converted to electrical energy. Here it is. Here is an alternative explanation. Here we need to give reasons for our preferences and the rejection of an alternative explanation. Do you still

	tlameileng ho tla le di-'reason' why o chose e, e. Wa gopola akere?"	remember?]
55. G1GL2*:	Why re chose cell? Alternative explanation it just means any other explanation?	Why do we choose a cell? Alternative explanation it just means any other explanation?
56. GIBL1:	Ja, any other, so wena [inaudible] choose and explain better, give me a reason why you choose the explanation.	Yes, any other, so you need to choose and explain better with reasons for the preferred explanation.
57. G1BL	Bare a better explanation.	The instructions require a better explanation.
58. G1BL2:	Mare an alternative explanation and le ena e re fa better, ke yona eleng…" [Interrupted]	But an alternative explanation gives a better explanation. It is the one that… [Interrupted].

Analysis:

Episodes 8 to 58 above, illustrate learners working on a set of concepts or essential data to argue in favour of one concept against a specific explanation of the concept. These episodes are evidence that learners struggle with gathering; selection and use of data to construct evidence for pronounced claims (McNeill et al., 2006; Sampson and Clark, 2008). This struggle with the provision of evidence emanates from being "confronted with more data than is appropriate to use as evidence […]" McNeill et al. (2006, p.156). Learners extracted the potential difference explanation from their school prescribed textbook in addition to the shortened definition given in the activity handout. The textbook version is quoted verbatim by **G1BL1,** turn 46 sentences 4 to 7 (the translated speech act). **G1BL1** suggests that the group extract part of the textbook explanation of the potential difference and present it as their alternative explanation. He discards and does not point out the error in the explanation given alongside the shortened definition of potential difference (refer to 'classroom dialogue prompts 1 appendix A.2'). The goal of the task was to establish the credibility to the definition of potential difference (shorten or elaborated version) by aligning it with evidences provided and use relevant principles to show that indeed the evidence provided supports the definition. To strengthen their argument, it was essential to attend to and refute the alternative explanation written alongside the potential difference definition. **G1BL1**'s recourse to textbook version definition was in essence, the provision of additional data without warrants and backings, hence **critics** voices emerged (Brown and Palincsar, 1989). Turns 47, 49, 55, and 58 attest to episodes where a conflict arises among group members. **G1GL1***, **G1GL2*** and **G1BL2** are dissatisfied with **G1BL1'**s choice of argument-core elements and associated explanations. For example **G1GL1*** in ***turn 49*** attends or responds to peer's explanation that muddles real meanings of concepts.

In conclusion, the turns prove that although learners may "realize the importance of including data to construct their explanations" they often do not adequately attend to alternative conflicting explanations, McNeil et al. (2006, p156).

Analysis:

Questioning is one aspect of being actively engaged with seeking solutions to the group's problem. Below is an analysis of questions posed by **G1GL1*, G1GL2*** and **G1GL3*.**

The transcript reveals that **G1GL1***, **G1GL2*** and **G1GL3*** frequency of questioning peers as one of meaning-seeking strategy of learning is (14 out of a total of 31utterances), (5 out of 16 utterances with 2 off-task utterances), and only (6 out of 17 utterance) respectively. Eleven (11) of **G1GL1***'s questions enquired about core argument structures, that is, *claim*, *evidence* and *rationale*. For an example at ***turns 117*** she required an explanation as to why one concepts can serve as both a *claim* and an *evidence*. At ***turn 125*** she disagrees with the notion of equating a *claim* to an *evidence*. The **critic** role **G1GL1*** assumes compels group members to defend or elaborate solutions, which might cause a mature resolution to emerge from the dialogue (Brown and Palincsar, 1986).

G1GL2*s two of the five questions required group members to identify the alternative explanation (***turns 62 and 64***) in pursuit of reaching consensus to provide reasons for rejecting the alternative explanation to the group's claim.

Four (4) of **G1GL3***'s question could be categorized as follows: One (1) is an incomplete question because of interruption (***turn 36***) one (1) concerns recognition of a *rationale* (***Turn 85***), while the other (1) wanted a reason for not choosing the concepts she probably preferred (***Turn 116***). The last question required an explanation as to why one concepts cannot be used as a *claim* and an *evidence* (***Turn 124***).

In line with Engel & Conant's (2002) principles of fostering productive disciplinary engagement, placing learners in a group posed cognitive demands on participants in respect of evoking an argument thus "eliciting opposition between two incompatible positions," Mason & Santi (1994, p. 4). Working in small groups problematized content through the encouragement of questions, proposals and peers' intellectual contribution (Engel & Conant, 2002). Group-work settings gives authority to learners as they "develop their own hypotheses and report their ideas back to the whole class," Mortimer, Scott & Aguiar (2005, p. 625.).

4.2.2. Discussion of emerging arguments.

Drawing on literature, especially Engle and Conant (2002); Brown and Palincsar, 1986; Kuhn and Udell, 2003; Ford, 2008) and analysis of patterns emerging from learners' participation, the study observed that progressed learners' engaged productively with content and scientific practices. One amongst several ways of being productively engaged in a domain is through asking question, critiquing other ideas, as well as eliminating confusion (Brown, 1997). Learner **G1GL1***, certainly engaged in a discipline specific way by asking several relevant questions. She also asked clarity-seeking questions and summarised her understanding of the task from time to time. Without questioning, clarifying, summarizing and predicting one does not learn (Brown, 1997). It is in collaborative contexts and activities that learners are held accountable to peers and disciplinary norms and practices, to consult others in constructing their understandings in a domain; they cannot purposely ignore the relevant work of others without justification (Engle and Conant, 2002). The high frequency of questions among group members attests to engaging productively in a domain specific ways.

Questioning plays a vital role towards the construction of an elaborate explanation which is indispensable towards construction of a sound argument. An argument comprised of a claim that is coordinated with evidence is central in persuading peers of one's perception of an idea. This enhances the understanding not only of the idea under discussion, but also of related constellation of ideas within the discipline. The instructional implication of this practice of allowing learners to be in a dialogic discourse with peers, content and experts in explaining meaning of concepts entails "picking up another person's utterance (Bakthin, 1986) from its time, context, and purpose, and using it in one's own situation, to advance one's own feeling of understanding" Ford and Wango (2011, p.371).

The teachers' role is to include a list of questions that requires learners to give causal answers. Although progressed learners showed a high level of questioning, the nature of their questions was predominately about the argument structure and there were few questions probing for reasons, which is central to understanding as espoused by above quotation.

4.3. Discussion of the nature of learners' arguments during whole class interaction in the chemistry topic.

Now we focus on teacher-led discussion of the chemistry section which took place three weeks after the Physics-current electricity activity was completed. The chemistry discussion mainly focused on the adopting a 'construct-critique duality' approach to knowledge as a tool to making sense of concepts (Ford, 2010). It is worth mentioning here that a feedback on learners' extent of critiquing peers' choices and reasons provided-during electric current activity-was minimal and was a source among others that prevented a profound engagement with the concepts. Throughout the communication of curriculum sections-post current electricity activity- "individual strategies such as questioning, classifying, and summarizing to help [learners] monitor their [comprehension] progress" was deliberately and constantly emphasized, as a prerequisite to effectively critique peers' claims and evidence, Brown (1997, p.401). Summarization of texts was the strategy I mostly stressed and offered learners an opportunity to practice, through setting aside 20-25 minutes of an hour long period to capture key ideas discussed. The summarization rules espoused by Brown et al. (1981) were practiced, that is, "*selection of a topic sentence, deletion of unnecessary material*, and '*substitution of a superordinate term,*" (p.17). Emphasis in the original text.

It is in the application of these strategies that I believe that the act of reminding learners of the need to question each other and seek clarification brought about an improvement in the degree of critiquing peers claims and reasoning. The below episode extracted from the attached transcripts attest to learners' intense application of the scientific practice of 'construct-critique' approach.

G1GL1, **G2GL1**, and **G1BL1** denote 'group 1 girl learner 1', 'group 2 girl learner 1', and 'group 1 boy learner 1' respectively.

1. **Teacher**: What is the group's understanding of Arrhenius theory and [inaudible]? (*Line 1*)
2. **G1GL1**: Sir [inaudible] an acid is a substance that dissolves in water to give hydrogen ions ($H^+_{(aq)}$) and a base is a substance that dissolves in water to give hydro.. hydroxyl ions ($OH^-_{(aq)}$). (*Line 5*)
3. **Teacher**: But there was a question from group 'ke group mang eo' [What group is it,] (*Line 6*) Group2? What was your concern about their definition? (*Line 7*)
4. **G2GL1***: Yes sir, I was asking what do they mean when they say an acid [inaudible]? (*Line 8*)
5. **G1GL1**: Sir we never agreed, not at all. (*Line 9*)
6. **Teacher**: You never presented [inaudible]. (*Line 10*)
7. **G1GL1**: Let's put it in a different way. (*Line 11*)
8. **G1BL1**: Ya sir ke kopa ho e bea straight [Translated as: Let me be precise. An acid is a substance that increases the concentration… (*Line 13*)
9. **Teacher**: Not the solution? (*Line 14*)
10. **G1BL1**: Yes concentration. (*Line 15*)
11. **Teacher**: According to group1, they say 'according to Arrhenius theory, an acid is a substance that increases the concentration of H^+ in a solution. [Group 1's definition written on the chalkboard and labelled Group1] Now how? You now say an acid is a substance that increases the concentration of hydrogen ions in a solution. And precisely if we go to group 2's question. In trying to refine it, they picked up the mistake, the initial definition where now, an acid was according to them-according to their presenter- 'an acid is a substance that increases the solutions of hydrogen ions'? Is it how you said it initially, is it how you will defined Arrhenius theory group 2?
12. **G2GL2***: Sir according to our group, we'd define it as a substance that dissolves in water to form hydrogen ions, like [inaudible] in the presence of water. According to us, during that reaction hydrogen ions will separate [inaudible] and [inaudible] positive side of water and hydrogen ion on the negative side of water, yes. (*Line 28*)

13. **Teacher**: Ok is it your understanding? We can show that in an equation. Other group?
14. **G1BL1**: Yes sir, from Arrhenius [inaudible] an acid or base, it does not form [inaudible] in a solution. Ke ena mistake wagago [Translated as: Here lies your mistake][inaudible] (*Line 31*)
15. **Teacher**: So are you are saying we need to be very precise, careful about what we say? An acid is a substance that doesn't form hydrogen ions, it just increases the concentration of hydrogen ions? What is wrong when this group's '…it forms'? This group, group 2 they were corrected when they said 'an acid is a substance that forms hydrogen ions in a solution'. Group 1 objects to that to. (*Line 36*)
16. **G1BL1**: Increases hydrogen ions in a solution. (*Line 37*)
17. **Teacher**: Where do these hydrogen ions come from? (*Line 38*)
18. **G1BL1**: Acid "etlo forma, etlo" [will form, react] in an aqueous solution. In that aqueous solution [it has] hydrogen. So "ena e tlo kena at least, etlo" [it will] increase hydrogen ions in a solution, "e ka se iforme, e di thotse dile teng moo" [it doesn't form them, since they are part of an acid]. (*Line 41*)

Discussions pose cognitive demands on participants in respect of evoking an argument thus "eliciting opposition between two incompatible positions". Resolving these differences calls for expertise in argumentation which "is a technique which guarantees rational and [prudent or carefully thought] decisions," Mason and Santi (1994, p. 4). Progressed learner: **G2GL1*** (*Turn 4*) productively engages with peers in questioning the definition thus showing dissatisfaction with the proclaimed definition of Arrhenius theory of acids. It is an indication of 'grasp of practice' which entails finding fault with peers' construct, in an effort of refining it, (Ford, 2010). It is this "argumentation attitudes and skills, […] looking for reasons and considering alternative positions," that prompt peers to reflect on their thoughts. Mason and Santi (1994, p. 4). By reflection in this study I mean "not simply 'learning in the raw' but making what you learn make sense," Brown (1997, p.399).

It is **G2GL1'**s (*turn 4*) act of seeking clarity that group 1's initial definition was revised to a much refined definition, refer to **G1BL1** (*Turn 8*). The reason for choosing a precise definition of Arrhenius acid is for a need to eliminate the possibility of multiple interpretations of the theory. The clarity seeking question from **G2GL1*** necessitated an explanation from group 1 to show how their revised version of an acid "[…] advance[s] [their] own feeling of understanding"

Ford and Wango (2011, p. 371). This is the explanation of group 1: **<u>G1BL1</u>**: (Translated version): An acid will form, react with aqueous solution. In that aqueous solution it has hydrogen. So […], it will increase hydrogen ion in a solution, it will not form it, it found it there.'] (*Turn 9*).

In terms of the instructional support and encouragement to summarize, critique, and use available interpreted data, learners took a "critical approach to learning" in refining peers' assertion, (Department of Education 2012, p.8). This-given a short period of this study-is an "evidence of grasp of practice or oppositional voice," which is key to meaning making, Ford (2012, p.214). The grasp of the central tenet of scientific practice of constructing and critique-by learners- relate directly to this study's sub-questions:

1. What is the nature of learners' arguments as they engage with peers in small groups?
2. What is the nature of learners' written (and displayed) arguments when reporting to the whole class?
3. What us nature of learners' arguments during whole class interaction?

In a collaborative discourse which Nussbaum (2008) defined as a "social process in which individuals work together to construct and critique arguments" about content, students not only take sides such as in the debate, but are flexible to make concessions(p.348). Following Nussbaum (2008) and Cavgnetto and Hand (2012), I used 'collaborative discourse' to precisely focus on learners' ability to construct explanation, and 'critical collaborative discourse' to refer to learners' adeptness in the use of "arguments, counterarguments, refutation to resolve their conflicting opinions" and hence communicate their understanding, Nussbaum (2008, p.349).

Refer to the verbatim whole class discussions of acid-base theories above.

Sense-making (understanding-building) and persuasion moves in learners' collaborative discourse.

Turn 2: Group 1's member pronounced their claim, of what is an acid according to Arrhenius acid-base theory. It is this discourse move that involves being engaged in sense-making of an idea which Berland and Reiser's (2010) analytical framework characterized as constructing a claim.

Turn 4: Was a direct question to group 1's version of Arrhenius' acid. The posed question although on the surface could be regarded as a seeking clarity question, it (question) prompted group 1's members to revise, attend to group 2's contention, and thus evaluate their Arrhenius' acid definition.

Driver et al. (2000) contend that the key role of discourse in conceptual change is not much to induce cognitive conflict, although that may still be important, but to provide students with an opportunity to reconstruct their knowledge (p.352). The question also encouraged the construction of a more elaborative explanation and reorganisation of their claim. According to Nussbaum (2008), reorganisation requires in-depth cognitive processing (p.352). *Turn 7* and *turn 8* attest to how counterarguments induce the need to defend one's claims, through the construction of an elaborate explanations of ideas. The afore-listed verbatim transcript of whole class guided discussion shows how collaborative discourses and argumentation afford learners to build understanding of ideas as well persuading peers of their understanding.

By engrossing learners in discussion and argumentation as tool or means of promoting 'reflection, meaning-making, grasp of practice and thinking about one's thought' skills (Brown et al. 1981, Ford 2006, and Kuhn 1998 respectively, I was able to infer learners' implicit arguments. That is, the exact meaning of scientific theory, principles and laws-drawing from Brown's et al. (1981)-are more comprehensible when one take into consideration the categorical organization inherent in the material. What evidence do I have for the inference I have just made? Throughout the acid-base theory the words "form, release, produce" were correctly rejected by the class in preference of the word "increases." There was no reason articulated, while insisting that the words "form/give hydrogen ions (H^+)" are unacceptable-until the teacher's prompt by the question: "where do these hydrogen ions come from?" rung the bell. (*Turn 17*). The inferred reasons could be simplified as follows: Chemistry generally gives meaning to the observable characteristics of matter in terms of microscopic composition. Instructional implication is that in order to help learners think about concepts in a scientific way, they must be taught the learning strategies as articulated by Brown et al. (1981). Learning Physics at the elementary level, entails the correct identification of formulae, mathematical manipulation of these formulae variable to show how the physical quantities involved in these formulae relate to each other. It further involves depiction of these physical quantities graphically. At the highest level of the discipline's intellectual demands, is the interpretation of variables qualitatively and quantitatively at explicitly stated qualifiers. Although there was quite a number of critiquing peers' version of theories, not a single question explicitly invoked a need to consider the highest level of disciplinary engagement. That is, the analysis of substances' inherent microscopic composition to explain why the acids ionizes in water to increase the concentration of hydrogen ions.

These learning strategies aimed at memorization, recall and retention of Physics knowledge is what Brown, Campione and Day (1981) termed categorization and elaboration. In their words:

Categorization as a strategy to enhance recall demands that any categorical organization inherent in the material be familiar to the learner and be used to design a plan for learning. Elaboration is a strategy whereby the learner imposes meaning or organization on material to render it more comprehensible (p.14).

Physics-electricity- lesson discussion

What the activity meant to achieve was for learners to first, define potential difference as energy transferred per unit positive charge-V=(W/E)/Q- as well as to point out that the assertion "the battery produces charges," was a misrepresentation and misinterpretation of the battery's role in an electrical circuit. Secondly, and crucial to thinking about these concepts was to provide an evidence illustrating that the definition of the concept 'potential difference' (as a theoretical construct) advances our understanding of the role of the battery in a circuit. To account for how the battery supplies energy to charges, it is typical within science discourses to refer to the processes occurring within the battery. Finally, as a strategy to foster their skills to produce a counterargument to strengthen their cases, learners were expected to show that the assertion "a battery produces charges" is a misrepresentation of the battery's role in an electrical circuit. An overarching goal of this activity was to afford learners an opportunity to practice the scientific skills 'constructing and critiquing' arguments.

4.4. Analysis and discussion of groups' written and displayed arguments

Simplified version of Toulmin's (1958) analytical framework was used to analyse learners' final arguments as reflected on their posters when reporting to the whole class. The structure of

Toulmin's (1958) argumentation model is about construction of "justificatory arguments," thus showing how argument's sentence by sentence justify conclusions (Neilsen, 2013). He proposed an ordered pattern, namely; data (an answer to "what have you got to go on?"), a claim, warrant (an answer to "how do you get [from data to claim?]"), backing (an answer to "but why do you think that the [warrant is justified]?), qualifier, and rebuttal (an answer to "[what are the] circumstances in which the general authority of the warrant would be set aside[?] (Neilsen, 2013). The simplified version of Toulmin's (1958) argument framework which was used in this study is Sampson and Gerbino's (2010). This analytical framework to appraise an argument structure consists of: Claim (data and claim conflated); Evidence (warrant), and Rationale (Backing or reasons showing why the evidence supports the claim).

Below is the final arguments of the three groups, refer to it to follow the discussion underneath the tabulated arguments:

Group1	Group 2	Group 3
Claim: Cell converts chemical energy into electrical energy. *Evidence:* Potential difference is work done to move a charge form a point of high potential to a point of low potential. *Rationale:* Electric field $E = \frac{F}{Q}$ is the region in space where a charge experiences an electrostatic force.	*Claim:* Potential difference is work done to move a charge form a point of high potential to a point of low potential. A voltmeter measures energy transferred per unit charge. *Evidence:* $V = \frac{W/E}{Q}$ Over some time-in use- the battery becomes "flat" because chemical reactions within it have reached equilibrium. *Rationale:* If the charges in the battery are over-used, the battery won't be able to measure energy transferred per unit charge.	*Claim:* Potential difference is work done to move a charge form a point of high potential to a point of low potential: $V = \frac{W/E}{Q}$. *Evidence:* A voltmeter measures energy transferred per unit charge. *Rationale:* A voltmeter measures the potential difference across the component.

Prior to the argumentation activity learners were explicitly taught how Physics-the discipline within which current electricity is subsumed- generally, encodes its conclusions in equations.

The transcript below (translated version) provides a glimpse into learners' discussions in search for an equation as a strategy to explain an idea of potential difference which is in line with Physicists' way of explaining ideas.

<u>G1BL1</u> denotes Group 1boy learner 1
1. **<u>G1BLI:</u>** "Guys we start with the potential difference. Our concept 1 will be potential difference, our equation is $V = \frac{W}{Q}$. We need to change our definition, so that it is easy for us to understand it, and then we must also get a fact to use as our alternative explanation, as well as concepts associated with potential difference.

This learner's statement reveal that, although learners are aware of equations as constructs devised to help recall and articulate Physics knowledge and its organization, they are unable to first, construct a coherent argument for an account of an official definition of potential difference and second, to illustrate how a popularly held misconception of an explanation associated with potential difference is a misrepresentation. The group's evidence for a claim that "a cell converts chemical energy into electrical energy," although it is distinct from a claim, it cannot be used as an evidence because it is an official definition of potential difference. The groups' evidence is certainly not a justification of a posited claim. A rationale supplied does not show how the evidence provided are plausible reasons in support of the claim. Their rationale speaks to how a battery keeps charges moving within a circuit. Their reasons for rejection of an erroneous statement on the role of a battery is based on the length of the statement and not on actual meaning of the statement. This reveals their inability to identify the error in the statement and attach meanings to concepts.

Five members group 2 is comprised of four boys with one of them with Physical Sciences' proficiency level of between 09-26% and the other three boys exhibiting a proficiency in Physical Sciences of between 31-41%, and one girl whose Physical Sciences' proficiency level is between 26-32%. One of the group's four boys are branded as progressed learners in terms of their Grade 10 overall results. This group's evidence for the claim could best be used as a rationale as it speaks to how the battery tend to lose its ability to provide energy to charges. It does not point out to the processes occurring within a battery that allow it to generate energy, which it transfers to the charges. The group exhibits its awareness and application of the "categorical organization inherent in material" through their use of formulae and attempts to relate formulae's physical quantities, Brown et al. (1981, p.14). There is no effort made to elaborate meanings inherent in the formulae and to correct an erroneous statement in terms of an emerging meaning from elaboration of material. The group's rationale is wrong and exhibits a misconception of the role of the battery and a misunderstanding of processes occurring inside it. The group's argument in terms of the Toulmin's (1958) model does not adequately justify its claim.

Five members group 3 is a girl-only group consisting of members whose Physical Sciences' proficiency level is between 10-33%. Two of this group's five girls are considered as progressed learners in respect of their previous grade's overall results. This group's evidence is not reasons in support of the claim posited, but a reiteration of the claim by specifying an instrument used to measure the potential difference. Its rationale and evidence are similar and it shows no attempt to correct an erroneous statement and use discipline way of knowing of imposing meanings to concepts.

Applying Toulmin's (1958) analytical framework to each group's argument pattern, the below inferred argument in response to Toulmin's (1958) prompts inherent in his argument's components would take the following dialogue form:

Group 1's poster dialogue form response to Toulmin's (1958) is as follows:

Toulmin (1958) (data): What have you got to go on?

Group 1 (claim): We have interpreted data to conclude that: 'a cell converts chemical energy into electrical energy'.

Toulmin (1958) (warrant): How do you get [from data to claim]?

Group 1 (evidence): Our conclusion (claim) is based on expert opinion in which potential difference in Physics has evolved to mean 'work done to move a charge from a point of high potential to a point of low potential.'

Toulmin (1958) (backing): But why do you think that the reason 'potential difference is work done to move a charge form a point of high potential to a point of low potential,' is adequate to conclude that 'cell converts chemical energy into electrical energy?'

Group 1 (rationale): Experts further argued that the difference in potential energy between the battery's terminals sets up an electric field. Scientists defined the electric field as: '$E = \frac{F}{Q}$ *is the region in space where a charge experiences an electrostatic force*.'

Although Group1 seems to have constructed an argument that plausibly illustrates "structural interrelations among different positions and reasons" of all groups, it however does not provide a solution to the task's problem of showing why the definition of potential difference is the best possible explanation.

Subjecting **Group 2**'s constructed argument to Toulmin's data, warrant, and backing questioning, the following responses emerge:

Group 2's poster dialogue form response to Toulmin's (1958) is as follows:

Response to data question: "We have this conclusion (claim) '*potential difference is work done to move a charge from a point of high potential to a point of low potential*'. **Response to the warrant question:** "We came to this conclusion because *over some time in use the battery becomes 'flat' because chemical reactions within it have reached equilibrium*". **Response to the backing question:** "*If the charges in the battery are over-used, the battery wouldn't be able to measure energy transferred per unit charge*". The group backing first, does not how their proclaimed evidence adequately supports their claim. The example will clarify this inability. Interpreting their response to the backing prompts, the following dialogue emerge:

Toulmin (1958): But why do you think that your reason '*over some time in use the battery becomes "flat" because chemical reactions within it have reached equilibrium*' is adequate to conclude that the '*potential difference is work done to move a charge form a point of high potential to a point of low potential?*'

Group 2 (backing statement): '*If the charges in the battery are over-used, the battery won't be able to measure energy transferred per unit charge.*' The group's response to Toulmi's (1958) backing prompt is implausible, thus unable to prove the credibility of their claim. Secondly, their rationale or reasoning is not informed by models, theories, and laws important in the discipline. Theirs, is a misconception associated with battery as a source of energy.

Considering **Group 3'**s response to Toulmin's (1958) analytical framework for arguments, the following argument was inferred:

Group 3's poster dialogue form response to Toulmin's (1958) is as follows:

Response to the data question is identical to Group 2's. **Group 3's response to the warrant question:** '*A voltmeter reading is an empirical evidence to our claim that the potential difference is work done to move charges*'. The dialogue form between Toulmin (1958) model and Group 3' backing is presented below to show learners' struggle with converting data to evidence.

Toulmin (1958): But why do you think that your reason 'a voltmeter measures energy transferred per unit charge' is adequate to conclude that the 'potential difference is work done to move a charge form a point of high potential to a point of low potential?'

Group 3 (backing statement): *A voltmeter measures the potential difference across the component*. This rationale repeats evidence given by substituting 'energy transferred per unit charge' with 'potential difference.'

All three groups' quality of their arguments situate at level 1 according to the teacher's guidelines -refer Appendix A.3. Table 1 in the appendix section-used in assessing these arguments. Learners' final arguments indicate inability to adequately justify their claims. It is the inability to explain phenomena using established scientific principles. The complex process of scientific argumentation is central to critical thinking. The instructional implication of this practice, is to explicitly teach learners the specific discipline learning strategies as well as encourage the consistent application of these application, as it is espoused by Brown (1997) namely, questioning, clarifying, summarizing and predicting. This is crucial towards the construction of a coherent argument because one is prone to correctly link several concepts if one has robust knowledge base on the subject on which one is to argue about. It is within the broad knowledge base that one is susceptible towards forging links, thus provide plausible reasons for holding a particular view over the other. Alternatively said, to justify knowledge claims adequately entails first, to make: "[the] distinction between an assertion and an external evidence bearing on it" and second, "[an] establishment of correspondence between assertion and evidence" Kuhn (1999, p.19). The inadequate critiquing of peers' concepts as listed under various argument structures, reveals learners inability to relate evidence to claim in a level espoused by Kuhn (1999). According to Kuhn (1999), central to thinking really well about issues-thinking about one's thoughts- is the ability to first, be aware of "the distinction between an assertion and an external evidence bearing on it" and second, "establishment of correspondences between assertions and evidence outstrips maintenance of distinction" (p.19).

These findings are unsurprising since research reveals that learners find it easy to articulate their claims, but usually struggle to align these claims to relevant evidence (cf. McNeill, 2008; Sampson and Clark, 2008). The second order intellectual demand-as identified by Kuhn (1999) - in terms of use of evidence, is at this introductory stage of 'arguing to learn' attainable through sustained practice of partaking in collaborative settings (Chinn and Clark, 2013).

4.5. What can be deduced about learner's conceptual understanding?

Learning Physics at the elementary level, entails the correct identification of formulae, mathematical manipulation of these formulae variable to show how the physical quantities involved in these formulae relate to each other. It further involves depiction of these physical quantities graphically. At the highest level of the discipline's intellectual demands, is the interpretation of variables qualitatively and quantitatively at explicitly stated qualifiers. All the above-mentioned disciplinary procedure are also embodied by scientific explanations.

As Osborne and collaborators (2012) have pointed out, referring to Ogborne (1988), "scientific explanation attempt to answer three questions: what we know (the ontological question), why it happens (the causal question), and how we know (the epistemic question)." The '*what-aspect*' of scientific explanation primarily addresses the *identity* feature of an idea or concept. It sets it apart from other ideas. It is an articulation that points out the various basic components of an idea that distinguishes it from other perceivable ideas. It separates an idea from myriad of other ideas, thus this identity aspect of an idea lends itself to the classification process. Classifying an idea on the basis of its identity is the first step and essential step in the understanding of how an idea situates itself amongst multiple ideas.

The '*how-aspect*' lends itself first, to the processes the constituent parts of the idea undergo when subjected to various external conditions. Secondly, it sheds light into how the idea manifest itself to the observer. This aspect of scientific explanation addresses how the external conditions affect individual parts of an idea's identified structures. The Physics' strategy-amongst others-in understanding an idea is normally to encode this relation cause (process) and effect (reaction to the cause) in an equation.

The '*why-aspect*' of a scientific explanation speaks to the reasons the idea appears in a manner in which it manifests itself to an observer. It is a feature of a scientific explanation that addresses how in relation and/or reaction to the imposed conditions the constituents parts of an idea manifest itself. It also delves into how these manifestations interact with the observer's sense organs and instrument of measuring. It is in Physics' nature to relate constructed formulae's variables, while specifying conditions under which these variables relationship apply.

The results of this study has the following instructional implication: enhanced learner participation that foster conceptual understanding requires the explicit teaching of learning strategies as well as consistent application thereof, alongside the enactment of the process of argumentation.

In light of learners' brief practice and encounter with argumentation and a fair strides they have shown towards justifying their claims, through the invocation of central disciplinary postulates, principles and laws, I conclude that with sustained practice learners can constructively engage with scientific ideas at a high level of abstraction.

4.6. Conclusion

All three groups satisfactorily coordinated various epistemic operations in constructing their arguments as a profound account of '*potential difference'* and '*Arrhenius theory of acids*'. "Epistemic operations involve referring to the context, past knowledge, data, general principles, defining problems, isolating important contributing variables, evaluating progress, etcetera" Brown and Palincsar (1986, p.22).

Group 1's argument although did not adequately address the task's problem, referred to the domain (Physics) specific way of using general principles as its rationale. Group 2's argument correctly identified and addressed the task's problem without using relevant principles to show that its evidence is indeed a justification of its claim. Group 3's argument is a typical example indication how learners struggle with transforming available data to justify their claims.

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Chapter 5: Conclusion

5.0. Introduction

In response to this study's broad question: *What is the nature of learner engagement after introduction after introduction to argumentation and how does it facilitate learner conceptual understanding?* The following hypothesis was advanced: Embedding learners in a dialogic discourse will help them to 'think about their thoughts'- to borrow Kuhn's (1989) phrase. It is in these types of contexts where:

1. Engel and Conant's (2002) four principles of fostering productive disciplinary find applicability.

2. Scientific duality mind-set of 'construct and critique' which is central to 'grasp of practice,' develops, Ford & Wango (2011).

3. Communities of learners are fostered "leading children to discover the deep principle of the domain and to develop flexible learning and inquiry strategies of wide applicability," Brown (1997, p.399).

This research question was explored in terms of three sub-questions as follows:

1. What is the nature of learner arguments as they engage with peers in small group?
2. What is the nature of learners' arguments when reporting to the whole class?
3. What is the nature of learner arguments during whole class interaction on the chemistry topic?

5.1 Summary of findings

5.1.1 Findings of emerging patterns of learner participation

Although progressed learners showed a high level of questioning in their groups, the nature of their questions was predominately about the argument structure and with very few questions probing for reasons, which is central to understanding as espoused by Ford & Wango's (2011). The challenge of posing thought-provoking questions was common to all groups, irrespective of how they are classified in terms of their previous grade's final marks, that is, "progressed," "at-risk" or "promoted" learner.

Progressed learners-focus of this study- benefited immensely from engaging with peers to solve the group's problem, since they normally withdraw from social interaction in the classroom. Engagement with the group's problem helped them to learn and practice the essential discipline-specific learning strategies of questioning, summarization and predicting as espoused by Brown (1997). This study's findings suggest that longitudinal studies of argumentation-based instructional strategy should be extended to include lower grades all the way to Grade 12.

5.1.2. Findings of learners' arguments in pursuit of consensus

The study showed quite a number of critiquing peers' version of theories, with limited number of questions that explicitly invoked a need to consider the highest level of disciplinary engagement. This is a positive finding since it indicates which aspect of instructional strategies need to be implemented, namely, sustained argumentation practice in classrooms to help promote high order thinking amongst learners.

Central to thinking really well about issues is thinking about one's thoughts or the ability to first, be aware of "the distinction between an assertion and an external evidence bearing on it" and second, "establishment of correspondences between assertions and evidence outstrips maintenance of distinction" Kuhn (1999, p.19). The findings of my study show emerging learner argumentation skills. Learners began to question each other even though they could not yet make the distinction between an idea and the evidence bearing on the idea. The second order intellectual demand in terms of use of evidence has not yet been realised for this group and would hopefully be the focus of my future research.

5.1.3. Deduction of learners' conceptual understanding in terms of the quality of their arguments

On the basis of presence of some misconceptions about central disciplinary postulates, principles and laws on learners' charts that were presented to peers, as well as the inability to relate evidence to a claim, I conclude that learners have difficulty in selection, use of available data to adequately substantiate their claims. With sustained practice on analysing data to draw conclusions learners can make well substantiated claims.

5.2. Recommendations

The instructional implication of this practice of allowing learners to be in a dialogic discourse with peers, content and experts in explaining meaning of concepts entails "picking up another person's utterance (Bakthin, 1986)-that is, the scientific idea-from its time, context, and purpose, and using it in one's own situation, to advance one's own feeling of understanding" Ford and& Wango (2011, p.371). The teachers' role is to include a list of questions that requires learners to give causal answers.

The instructional implication of this practice is to first, explicitly teach learners the specific discipline learning strategies as well as encourage the consistent application of these application, as it is espoused by Brown (1997) namely, questioning, clarifying, summarizing and predicting. This is crucial towards the construction of a coherent argument because one is prone to correctly link several concepts if one has robust knowledge base on the subject on which one is to argue about. It is within the broad knowledge base that one is susceptible towards forging links, thus provide plausible reasons for holding a particular view over the other. Alternatively said, to justify knowledge claims adequately entails first, to make: "[the] distinction between an assertion and an external evidence bearing on it" and second, "[an] establishment of correspondence between assertion and evidence" Kuhn (1999, p.19)

5.3 Implication

The prerequisite towards conceptual understanding is to know the learning strategies applicable to the discipline. The strong and healthy understanding of ideas is essential towards articulating these ideas to peers and therefore persuade them to your version of an idea. As Ford (2011) stated to understand the idea is to be in dialogue with it.

Chapter 6 References

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Appendix A

A.1.: Resource to be used by learners in arguments construction and critique

Protocol Number: 2017ECE021M

School Name: Mabuwe Secondary School

Grade 11

Physical Sciences

Teacher and Researcher: E.M. Rikhotso

Week Ending: 25 August 2017

Scientific Practice 'A habit of the Mind' or 'A Particular Way of Doing Things'

Scientific Practice is a *Complex Process* that can be mastered through Practice using *Argumentation as a Tool* to make sense of concepts. It is a Social Practice where Individuals contribution is to *Critique (find fault with) Claims* to Refine Them.

Introduction

The activities/processes scientists perform in constructing knowledge we learn is generally referred to as *Scientific Practice*. It is a process of giving meaning to an **idea/claim/descriptive statement/conclusion/an answer to an investigative question.**

A **claim** should be *supported/shown to have meaning* by **evidence.** An evidence-reasons given for a claim- is interpreted/clearly explained **data/observable facts/measurements** that shows that the claim is *true/believable and makes sense.*

Rationale/Set of Reasons "are statements that explain *how evidence supports the claim* and *why the evidence should count as evidence*" Sampson & Gerbino (2010; p.428) [Emphasis not in original text]. These are statement that show how proposed knowledge agrees with established scientific theories and laws as well as how it improves our understanding of concepts studied.

Finding error with/Critique of the claim by peers is a very important practice of scientists. It is the process of creating possible statements/situation that shows that the idea put forward is not true. It is a process the constructor of a claim anticipates *through carefully:*

1. *Controlling of variables;*
2. *Collecting data and*
3. *Analyzing/Interpreting Data* during an Investigation.

Critique is a process of refining claims. It is a final test which a claim should pass for it to be classified as Scientific Knowledge.

To make meaning of a scientific knowledge we need to examine:

1. Evidence and rationale brought forward as its support.
2. Critique it passed.

This background information should always be referred to in groups you are assigned to every time a concept is discussed in the classroom.

A.2.: Classroom Dialogue Prompts 1

Protocol Number: 2017ECE021M

Day 1

Grade 11

03 October 2017

In this recorded lessons I am framing- linking and expressing our classroom activities with scientists' practices. Said differently, we review a unit on current electricity which was done and assessed. We express this unit to allow a dialogue within a group and across groups on key electricity concepts as framed by scientists. It is through expressing our understanding socially that we individually fully understand concepts, after peers refine –critique- our understanding by pointing at flaws or errors in it.

Instruction to groups

- In this session we will be reviewing DC current electricity's key concepts. This process is done in an effort to *refine* our individual understanding through being in a dialogue with peers.
- Scientists are always seeking fault with peers' claims to improve the understanding of concepts.
- Our refinement-process will be done through the comparison of groups' choices and reasons given for making those choices from possible explanation of current electricity's concepts.

Concept 1

Concept or Idea	Equation	Definition	Source	Alternative explanation	Associated concepts or ideas
Potential difference	$V = \frac{W/E}{Q}$	Energy transferred per unit charge.	Battery	A battery supplies or produces charges that are simultaneously pushed and pulled at its terminals.	➢ Current. ➢ Ohm's law.

Activity

1.1. In your groups make a choice – **on a poster**- of what is a *refined or better* explanation of the concept of *potential difference*.

1.2. Give *reasons* for your preferred *choice* and *rejection* of an alternative explanation.

1.3. In your explanation while *arguing for your choice* and *against an alternative explanation*, clearly state your *claim, evidence and rationale* as follows:

Our claim is …	Our evidence is …
Our rationale is…	Remember the rationale is the reasons showing how the evidence supports the claim.

Useful resource cards or evidence cards:

A battery converts chemical energy into electrical energy.	A battery sets up an electric field –when connected to the external components of the circuit.	An electric field is the region in space where a charge experiences an electrostatic force. $E = \frac{F}{Q}$	Generally, particles are charged through friction.

[Type here]

Over some time-in use- the battery becomes "flat" because chemical reactions within it have reached equilibrium.	A voltmeter has a high resistance and is always connected in parallel across the component of the circuit.	A voltmeter's high resistance does not allow charges to pass through it.	A voltmeter measures energy transferred per unit charge.

A.3.: Teacher's guidelines to grade learners' engagement with content and the incorporation of content material in the argument structure template

Table 1

Grading in terms of engagement with material	Extent of engagement with material in light of argument structure provided	Example from Electrical Current-Physics-section	Example from Acid-Bases-Chemistry-section
Level 1	**Evaluation of leaners' Evidence** ➢ Participants follow an activity prompts of constructing an argument, that is, they explicitly delineate *Claim, Evidence, and Rationale* from Sampson & Gerbino's (2010) perspective of an argument structure. ➢ The Evidence used is distinct from Claim-Kuhn (2003)-but does not relate to the	*Claim:* $V = \frac{E}{Q}$ *Evidence:* Voltmeter measures energy transferred per unit positive charge *Rationale:* Will therefore be premised on the evidence that does not relate to the claim, albeit distinct from it.	*Claim:* Arrhenius acids release $H^{+}(aq)$ in a solution

	underlying postulate of a claim.		
Level 2	**Evaluation of learners' Rationale** ➢ Attains level 1 above, and in additions shows awareness and a deliberate application of "categorical organization inherent in the material [or discipline]" in provision of evidence, Brown et al. (1981, p.14).	*Claim:* $V = \frac{E}{Q}$ *Evidence:* Battery converts chemical energy into electrical energy, hence sets up an electric field$E = \frac{F}{Q}$. Use of equation as used by Physicists without interpretation of the equation.	*Claim:* Arrhenius theory releases-and does not produce-hydrogen ions in a solution. Or, Arrhenius acid releases hydrated hydrogen ions in a solution. *Evidence:* Arrhenius acid contain hydrogen as part of the molecule.$HA \rightarrow H^{+}(aq) + A^{-}(aq)$ Or, $HA + H_2O \rightarrow H_3O^{+}(aq) + A^{-}(aq)$
Level 3	**Evaluation of strength of learners' arguments** ➢ Attains level 1 and level 2, and in addition impose meaning to evidence-elaboration-whether in an equation form or not in an effort to persuade peers, thus expose as the shortcomings of an alternative explanation	$V = \frac{E}{Q}$ $12V = 12J.C^{-1}$ The battery transfers 12J of energy per 1C of a charge in a circuit. $I = \frac{Q}{\Delta t}$ $6A = 6C.s^{-1}$ 6A means 6C of charges passes a point in a circuit in 1s	➢ The inclusion of hydrated speaks to water dissolving an acid and separating $H^{+}(aq)$ conspicuous, thus their presence in solution, assuming a basic distinguishing characteristics of Arrhenius acids. ➢ The idea of

			'releasing of hydrogen ions' of Arrhenius acids in water, constricts acids to have hydrogen atom as part of their formulae, and is pointed out as the theory's shortcoming.

Evaluation of Learners' Reports Framework

Claim: Potential difference is energy transferred per unit positive charge. In an equation form: $V = \frac{E}{Q}$; where V denotes potential difference in volts V; (E) is energy transferred in Joules (J); Q denotes a charge in Coulombs (C). Note the epistemic practice of encoding an idea or construct in an equation as a compact representation of an idea.

Evidence: Chemical reaction occurring within the battery are sources of energy. A Battery converts chemical energy into electrical energy. This idea-of energy conversion inside the battery- is a plausible account of why over some time-in use or in a shelf- the battery becomes "flat" because chemical reactions within the battery have reached equilibrium. This a *rationale* for an evidence that chemical reactions occur inside the battery and are sources of energy that is transferred to the charges.

Rationale 2: When a battery is part of the circuit it sets up an electric field throughout the circuit. An electric field $E = \frac{F}{Q}$ is a region in space in which a charge experience an electrostatic force.

Rebuttal of an assertion "batteries produce positive charges that are pumped and pulled at positive and negative terminals respectively" can be in conceptualizing a battery as a supplier of energy to charges which are a constituent part of matter.

Rational 3: The idea that charges are a constituent part of matter explains why there is no time-lag to detect charges by an ammeter placed at appoint from the battery.

Elaboration: Imposition of meaning to the concept of potential difference and the flow of charges-current- in a circuit is achieved by the interpretation of voltmeter and ammeter readings. 12V means a battery transfers 12J of electrical energy per 1C of positive charges, whereas 3A means 3C of positive charges passes a cross-section of a conductor per second-in one second.

A.4.: Transcription of Whole Class Discussion of Acids-Base Theories

Protocol Number: 2017ECE021M

Grade	Date	Lesson's Topic	Detail of Activity
11	23/10/2017	Refinement of Acids-Base Theories' Concepts	Explanation of Acid-Base Concepts

In this –teacher led-whole class discussion learners are required to present their group's definition of Arrhenius acid-base theory and critique other groups' definitions.

Abbreviations: G1, G2 and G3 denotes group 1, group2 and group 3 respectively. ML1, FL1, ML2 and FL2 denotes Male learner1, Female learner 1, Male learner 2 and Female learner2 respectively. G1BL1, G1GL1, G2BL1, G2GL1, G3BL1 and G3GL1 represent Group's 1 boy learner 1; Group's 1 girl learner 1; Group's 2 boy learner 1; Group's 2 girl learner 1; Group's 3 boy learner 1 and Group's 3 girl learner 1 respectively.

1. **Teacher:** What is the group's understanding of Arrhenius theory and [inaudible]?
2. **G1GL1:** Sir akere re tlo ba three [inaudible] an acid is a substance that dissolves in water to give hydrogen ions (H^+_{aq}) and a base is a substance that dissolves in water to give hydro.. hydroxyl ions (OH^-_{aq}).
3. **Teacher:** But there was a question from group ke group mang eo? Group 2. What was your concern about their definition?
4. **G2GL1:** Yes sir, I was asking what do they mean when they say an acid [inaudible]?
5. **G1GL1:** Sir we never agreed, azang re agree.
6. **Teacher:** You never presented [inaudible].
7. **G1GL1:** Let's put it in a different way.
8. **G1BL1:** Ya sir ke kopa ho e bea straight. An acid is a substance that increases the

concentration…

9. **Teacher:** Not the solution?
10. **G1BL1:** Eya concentration.
11. **Teacher:** According to group1 ee, they say 'according to Arrhenius theory", so they say according to group 1, I'll write group1, they say 'an acid is a substance that increases the concentration of hydrogen ions (H_{aq}^{+}) in a solution.

[**Teacher writes Group 1's definition on the chalkboard and labels it 'Group1'**] Now how? You now say an acid is a substance that increases the concentration of hydrogen ions in a solution. And precisely if we go to group 2's question akere? In trying to refine it, they picked up the mistake, the initial definition where now, an acid was according to them- according to their presenter- an acid is a substance that increases the solutions of hydrogen ions akere? Is it how you said it initially, is it how you will define Arrhenius theory group 2?

12. **G2GL1*:** Sir according to our group, we'd define it as a substance that dissolves in water to form hydrogen ions, like [inaudible] in the presence of water. According to us, during that reaction hydrogen ions will separate [inaudible] and [inaudible] positive side of water and hydrogen ion on the negative side of water, eya.
13. **Teacher:** Ee, ya is it your understanding? We can show that in an equation. Other group?
14. **G1BL1:** Ya nna sir, from Arrhenius [inaudible] an acid and base *it does not form [inaudible] in a solution*. *Ke ena mistake wagago [inaudible]*.
15. **Teacher:** So are you saying we need to be very precise, careful about what we say? An acid is a substance that doesn't form hydrogen ions, it just increases the concentration of hydrogen ions. What is wrong when group ena, I say it forms? This group, group 2 they were corrected akere, ba itse an acid is a substance that forms hydrogen ions in a solution. Group 1 objects to that to say no.. to increase what?
16. **G1BL1:** Increases hydrogen ions in a solution.
17. **Teacher**: Where do these hydrogen ions come from?
18. **G1BL1:** Acid etlo forma, etlo react le aqueous solution. In that aqueous solution e nale hydrogen. So ena e tlo kena at least, etlo increase hydrogen ions in a solution, e ka se iforme, e di thotse dile teng moo.

19. **Teacher:** Okay, that is why you say nthwena, it increases the concentration of hydrogen ions in a solution? The number of moles of hydrogen ions per unit volume? And now how will you show it in a formula, in an equation? In an equation you can say, there is an acid general formula:

$$HA_{aq} + H_2O(l) \rightarrow H_3O^+_{aq} + H^-_{aq}$$

Do you agree, will it? So you do not say it 'forms' but 'increases' the concentrations of it, or can you say release? How about release? So they release hydrogen ions, but they do not form them because they already got them. According to Arrhenius acids, Arrhenius acids must contain Hydrogen. So that is one of the shortcoming ya eng? Ya Arrhenius theory. It says … 'a substance that releases hydrogen ions' and 'substance that increases hydrogen ions is a solution.' I agree with that, so we have refined our definition. Other group?

20. **G3GL1*:** An acid is a substance that produces hydrated hydrogen ions in an aqueous solution1.
21. **Teacher:** Hydrated. We've got in another [inaudible]. They say it produces hydrated. I'll write it group 2's on the board. Ee reile rae correcta. Should we write it on the board or should we leave it out?
22. **Part of the class:** Leave it out.
23. **G2BL1:** Sir an acid is a releases hydrated hydrogen ions in an aqueous solution. Acid sir [inaudible].
24. **Teacher:** You object, where?
25. **G2BL1:** Produces.
26. **Teacher:** What is wrong ka produces? We stick to releases? Group 4 what is your input?
27. **G4BL1:** [inaudible].
28. **Teacher:** the definition is more correct-they release hydrogen ions, they are hydrated and attach themselves to form hydronium ions.
29. **Teacher:** So an acid is a substance that, according to Arrhenius that releases hydrated hydrogen ions in an aqueous solution. Now I have a problem ka hydrated. What do you mean ka hydrated [inaudible], no the term hydrated. Ooh! Gona le input.
30. **G4BL1:** [Inaudible] substance basically means that gore sir that substance is surrounded by hydrogen [inaudible]

31. **<u>Part of the class:</u>** Water
32. **<u>Teacher:</u>** That definition is more correct ka gore these hydrogen ions released become hydrated or surrounded by water molecules and then form hydronium ions. So it is like acids release hydronium ions because hydrogen ions attach themselves to water. I think we have exhausted Arrhenius theory, now how do we go to the representation of it in an equation form. Wa bona ena this one, when we say hydrated then we must include water molecules in our equation ok. What about [inaudible] any other definition we must take?
33. **<u>Part of the class:</u>** E kaya group 4
34. **<u>Teacher:</u>** Group 4 please.
35. **<u>G4BL1:</u>** [Inaudible]
36. **<u>Teacher:</u>** How many minutes?
37. **<u>G4BL1:</u>** Like definition tsei two Sir.
38. **<u>Teacher:</u>** Which one do you take as the most, better definition?
39. **<u>G4BL1:</u>** Di lei two Sir.
40. **<u>Teacher:</u>** Lets hear..
41. **<u>G4BL1:</u>** Ya boi one ke gore, according to Arrhenius theory eh if an acid is reacted with water, Sir it releases hydrogen ions in water. It gives hydrogen ions. Ya boi two, according to Arrhenius theory an acid will release hydrogen ions in a solution with water.
42. **<u>Teacher:</u>** It is a question of I don't know what you think.
43. **<u>Part of the class:</u>** They are playing with words, they are saying ntho ei one.
44. **<u>Teacher:</u>** You do not agree with what they are saying?
45. **<u>Part of the class:</u>** Yes.
46. **<u>G4BL1:</u>** Re spanise equation?
47. **<u>Teacher:</u>** Go nale input. People lets hear the input.
48. **<u>G4BL1</u>**: Sir ha gona mo modi grouping kaofeela according to Arrhenius theory, ha gona motho oi one o builеng ka base.
49. **<u>Part of the Class:</u>** [disagrees] Ha re so fitlhe ko di-base, re bueleng ka base. [Inaudible] base gona le base, gona le acid [inaudible]. Ko exams ha bare efa definition of Arrhenius theory [inaudible].

[Type here]

50. **Teacher:** They will say, that is why we need to be more specific to say Arrhenius acid and Arrhenius base. Now in an exam they will say: 'what is an acid according to Arrhenius or what is a base according to Arrhenius theory.

51. **Part of the class:** Yes Sir [inaudible] o buile gore if it forms [inaudible] something e tlo forma hydronium.

52. **Teacher:** So you you say a base is the opposite of that one?

53. **Part of the class:** Yes, yes e bile sa bua something.

54. **Teacher:** But I should say so far se re definile acid. So how do you remember? Group 1 was very much precise ka 'releases' they don't want 'produces,' so we stick to release.

55. **Part of the class:** So we must write release.

56. **Teacher**: Haah! Ya lona e different group?

57. **Part of the class:** Group 5

58. **Teacher:** Ok! Let's hear group 5's.

59. **G5BL1:** An acid is a substance that releases hydrogen ion in a solution.

60. **Teacher**: So it's the same.

A.5.: Below is the continuation of un-tabulated group 1 transcript

59**. G1BL1:** "Guys give reasons for your preferred choice and the rejection of an alternative explanation."

60. **G1BL2:** "Why re reject an alternative explanation?" **Translation:** [What are the reasons for the rejection of an alternative explanation?]

61**. G1BL1:** "Why re reject an alternative explanation?" **Translation:** [What are the reason for the rejection of an alternative explanation?]

62**. G1GL2***: "E kae alternative explanation? E kae?" **Translation**: [Where is the alternative explanation? Where is it?]

63. **G1BL1:** "Ena, why le reject alternative explanation le choose engwe?" **Translation**: [What are the reason for the rejection of an alternative explanation and the adoption of another explanation?]

64. **G1GL2***: "Re choose the other one?" **Translation**: [[Reasons] for choosing the other one?]

65. **G1GL4:** “Ke yee!” **Translation**: [Here it is.]

66. **G1BL1**: “Obvious, re tlo ngwala the other one that we came up with.” **Translation**: [It is obvious that we need to write down the one we came up with.]

67. **G1BL1**: “Ke ye re ka se ngole like tshwanetse re ngole di-reasons pele.” **Translation**: [Here it is, but we need to write down the reasons first.]

68. **G1GL2***: “Guys noo!”

69. **G1GL1***: “Chemical energy is converted to electrical energy.”

70. **G1GL2***: “Ha ke understandi hore ke kgone ho argue hantle.” **Translation**: [I do not understand. I need to understand to argue effectively.]

71. **G1GL1***: “Ke ye 1.3[from handout instructions]” **Translation**: Here is 1.3 from the handout instruction].

72. **G1GL3***: “In your explanation while arguing for your choice and against an alternative explanation, clearly state your claim, evidence and rationale as follows.”

73. **G1GL1***: “Ba re file the evidence cards and re choose from tsona.” **Translation**: [We are given evidence cards to choose from.]

74. **G1BL1**: “Guys re nale 45minutes.” **Translation**: [Guys we have 45 minutes to finalize [our argument].]

75. **G1BL2**: “Re nale bo kae?” **Translation**: [How much time do we have?]

76. **G1GL1***: “Ke e Claim ya rona. Re tlo nka e.” **Translation**: [Here is our claim, we will take this one.]

77. **G1BL2**: “Keng wena?” **Translation**: [What wrong with you?]

78. **G1BL1**: “Ya o bua ‘waar’[truth].” **Translation**: [Yes, she is telling the truth.]

79. **G1GL1***: “Akere e ke Claim, ke Rationale ke eng ee?.” **Translation**: This is a claim and this is the rationale, okay? What is this?].

80. **G1BL2**: "E measure[riwa] ka voltmeter ne?" **Translation:** We use a voltmeter to measure it, okay.

81. **G1GL1***: "Ke claim, ke evidence." **Translation**: This the claim and this is the evidence.

82. **G1GL2***: "Ke claim." **Translation**: [This is the claim.]

83. **G1BL1**: "Ke claim ya rona." **Translation**: [It is our claim.]

84. **G1BL2**: "Evidence ke e, ke tse tsei two." **Translation**: [Here is an evidence, we have two of them.

85. **G1GL3***: "Rationale? Tse tse ding? Tse?' **Translation**: [What about rationale, and other [argument components]? What are these?]

86. **G1BL1**: "Sheba. Sheba, in a circuit charges move from a point of high potential to a point of low potential, and electrical energy is changed to other forms of energy. A battery sets up an electric field-when connected to the external components of the circuit. Sets up an electric field." **Translation**: [Look, look, in a circuit charges move from a point of high potential to a point of low potential, and electrical energy is changed to other forms of energy. A battery sets up an electric field-when connected to the external components of the circuit. Sets up an electric field].

87. **G1GL1***: "E ke eng, E ke eng?" **Translation**: [What is this, and what is this?]

88. **G1BL2**: "Hee wena, re tlhalosa circuit le kamo." **Translation**: [Hey! Here we are supposed to explain the current.]

89. **G1GL1***: "Re ka nka ee? Nna ke thlakatlhakane." **Translation**: [Can we take this? I am confused.]

90. **G1BL1**: "Sheba, mamelang, mamelang nna. Ke kopa le mameleng, wa bona 1.1. In your groups make a choice – on a poster- of what is a refined or better explanation of the concept potential difference." **Translation**: [Look, listen, listen at me. Please listen at what I am about say. Consider instruction 1.1: In your groups make a choice – on a poster- of what is a refined or better explanation of the concept potential difference.]

91. **G1GL3***: 'Sei yenzile mos." **Translation**: [We have already done this.]

92. **G1BL1**: "Re entse." **Translation**: [We have done it.]

93. **G1BL2**: “Mmm” **Translation**: [okay.]

94. **G1BL1**: “Give reasons for your preferred choice and rejection of an alternative explanation. Ee ha re so e etse. But you guys can come up with your own reasons.” **Translation:** Give reasons for your preferred choice and rejection of an alternative explanation. We have not done this one, but you guys can come up with your own reasons

95. **G1GL1*** and **G1GL2*** speak simultaneously and are [inaudible]

96. **G1BL1**: “Ke e reason. Give a better understanding. O feditse. Re feditse 1.1 le 1.2. Guys re feditse ka yona. Our claim, our evidence is that. [Interrupted].” **Translation**: [Here is the reason. Give a better understanding. You are done. We are done with 1.1 and 1.2. Guys we are done with them. Our claim, our evidence is that. [Interrupted]].

97. **G1GL3***: “I Claim yethu is: “A battery converts chemical energy to electrical energy?” **Translation**: [Our claim is: “A battery converts chemical energy to electrical energy?]

98. **G1GL1***: “Evidence ke eng?” **Translation**: [What is the evidence?]

99. **G1BL1**: “No. Evidence ke: ‘A battery converts chemical energy to electrical energy.’ Ke yona ya number 1.” **Translation**: [No evidence is: ‘A battery converts chemical energy to electrical energy.’ That is for number 1].

100. **G1GL2***: “Ke yona evidence?” **Translation**: [Is that the evidence?]

101: **G1BL2**: “Hey!”

102. **G1GL3***: “He evidence le?” **Translation**: [Is that the evidence?]

103. **G1GL1***: “A claim is what you say akere?” **Translation**: [A claim is what you assert, okay?]

104. **G1BL1**: “Mmm” **Translation**: [Yes].

105. **G1GL2***: “Hase yona ee?” **Translation**: [Is this not the one?].

106. **G1GL1***: “Ke claim ena akere [inaudible] from a high to low?” **Translation**: [This is the claim [inaudible] from high to low?].

107. **G1BL1**: “Like from a high to a low, it’s obvious if a cell converts chemical energy into electrical energy. E ke claim ya rona.” **Translation**: [Like from a high to a low, it’s obvious if a cell converts chemical energy into electrical energy. That is our claim].

108. **G1GL1***: “And then evidence ya rona?” **Translation**: [And then what will be our evidence?].

109. **G1BL1**: “Re chooza from mo. Ke evidence.” **Translation**: [We choose from here. That is evidence.].

110. **G1GL2***: “Ha se yona ee?” **Translation**: [Is this not the one?].

111. **G1GL1***: “Ya rona ne re entse eng? Ya rona ne re entse eng?” **Translation**: [What was our initial evidence?].

112. **G1BL2**: “Wena o complicata dilo mos. Ke yona! Ke yona evidence ena, ke yona. **Translation**: [You complicate matters. This is it! This is our evidence].

113. **G1GL3***: O ya bona le [inaudible] you’re de..defining it. **Translation:** [Look [inaudible] now you are defining it].

114. **G1BL2**: It can be evidence and claim ka nako ei one, bona… Our claim is…. Our evidence is… Our rationale is….**Translation**: [It can serve as both a claim and an evidence].

115. **G1BL1**: [Calling out G1GL1’s name twice] Sheba table, o sheba dievidence cards. Claim ke ee. Ke claim ena, ke evidence ena, ke rationale. E ke, remember the rationale. To the external of [inaudible all group members speak at the same time]. **Translation**: [Refer to the table, you search the evidence from evidence cards. This is the claim, evidence, [and] rationale. To the external of [inaudible all group members speak at the same time].

116. **G1GL3***: Why se nga enze e evidence yethu le?” **Translation**: [What are reasons for not choosing this one as our evidence?].

117. **G1GL1***: Nna ho nale ntho e ke sai understanding. Why lere claim e tloba evidence gape?” **Translation**: [There is something I do not understand. Why do you say a claim can also serve as an evidence?].

118. **G1BL1**: Hai re entse mistake. **Translation**: [No, we made a mistake.].

119. **G1GL3***: “Another mistake wena?” **Translation:** [You mean another mistake?].

120. **G1BL1**: He mona o ka se etse evidence ai lona [inaudible] evidence. **Translation**: [We cannot make it an evidence [inaudible].

121. **G1GL1***: Ke kopa o mpontshe yona mo pampering. **Translation**: [Will you please show me the evidence by pointing it on paper.]

122. **G1BL1**: Bua understanding ya lona. **Translation**: [Articulate your understanding.].

123. **G1GL1***: “Utlwa, ere ke thlalose. **Translation**: [Listen let me explain.].

124. **G1GL3***: “Mina ngithi e claim yethu he le! Why se nga sebenzisi as evidence? **Translation**: [I say, this one is a claim. Why can’t we regard it as an evidence as well?].

125. **G1GL1***: “Claim e ka sebe evidence hape nna kea hana.” **Translation**: [An idea cannot be a claim and an evidence. I disagree.].

126. **G1BL1**: “Re tswile moo guys. **Translation**: [Guys we are done with that.]

127. G1GL3*: “Ngithe e claim sengai sebenzisa [interrupted]. **Translation**: [I insist that a claim can be used (interrupted)].

128. **G1BL1**: [Calls G1GL3 twice by her real name], “understand claim, o understand evidence. Re buele claim. Re ka senke evidence re e etse claim.” **Translation:** [You need to understand what is meant by a claim, and an evidence. We specified our claim. We cannot make it an evidence as well.]

129. **G1GL3***: “Okay, mamelane. [Calling G1BL1 by his real name. (Interrupted)].” **Translation**: Okay listen here G1BL1 interrupted)].

130. **G1BL1**: “Sheba [calling G1GL3* by her real name], guys mamelang”. **Translation**: [Listen here G1GL3*]

131. **G1GL1***: “Guys ke batla re fete, wena o araba [Calling G1GL3* by her real name]. **Translation**: [Guys we need to go beyond the disagreement and you respond to G1GL3*].

132. **G1BL1**: “Guys mamelang, listen [inaudible] [calling G1GL3* by her real name] are mo cuteng. Evidence ya rona.” **Translation**: [Listen guys, [inaudible], avoid [calling G1GL3* by her real name]. This is our evidence.]

[Teacher gives instruction for groups to record their discussions conclusions on the poster for presentation session]

Group’s discussion while recording group’s argument structures on the poster

133. **G1BL1:** “A charge ne eee a potential difference is the work done to move a charge from a point of low potential to a high potential. Definition ya teng?” **Translation**: [A charge, no. A potential difference is work done to move a charge from a point of low potential to a high potential. This definition?]

134. **G1GL1***: “Potential Difference?”

135. **G1BL1**: “Eya ke ye, our rationale [inaudible] ke ye… an electric field, tshwanetse o gopole e-field ke eng ya gago. Moo ha re re it moves from a high to low point. Ho la re reng emm a charge has a high potential energy ne, a difference in potential energy at different points, this potential difference is equal to the work done to move a charge between A and B. Definition e reng? Definition e reng? Potential difference in an electric field is the work done to move a charge from point of lower potential to one of [inaudible] potential.”

136. **G1GL1***: “Is it possible, I’m not sure whether ee e kaba evidence or rationale.” **Translation**: [Is it possible, I’m not sure whether this can be used as an evidence or rationale.]

137. **G1BLI:** “Eya o right daar, kaofeela.” **Translation**: [Yes you’re correct, the whole sentence.]

138. **G1GL1***: “E le so, e le so? This is going. Eka ba evidence.” **Translation**: [The whole sentence as it is? This is going. It is an evidence.]