CHAPTER 1: INTRODUCTION

1.0 Introduction

The background to the study of this project is discussed in this chapter and it is generally from my interacting with CAPS and IQMS documents as well as the literature on teaching for conceptual understanding. My rationale to the study is all about my experience at my current school where I am teaching physical science with one female colleague. The chapter also contains the problem statement, which then leads to two research questions that underlines this study.

1.1 Background to the Study

In November 2011, South Africa's National Department of Basic Education produced an amended single curriculum document known as the Curriculum and Assessment Policy Statement (CAPS), for grade R – 12. The changes in the curriculum were implemented as from January 2012 (Department of Education (DoE), 2011). The CAPS document is a single comprehensive document for each subject that represents the National Curriculum Statement (NCS). Previously, the NCS comprised of the Learning Area/Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines for Grades R - 9 and Grades 10 – 12 (Department of Education (DoE), 1997). All these documents have now been merged into one: the CAPS.

CAPS seeks to engage learners in, "Active and critical learning: encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths" (Department of Education, 2011, p. 4). To some extent, the CAPS document is guided by a constructivist paradigm. This is evident in the policy document because it states that the curriculum aims to ensure that learners gain and apply knowledge and skills in ways that are meaningful to their own lives (DoE, 2011). This is in agreement with what the other scholars say, that teachers should foster learning by engaging students in building explanations of the world around them (Driver, Asoko, Leach, Mortimer, & Scott, 1994). The principle of active construction, as argued by Crawford, Krajcik, & Marx (1999) puts emphasis on the learner to actively build understanding upon previous knowledge. In the social-constructivist, perceptive learners are able to construct new knowledge through discourse and conversations situated in familiar contexts. One of the pedagogical approaches that seem to foster meaningful learning, is pedagogical link-making as articulated by (Scott, Mortimer & Ametller, 2011). I will explore the concept of pedagogical link-making in detail in Chapter two.

The assessment requirements of the CAPS document imply that teachers should engage learners in pedagogical link-making in their teaching and learning approaches. This is implied in the CAPS document stipulation that learners' progress is to be monitored daily through informal assessments such as observations, discussions, practical demonstrations, learner-teacher conferences and *informal classroom interactions* (my emphasis) (DoE, 2011). My understanding of informal tasks in this context means those assessment tasks that do not contribute towards the final mark or performance accorded to the learner at the end of term or year. The DoE (2011) argues that such assessment should be on-going and should not be treated as separate from learning activities taking place in the classroom. Thus the Department of Basic Education advocates meaningful learning.

According to Novak (2002), meaningful learning happens when a meticulous learner chooses to incorporate new knowledge to previously gained knowledge. Furthermore, Mortimer and Scott (2003) refer to such kind of learning as a meaning-making process. A meaning-making process can be viewed as a process where learners bring together their pre-existing points of views, along with those new ideas presented in the classroom talk (Mortimer & Scott, 2003). However, my view of meaning-making or meaningful learning is the ability of the learner to successfully link the previous knowledge (due to earlier instruction) with the new concepts (current classroom talk). If a conflict arises, the classroom talk must be able to resolve it, for the successful integration of new and existing ideas. Such an approach encourages learners to engage with each other and the teacher in a social platform (Scott *et al.*, 2011; Driver *et al.*, 1994).

The Department of Basic Education has an instrument called Integrated Quality Management System (IQMS) that consists of two programmes, which are designed for improving and monitoring performance of the education system. These are: Developmental Appraisal (DA) and Performance Measurement (PM). The purpose of the DA programme is to assess individual educators with an understanding of determining areas of strength and weakness, and to draw up programmes for individual development Department of Education (DoE), (2009). The IQMS instrument consists of two parts; lesson observation with 4 Performance Standards (PS) and 13 performance standards that evaluate aspects outside the classroom. The four performance standards of the lesson observation instrument consist of;

(i) Creation of a positive learning environment;
(ii) Knowledge of learning programmes and broad curriculum;
(iii) Learning activity: planning, preparation and presentation and
(iv) Assessment of learner in terms of achievement of outcomes (DoE, 2009).

The view of meaningful learning is also enforced in the creation of positive learning environment as a PS 1 (b) score 4 in the Integrated Quality Management System (IQMS). The IQMS states that “learners must participate actively and must be encouraged to exchange ideas with confidence and must be creative” (DoE, 2009). These standard performances are used to rate the educator’s performance during the classroom visits by a group of colleagues called the Development Support Group (DSG), who will be assessing a particular educator for appraisals. In order for a teacher to be rated with a maximum score of 4, he/she should be able to exhibit the following performance indicators;

(i) Learners are lively participants and contribute to knowledge creation and acquisition;
(ii) Educator creates a learning environment that recognizes the multiple intelligence of learners;

(iii) The lesson is carefully structured to allow for meaningful engagement; etc., (DoE, 2009).

For the educator to get a poor score of 1, the performance indicators will include among other things, the use of the lecture method. See Table 1 below for extracts of some of the performance indicators that can be linked to the pedagogical link-making approach from the IQMS document:

Table 1: Performance Standard Two: Knowledge of Curriculum and Learning Programmes

Criteria	Performance indicators	
	Score 1	Score 4
Knowledge of Learning Area (A)	Educator relies on the lecture mode of teaching exclusively	
Skills (B)		The educator is proficient with varying teaching modalities
Goal Setting (C)	-The lesson appears disjointed and does not build on previous knowledge -An educator uses appropriate strategies to extend knowledge of the learners	-Lessons are creatively linked to other sections of work -The educator is able to successfully link the lessons to the past and future learning experiences of the learners -The educator is also able to link learning across learning areas
Involvement in Learning Programmes (D)	Learners appear frustrated since they cannot build on previous knowledge , skills, attitudes and values	Learners are able to see the relevance of the lessons in relation to their own experiences and across learning areas

It is evident from the IQMS requirements that the Department of Basic Education discourages the use of the lecture method in South African classrooms. Rather it encourages teachers to explore and implement such pedagogies that foster conceptual understanding in learners. There is an array of pedagogical approaches that can be employed to accomplish the aims of the Department of Basic Education. This also includes pedagogical link-making approach.

The aim of this case study is to explore how one teacher, teaching the topic “Reactions in aqueous solutions”, could engage with their learners so as to pursue and implement the Department of Education's goals as stipulated in the IQMS document successfully. The topic "Reactions in aqueous solutions" under chemical change Grade 10 Physical Science learners, has been chosen due to its complexity to explain to learners as it is an abstract topic. Despite the fact that the topic has a number of practical activities, it remains an abstract concept to learners, especially when explaining what happens at the microscopic level (Kropman & Bakker, 2001). This study seeks to find out how the teacher makes use of pedagogical link-making approach to deliver meaningful lessons that enhance learner understanding of scientific concepts.

1.2 Rationale

In 2009 my school experienced a drastic drop in the Matric pass rate from 98 % to 60 % and it was mostly attributed to a high failure rate in science and mathematics. The science pass rate dropped from 86 % to 44 %. As a result, the school was placed in the category of underperforming schools in 2010. This led to the close monitoring of the school by the district and the provincial officials from the Department of Basic Education. During their visits, the district officials advocated for the use of teaching approaches that enhanced learners' comprehension against memorization as well as the implementation of IQMS stipulation that encourages quality teaching.

The management of the school in conjunction with the School Governing Board (SGB) considered possible reasons for the poor performance in 2009 and they developed a School Improvement Plan (SIP). The SIP addressed several issues that could have impacted on the poor results. These included:

- The learners who were doing Physical Science were encouraged to do Mathematics and not Mathematics Literacy;
- Improvement of teachers' pedagogical knowledge;
- Providing learnerships and finances of short courses for teachers
- Encouraging teachers to upgrade themselves in their subject matter knowledge.

Although the SIP addressed the whole school curriculum, the focus was mainly on Mathematics and Physical Science. In Physical Science, there were only two of us teaching the subject at Further Education Training (FET) level since 2007. We had never had any pass with a distinction in the subject at matric level. My classes had always achieved a higher pass rate than my colleague's. Our qualifications were also different; she had a Bachelor of Technology in Chemistry degree without a diploma in education and I had a Bachelor of Education degree majoring in Chemistry and a diploma in education majoring in Physics, Chemistry and Biology. I was enrolled for a Bachelor of Science Honours degree in Physical Science Education at the University of Witwatersrand. Hence, the school management team decided that she too would benefit from further studies and enrolled her for a Post Graduate Course at the University of South Africa (UNISA) in 2010.

In that same year, 2010, I taught the Grade 12 learners alone and the physical science pass rate rose from 44 % to 72 %. In 2011, after completing her studies she took over all the grade 12 classes and the pass rate rose from 72 % to 76 % with four distinctions. These were the first distinctions in science in the school since 1998. In 2012, I took all the grade 12 physical learners and the pass rate dropped to 74 %. It is this difference in our learners' performance as we both engaged in further studies that motivated this study. The table below shows the comparisons of percentage pass rates achieved between the two of us from 2007 to 2012. Note that from the year 2010, we are now alternating in teaching the Matric classes and not sharing as in the preceding years.

Table 2: Science pass rate from 2007 to 2012

Year	**Percentage Pass Rate (%)**	
	ME	**Colleague**
2007	80	70
2008	82	74
2009	50	39
2010	72	-
2011	-	76
2012	74	-

The improvement in her Matric results made me enquire from her the approaches she was now using. She told me that she was using the teaching methods she had learned in her Post Graduate's Certificate in Education (PGCE) course. One of the topics dealt with in her PGCE courses was “Teaching for conceptual change,” which is one of the aims of constructivism, to encourage educators to teach for understanding. I had also studied conceptual development in my course work for a Master’s degree in Science (MSc). However, what captured my attention most, was the pedagogical link-making and how it can enhance conceptual development. Therefore, I want to investigate how teachers incorporate and use it, to aid learner meaning-making by facilitating conceptual development or the evolution of learner understanding of concepts.

I then decided to investigate the concept of pedagogical link-making in my colleague’s practice as she taught the topic “Reactions in aqueous solutions.” The pedagogical link-making does not promote rote learning. The use of the pedagogical link-making approach may help teachers to teach for understanding and not to memorise answers given by the teacher. In their study on teachers’ competence in teaching reform-based science in large classes, Onwu and Stoffels (2005) found out that teachers do not consider learner input to homework answers but rather learners copy the correct answers in their notebooks given by the teachers. Pedagogical link-making does not disregard learner prior knowledge, instead learner prior knowledge is the basis of learner conceptual comprehension. Cook (2006) argues that prior knowledge influences conceptual learning, perception, and attention. The comprehension of concepts involves fusing the new and existing ideas and learners should be able to make links between new and pre-existing ideas (Scott *et al*., 2011). The other reason teachers resort to this old fashioned pedagogical approach, is because the syllabus is too long and the teacher does not have time to use other teaching and learning approaches that enhance science concept comprehension. My research will contribute to the understanding of the teaching on the topic “Reactions in aqueous solutions” with the use of pedagogical link-making, a teaching method that helps foster learner understanding instead of memorisation.

1.3 Problem Statement

The constructivist approach is grounded in the belief that learners' prior knowledge is the major factor in the teaching and learning outcomes of education (Piaget, 1964, 2003; Von Glasersfeld, 1991). Comprehension of concepts is achievable when learners are afforded an opportunity to develop new understanding with the teacher facilitating the process of learning rather than being a transmitter of knowledge (Chandrasegaran, Treagust, & Mocerino, 2008). The social constructivists further expand the comprehension of scientific concepts as involving a path from social plane to individual plane through the process of internalisation and not memorisation (Vygotsky, 1978). The internalisation process requires individual reconstruction of knowledge as the learners make sense of the prior knowledge with new ideas (Scott *et al.,* 2011). In my opinion and my few years of experience as a science teacher, a transmission teaching method does not promote the production of the use of social constructivism and science literate learners.

Teachers resort to the use of traditional methods with a belief that learners have little or no prior knowledge of the subject matter; hence they transmit knowledge for learners to have a set of good notes (Trigwell, Prosser, & Waterhouse, 1999). O'Loughlin (1992) argue that learners' meaning making occurs when learners are allowed to be active participants in developing personal constructed conceptual understanding of the scientific knowledge. Meaningful learning can be attained through pedagogical approaches that foster meaning making in the classroom. Hence Scott *et al.* (2011) asserted that if profound understanding of scientific conceptual knowledge is to be the outcome of teaching, learners should be subjected to the processes of link-making on the psychological plane.

As stipulated by the DoE in the CAPS document and IQMS training manual. Gabel (1999) asserts that chemistry concepts are abstract and are incomprehensible to learners without incorporating the use of analogies and models. Learners have labelled science as difficult because of the way science is taught. Johnstone (1991, pg. 76) does not squarely put the blame on the teacher in the difficulty of teaching and learning of science. Nevertheless, he acknowledges that teachers play a significant role in simplifying the teaching and learning of science when he argued that science;

> *".. is not being successfully transmitted. The faulty could lie in various places such as with the transmission system itself, the methods used and the facilities available or with the receivers (the learners) and the nature of their learning or even with the nature of the message itself. Almost certainly the problems lie with all three to varying degrees."*

Against this background, the question remains as to whether teachers incorporate the use of pedagogical link-making that foster meaningful learning as stipulated in the CAPS and IQMS documents in their day to day teaching. The purpose of this study is to assess how pedagogical link-making to support knowledge building can enhance learner comprehension in the teaching of an abstract chemistry topic such as 'Reactions in aqueous solutions'. Therefore, in this research, I intend to investigate if one particular teacher engages in meaningful teaching and learning through analysing and searching for pedagogical link-making elements in her teaching. The teacher will be observed teaching the grade 10 topic Reactions in aqueous solutions under Chemical Change.

The teacher (Mrs Foster) undertook a Postgraduate Certificate in Education (PGCE) with UNISA and one of her courses included The Educator as Mediator of Learning. This course encouraged teachers to be learner centred, to mediate learning and use teaching strategies and media that enhance learner comprehension in their teaching. After completion of her PGCE, there was a marked improvement in learner performance at the school. Pedagogical link-making is a learner centred approach which also encourages the use of various teaching strategies to enhance learner understanding. Even though the teacher did not do pedagogical link-making in her studies I intend to find out how elements of knowledge building are incorporated in her teaching strategies.

1.4 Research Questions

To what extent does the teacher use the pedagogical link-making approaches in the teaching of the Grade 10 topic of Reactions in aqueous solution under Chemical Change?

a. What approaches does the teacher use in the teaching of the topic Reactions in aqueous solutions?

b. How does the teacher use link-making for knowledge building approaches to promote learning in the classroom?

1.5 Conclusion

The following arguments were laid out in this chapter, that there was a significant change from my colleague's performance in her teaching probably due to her further studies in the teaching methodologies of the physical science subject. The Department of Basic Education through the CAPS and IQMS documents encourage the teaching for conceptual development in the South African schools. The question is, do teachers incorporate meaningful learning in the teaching of science concepts? The question leads me to undertake an investigation/case study of how one teacher incorporated the pedagogical link-making in the teaching of Reactions in aqueous solutions in the grade 10 topic of Chemical Change. The following chapter reviews literature on how the social constructivists believe that meaningful learning happens in the individual learner's physiological plane through the processes of socialisation and internalisation.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

In this chapter, the literature on how the social constructivist views the conceptual teaching of scientific concept, will be reviewed. Furthermore, I discuss the literature on how teaching approaches should be used as per the recommendations of social culturist in education. Lastly, the analytical framework which underlies this study, will be outlined in detail.

2.1 Socio-constructivism

This project is based on Vygotsky's theory of social-constructivism. Social constructivism is viewed by Hall (2007) as the building of knowledge based on the learner's previous knowledge and that knowledge is gained through interaction with the environment or society. The focal point of the theory advocates for the attainment of higher mental functions by the learner, first, through socialization (interpsychological plane) and then internalization of the acquired concepts or knowledge by the learner (intrapsychological plane). This is proposed by Vygotsky (1978) when he states that higher psychological structure emerges first, between people (interpsychological plane) and then later, inside the individual (intrapsychological plane). The learner's cognitive structures develop as a result of direct interaction with society, meaning that the learner is an active subject who acquires knowledge through direct involvement.

In the socio-cultural perspective, language and other semiotic mechanisms (symbols, text, and signs) are identified as tools that can be used to facilitate teaching and learning (Hall, 2007). Scott (1998) argues that tools such as language, are used on the interpsychological plane to improve and rehearse implications between individuals and are mediational revenues to individual cognition. Mediatory tools facilitate learning and this brings about cognitive development. Language is the most effective tool in the development of higher psychological functions. The mediatory tools are experienced on an interpsychological plane by the learner with the help of experts (teachers) and then on an intrapsychological plane as the learner start using the tools in doing activities (Hall, 2007; Wertsch, 1985). The use of the tools by the learner constitutes internalization; 'the internalization process is when the tools modifies and transform the learner's thought process as they begin to use these new tools to express their thinking' (Hall, 2007, p. 96). The learner develops higher mental functions as the result of internalisation, which is the result of the social process.

The cognitive development of a learner is not an outcome of direct involvement with an activity. On the contrary, it is the result of the interaction with the social environment by the individual (Wertsch, 1985). The development of learner understanding and meaning-making in the science classroom, is done through interaction of the interpsychological plane by the teacher and the student. The socio-constructivist identifies the teacher as a knowledgeable figure with a crucial role to play in mediating and passing on scientific concepts to the learner (Scott, 1998). This assertion is further supported by Bruner (1985) who argues that a human being cannot master and understand the conceptually organized symbolic world without the help and assistance of the others and Bruner identifies others as the world, in this case, be the classroom. Hence, the learner has to progress in the attainment of knowledge and cognitive development through interacting and collaborating with the teacher (expert) and the peers (world). Learning is not an individual matter but it is the acquisition of knowledge through social interactions within the social environment (Vygotsky, 1978).

The role of the teacher in social constructivism is that of assisting performance in the Zone of Proximal Development (ZPD). Vygotsky (1978) describes the Zone of Proximal Development as a distance between the actual developmental stage and the level of aptitude development. The actual development stage is that stage in which a learner can perform tasks without assistance from the teacher. In the classroom, such tasks as individual classwork and class tests can be used to ascertain the actual development stage of the learner. That is the learner can now use the semiotic mechanism tools that have been internalised in the intrapsychological plane as a result of previous socialisations on his/her own. Whereas the aptitude stage is that level in which the learner can perform tasks with assistance from the teacher or in collaboration with more competent peers. This is achieved through different platforms of discussions in the classroom, such as; teacher – whole class discussions; teacher – group discussions; teacher – learner discussion; learner pair and learner small group discussions. The ZPD describes the process by which the learner can develop cognitive structures with help from the teacher (Hall, 2007). The Zone of Proximal Development defines those mental functions which are immature but in the process of development, that is, they are in an embryonic stage and will only go through maturation through scaffolding learning from the most knowledgeable expert (teacher or peers) in society or classroom. The emphasis in ZPD is not the kind of assistance rendered to the learner by experts but it is centred on the learner’s cognitive development and maturation (Wertsch, 1985).

The role of the teacher in the ZPD is to know the actual stage of development of the learner(s). It implies that the teacher has to solicit the prior knowledge of the learners for him/her to know the actual stage of development of the learners. The teacher can access the learner’s previous knowledge through homework, question and answer, and classroom discussions. The activities which are inclined to social constructivism approach, must then be tailored to help the learner to gradually move from the actual stage to the potential stage of development. Vygotsky (1978) argues that the learner has to be subjected to activities within his ZPD. The learner has to be taught from known to unknown with the help from the experts. The teacher must choose those activities which will promote the implementation of the scaffolding approach. In the use of cooperative learning which is the backbone of the social-constructivism approach, the teacher can organize group learning activities with learners of mixed abilities to assist each other with learning. The task planned must not be over simplified but should be a little bit challenging to give learners problem solving skills. Scaffolding must be removed the moment the learner has reached the potential stage. The next task given to the learner, must be beyond the reached potential stage of development, as that signifies the extension of the proximal zone.

The sociocultural theory asserts that learning occurs within dynamic context, where construction of knowledge and individual learning is evident. Learning is focused on the development of cognitive skills and knowledge. Learning is initiated through pre-teaching to solicit prior knowledge and identify the actual stage of development to enable the teacher to provide support to mature learners' psychological tools in the ZPD (Hall, 2007). The role of the activities must increase the learner's roles and expertise in the use of tools and enhance the learner's involvement in the social interaction. The role of the teacher is to mediate learning through relationships and tool analysis to identify the ZPD. Crawford *et al.* (1998) argue that learners have diversified range of abilities which the teacher, as an expert can stretch the learners' capabilities through interacting with their outer boundaries of the learning zone. The social-culturist view classroom discourse as involving task sharing, exchanging, and critiquing ideas for the purpose of constructing knowledge. Hence learners must be involved in solving an authentic task in individual, groups, and the whole class to enhance socialisation in all dimensions.

2.2 Teaching and Learning Approaches

As an expert the teacher's task is to introduce learners to a certain way of knowing science concepts. Hence, the teacher assumes the position of an authority and more knowledgeable expert in the classroom discourse (Scott, 1998). In order to achieve meaningful learning, the teacher needs to recognise learners' ideas and engage with them in a socially dialogical environment. The arguments below will show that the classroom discourse lie on a continuum between being authoritative and dialogic functions but transmission or traditional approach is an undesirable practise in the classroom discourse.

The transmission approach undermines learners' capabilities as it does not offer learners opportunities to interrogate the authoritative voice of the teacher (O'Loughlin, 1992). In South Africa Onwu and Stoffels (2005) found out that teachers who practise the traditional approaches gave learners prescribed answers for the given homework questions rather than discussing learners' alternative answers. There is no learner engagement for meaning-making as is authoritative and dialogic discourses. Wertsch (1991) refers to this kind of approach as a traditional transmission model, which is univocal and authoritative with literal meaning and serves the purpose of mastering the meaning. It is also referred to as an information transmission/teacher focused approach and its goals is to transmit facts and skills but not on the relationship between them (Trigwell, Prosser, & Taylor , 1994).The transmission method assumes that learners do not need to be active in the teaching and learning process and treat learners as having little or no prior knowledge of the subject matter (Trigwell *et al*., 1999). Hence, teachers are discouraged to use this traditional approach, as it does not enhance meaningful learning. Scott, Mortimer, and Aguiar (2006) asserted that authoritative and dialogic approaches are the forms of discourses that perpetuate meaning-making for scientific conceptual development in science classroom.

The authoritative discourse can be described as that approach which perpetuates the scientific point of view and does not allow the bringing together and consideration of ideas (Scott *et al*., 2006). The purpose of the authoritative approach is to transmit the scientific point of view from the knowledgeable expert, the teacher to novice learners. Scott *et al*. (2006) argues that in this discourse the focus is on the scientific or school science point of view and any other view would not be tolerated or accepted. Authoritative discourse permits the gathering and examination of ideas and the teacher is concerned with the development of the school science point of view only, or the scientific story. If any questions are asked, which are contrary to the goal of the view of the school science, they are either ignored or reshaped by the teacher. Only ideas in line with the scientific view are adopted during the classroom discourse. The authoritative discourse is closed to other people's view point. In this particular case the learners' view point is not recognised but only those ideas that advance and support teacher's viewpoint, are accepted.

On the contrary, the authoritative view is necessary to a certain extent for scientific concepts are distinct. This argument is supported by Aguiar, Mortimer and Scott (2010) when they point out that science knowledge is constructed upon authoritative discourse that offers the structured view of the world and it is impossible to use scientific argumentative tools without the help of the teacher as an expect. The sociocultural school of thought further advocates for a discourse that provides learners with opportunities to develop new understanding with the teacher assuming a facilitator's role instead of a transmitter of scientific concepts (Chandrasegaran *et al*., 2008; Scott *et al*., 2006; Wertsch, 1991). That kind of discourse is referred to as dialogical discourse.

The dialogical discourse can be described as an approach that involves working on different ideas that have been brought together through exploration (Mortimer, 1998). Scott *et al.* (2006) came up with their own description of dialogic discourse: they argued that in dialogic discourse, the teacher is aware of the existence of other ideas from students and makes an effort to put them into perspective. This notion was first alluded to by Mortimer (1998): he described dialogic discourse as open to different perceptions, allowing teachers, and learners to become aware of any variances in points of view. In dialogic discourse, there is always an endeavour to recognise and appreciate the standpoint of others. Through dialogic discourse, the teacher attends to the students' points of view as well as to the school science view (Scott *et al*., 2006). Having defined the authoritative and dialogic discourses, it is clear that the two are totally opposite to each other and have adequately been differentiated in literature.

The dialogic discourse is open to diverse perspectives. That is, the teacher identifies and attempts to encompass the various ideas the learners present in the classroom discourse (Scott *et al*. 2006). Within the dialogic discourse, the scholars identify different levels of inter-animation of ideas; see Table 3 as adopted from Scott *et al*. (2006, p. 611):

Table 3: Dialogic discourse and inter-animation of ideas (adapted from Scott *et al.,* 2006)

DIALOGIC discourse	LOW level of inter-animation of ideas	Different ideas are made available on the social plane. For example: teacher lists student ideas on the board.
	HIGH level of inter-animation of ideas	Different ideas are explored and worked on by comparing, contrasting, developing.

The analytical framework of Scott (1998) draws distinction between authoritative and dialogue discourse, which characterises classroom discourse in terms of: (a) general features of the discourses; (b) the nature of teacher utterances and; (c) the nature of student utterances. Scott (1998, p. 48) argues that

> *"the authoritative–dialogic distinctions offers one means for distinguishing between situations where the teacher tends to approach this task from an authoritative stance (transmitting knowledge), and where the teacher adopts a more dialogue approach (encouraging exploration and development of meaning)".*

If the learners can develop meaning from the teacher's engagement, then meaningful involvement of learners in the classroom discourse will have been achieved. Scott *et al*. (2006) also did research on the meaning-making interactions in science lessons using authoritative and dialogue discourse as their analytical tool. Scott *et al.* (2006) grouped their analysis of the classroom interaction into three categories and each category was focused on a particular aspect of the classroom interaction. The categories were identified as (i) focus, (ii) approach and (iii) action. The three scholars centralised their study on the communicative approach where they analysed teacher interaction with learners to develop ideas in the science classroom. The communicative approaches are rolled into action through the use of specific arrangements of interaction and teacher involvement (Scott *et al*., 2006). One of their conclusions in their study was that development of ideas can best be achieved when learners are actively involved in the classroom discourse and a part to the lesson progression. Such a goal is attainable when learners are involved through activities, discussions, group work in the classroom discourse, in addition science lessons have to be punctuated with experiments or practical demonstrations.

Earlier on, I alluded to the fact the authoritative and dialogic lie on a continuum and this is evident in the communicative approaches proposed by Scott *et al.* (2006). Their communicative approach puts emphasis on analysing whether the teacher interacts with learners or not and if the teacher takes into consideration the views of the learners as the lesson progresses. The approach is categorised into four fundamental classes and are defined by characterising teacher-learner talk along two dimensions, dialogic – authoritative and interactive – non-interactive. The two dimensions of communicative approach are identified as interactive or non-interactive (Scott *et al.,* 2006). The teacher talk can be interactive if it allows more than one learner to participate or it can be non-interactive if the teacher excludes other learners from participating in the class discussions. By combining the two dimensions that of authoritative – dialogic and the interactive – non-interactive Scott *et al.* (2006, p. 611) came up with four classes of communicative approach tabulated in Table 4 below.

Table 4: Four classes of communicative approach (as adapted from Scott *et al.*, 2006)

Interactive/dialogic	Teacher and students consider a range of ideas. If the level of inter-animation is high, they pose genuine questions as they explore and work on different points of view. If the level of inter-animation is low, the different ideas are simply made available.
Non-interactive/dialogic	Teacher revisits and summarises different points of view, either simply listing them (low inter-animation) or exploring similarities and differences (high inter-animation).
Interactive/Authoritative	Teacher focuses on one specific point of view and leads students through a question answer routine with the aim of establishing and consolidating that point of view.
Non-interactive/ authoritative	Teacher presents a specific point of view.

In this study, the researcher evaluated whether the teacher's approaches to teaching and learning successfully engaged learners in terms of the dialogical or authoritative discourse. Thus, I ascertained how the teacher taught, for conceptual understanding or not. To determine how the conceptual development happens, I used the concept of link-making, which was developed by Scott *et al.* (2011). Link-making is regarded as being central to the teaching and learning of scientific conceptual knowledge (Scott *et al.*, 2011). Teaching for conceptual understanding is pivotal to my literature review above consequently pedagogical link-making becomes the basis of my analytical framework.

2.3 Analytical Framework

Scott *et al*., 2011 developed an approach that is central to the process of teaching and learning of scientific conceptual knowledge which they coined pedagogical link-making. The approach has its roots in social constructivism and focuses on the means in which teachers and students make connections between ideas in the on-going meaning-making interactions of classroom teaching and learning (Scott *et al*., 2011). For the accomplishment of link-making, learners must be able to learn using links provided by the teacher during lesson delivery. The approach acknowledges that learners are not blank slates (Von Glasersfeld, 1991; Piaget, 1964, 2003) but bring with them naïve concepts that have to be linked to new knowledge for comprehension of science concepts (Driver *et al.,* 1994; Mortimer & Scott, 2003). The depth of understanding and comprehension of the new concept depends on the depth of links made by the teacher in the classroom (Scott *et al*., 2011).

Scott *et al.* (2011) identified three forms of pedagogical link-making which are indicated in the Figure 1 below.

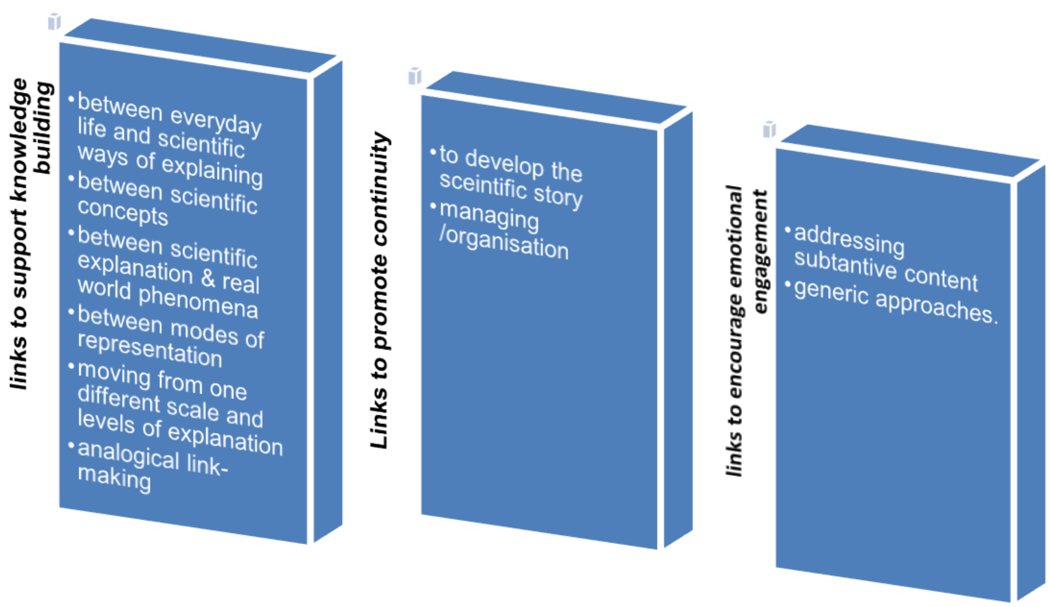

Figure 1: Forms of pedagogical link-making

In my study, I only focused on the pedagogical link-making to support knowledge building because of the time limit needed to finish this project for examination purposes.

2.3.0 Pedagogical link-making to support knowledge building

In the context of teaching and learning scientific conceptual knowledge, the pedagogical link-making seeks to support knowledge building to support students in increasing a deep comprehension of subject matter, through making links between diverse kinds of knowledge (Scott *et al.,* 2011). The different kinds of knowledge involve six approaches identified in figure 1 and briefly discussed below.

2.3.1 Approach 1: Making links between every day and scientific ways of explaining

This approach requires teachers to differentiate between everyday explaining of science phenomena with scientific way of explaining. Furthermore, the teacher needs to integrate the two explanations of ways for the in-depth understanding of the phenomena by the learner (Scott *et al.,* 2011). Suppose one is confronted with the concept of dissolving substances in solutions, for example, a substance like salt, the everyday explanation for the learner is that dissolution means changing from solid form to a liquid form, or after dissolution, a new substance is formed, or during dissolution, a solute is absorbed by the solvent (Uzuntiryaki & Geban, 2005). Whereas the scientific explanation is that all ionic solutes like salts are compounds made up of positive and negative ions. The process of dissolving a salt in water, involves three main steps: breaking the ionic bonds of the salt, breaking the hydrogen bonds in the water, and bonding water molecules to the ions (hydration). In the process, the solute breaks down into smaller invisible particles that are completely surrounded by particles of the solvent.

$$NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

2.3.2 Approach 2: Making links between scientific concepts

In this approach, the focus is on entwines between scientific concepts. The relationships between concepts are emphasised for there is no science concept that can be considered one at a time: their importance is drawn from the connections to another (Scott *et al.,* 2011). The learner must be able to connect and link concepts within the topic and with other topics in the body of chemistry. Concept mapping is another technique reported to enhance student conceptual understanding in science (Özmen, Demírcíoğlu, & Coll, 2007). Concept mapping gives an insight to the relationships among important concepts and helps learners comprehend the subject matter. Scott *et al.* (2011, pg. 8) argues that "learning scientific conceptual knowledge involves coming to recognise how the scientific concepts themselves fit together in an interlinking system.'

2.3.3 Approach 3: Making links between scientific explanations and real world

When learning for scientific conceptual knowledge, the learners must be able to make links, of the scientific phenomena to the real world, for the conceptual development and understanding of the scientific concepts (Scott *et al.,* 2011). The approach anchors on relevance of the scientific concepts to the real world that the teacher has to carefully and deliberately select for conceptual comprehension and arousing of learner interest. Research done by King, Bellocchi, and Ritchi, (2008) has shown that making real-life connections between chemistry concepts and the contexts in which they were realised have yielded positive affective outcomes for many senior secondary chemistry students.

Gabel (1993, p 193) in her symposium, Lecture and learning are they compatible, argued that if the chemistry concepts are taught out of context of everyday life, "students compartmentalized the knowledge as that learned in school, versus that needed in everyday life". The implication suggests that the science classroom discourse should incline to relevance of the real world situations of the learner. Although the context is imperative for the conceptual understanding of science, the context need to be familiar and simple (Johnstone, 1991).

2.3.4 Approach 4: Moving between different scales and levels of explanation

The learners' ability to use the macroscopic, sub microscopic and symbolic representations is of paramount importance for the conceptual understanding of chemistry concepts (Chandrasegaran *et al*., 2008). There are three fundamental levels to the scientific approach which learners need to be familiar with and these are macroscopic (phenomenological), microscopic (theoretical) and symbolic levels (Scott *et al.,* 2011). Research has indicated that learners generally memorise and regurgitate chemical equations without comprehension of the changes that occur at microscopic level.

The following are the descriptions of the three levels of representation according to Chandrasegaran *et al*. (2008);
Macroscopic representation, describes the visible and tangible science phenomena in everyday exepriences.
Sub-microlevel representation, describe the particulate level of matter, that is made up of atoms molecules and ions.
Symbolic representation has to do with the use of molecular structural drawings, diagrams and models.

Scott *et al*. (2011) and Chandrasegaran *et al*. (2008) use microscopic level and submicroscopic level to mean one and the same thing but in this research, the two are differentiated. In this project, microscopic level is defined as the theoretical level where the teacher describes what happens at a particulate level in theory. The sub-microscopic level is understood as the particulate level that is used in describing the movement of electrons, molecules, particles, atoms, anions and cations. These can be shown to learners as drawings, pictures, videos or animations.

To show understanding of scientific concepts, a learner must be able to move between the three scales of representation (Scott *et al*., 2011). That is, the learners must be able to describe what is seen at macroscopic level in terms of what is happening at the microscopic level using diagrams, pictures and drawings.

In her study on teaching the particulate nature of matter using symbolic, macroscopic, and microscopic, Gabel (1993) found out that learners who were taught more than one level of explanation performed higher than those who received one set of instruction. On the other hand Johnstone (1991) argued that learners need not to be taught all three levels for it unnecessarily complicates the teaching of science. Johnstone (1991) depicted the three levels of explanation as tripod levels of thought and argued that physics, chemistry and biology can be taught using such multilevel of thought, which he illustrated as shown on the diagram below.

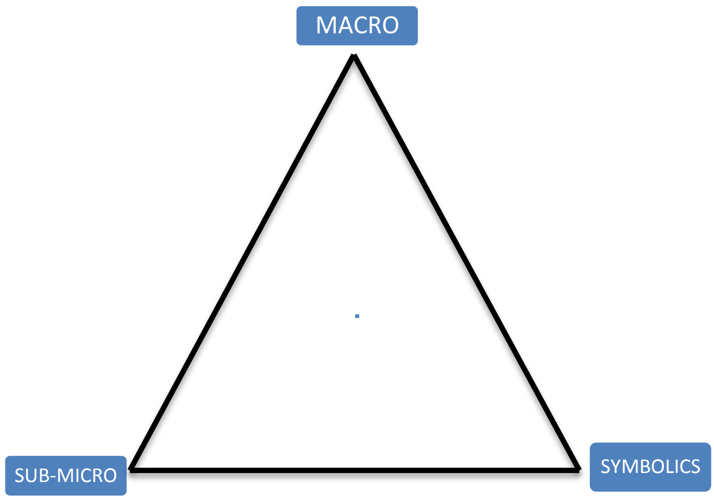

Figure 2: Triangle of levels of thought (Adopted from Johnstone (1991))

Johnstone (1991) argued that using all three levels, is moving at the centre of the triangle which gratuitously put a heavy work load on the learner and makes the science difficulty to understand. He asserted that school science can be understood by teaching learners on the macro level only. Gabel (1993) asserted that it is difficult to teach at the symbolic level, whereas Davidowitz, Chittleborough and Murray (2010) asserted that submicro level presents snags for greenhorn learners and learners find it difficult to make the link between the submicro and symbolic levels of representation. The difficulty of the symbolic and submicroscopic levels is due to the fact that they are abstract and cannot be experienced as they are not visible or tangible, (Chandrasegaran *et al*., 2008; Gabel,1998; Johnstone, 1991).

2.3.5 Approach 5: making links between modes of representations

The approach stems from the multimodal nature of scientific knowledge, which includes; graphical, diagrammatical, chemical equations, pictorial, and a number of different representations (Scott *et al.,* 2011). Gabel (1998) defined a diagram or a picture as a descriptive tool that can provide the learners with a technique of envisioning the notion that develops a intellectual model for the concept. Diagrams of sub-microscopic level comprise depictions of molecular, atomic and sub-atomic particles (Davidowitz *et al.*, 2010).

Davidowitz *et al.* (2010) defined a chemical equation of the net changes that occur in a chemical reaction, which lacks reaction mechanism detail. They further state that a chemical equation does not represent the submicroscopic nature of the reactants. The teacher's task is to help the learner link a scientific phenomenon with these different modes of representations. One representation is not sufficient to bring about learners making meaning from science phenomena. Scientific meaning is usually made by a combination of several modes of representation within one text (Cheng & Gilbert, 2009).

Teachers need to be familiar with multi-modal representations and should be able to link them to scientific concepts successfully to clarify and enhance scientific conceptual knowledge. Lemke (2004, pg 8) argue that;

> "*Students need to not just do hands-on science and talk and write science in words; they also need to draw science, tabulate science, graph science, and geometrize and algebraize science in all possible combinations*."

Davidowitz *et al.* (2010) concurred with this notion when they highlighted that meaningful learning occurs in a disciplinary discourse when multiple representations such as, chemical equations, submicro diagrams representations are used in science classroom talk. The problem is that learners have little understanding of the chemical changes that take place at the submicro level in a chemical reaction and as a result, learners resort to memorisation of the chemical equation (Chandrasegaran *et al*., 2008).

2.3.6 Approach 6: analogical link-making

The teacher assists learners to understand the scientific concepts through the use of known and relevant analogies. Analogies are used as a third part case that shares features of both the analogical case and the original case (Cement, 1993). Careful thought must be applied in selecting and teaching with analogies. Analogies may bring conceptualisation of knowledge in learners but, if not well chosen and when its short comings are not explained to learners, it may propagate the development of alternative concepts (Dagher, 1995).

2.4 Conclusion

This chapter covered the literature of the transmission method, the continuum between authoritative and dialogic discourses. I have shown that the latter two approaches are desirable in a learner centred approach. Literature on the social constructivism as well as the analytical framework of pedagogical link-making as derived by Scott *et al.* (2011) was discussed. Against this background of literature my methodology was based on the gathering of data to investigate to what extent the teacher used pedagogical link-making approaches in the teaching of the Grade 10 Chemical Change. The methodology was based on the instrumental case study of one physical science teacher at a secondary school in Gauteng South Africa.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

In this chapter, I will first describe the methods that were implemented in this research and then define what a case study is according to the literature and research findings. I will further highlight the way the data was gathered and analysed as well as enlightening the reader about the coding system that was used in this project. The justification of instruments and design approach will be discussed under reliability and validity. Lastly, I will mention how ethical issues were addressed as well as the time line to carry out the whole project.

3.1.0 Methodology

I did a case study of my colleague (Mrs Foster – pseudonym) teaching grade 10 learners physical science to get an in-depth understanding of how the pedagogical link-making is applied in the teaching of “Reactions in aqueous solutions.” Mrs Foster has 8 years experience of teaching Physical Science and holds a Bachelor of Technology in Chemistry degree and a Post Graduate Certificate in Education (PGCE) majoring in senior phase and Further Education Training. I chose to observe Mrs Foster due to the major changes in her teaching methods after she obtained her PGCE at UNISA. I noted a change in her teaching during her teaching practice for her PGCE for I was her mentor and used to sit and observe her teach.

3.1.1 A Case Study

A case study is a qualitative research method that can be defined as an in-depth, holistic description and analysis of a single unit in a natural setting (Merriam, 1998; McMillan & Schumacher, 2010; Opie, 2004). Opie (2004) explains case studies as intensive descriptions and analyses of a single unit or bounded system such as an individual, programme, event, group, or community. A bounded system is described by McMillan & Schumacher (2010) as being unique in reference to time, location and characteristics of participants. Case studies range from intrinsic, instrumental or collective cases depending on the focus of the study. The intrinsic case study focuses on a case itself that is usually unique. Instrumental case is that which provides insight into a specific issue and collective cause is that which considers a combination of different cases in one study (McMillan & Schumacher, 2010). The focus of the instrumental case study is generally known in advance and is designed around reputable theory or methods.

My research was an instrumental case study which seeks to investigate and provide a general understanding, on how a particular grade 10 physical science teacher's use of the pedagogical link-making approach in the teaching of chemical change. My focus was to investigate how the teacher supports knowledge building, a form of pedagogical link-making in the teaching of aqueous solutions with a particular grade 10 class. The case was an instrumental study for I used a particular case to gain a broader appreciation of the use of pedagogical link-making to support knowledge building.

3.1.2 Data Collection

My study consisted of a convenience sampling as I chose Mrs Foster specifically for the reasons that follow.

The selection of Mrs Foster was convenient in the sense that I am a teacher at the same school with her. Studying her practice was convenient for me because my teaching time was not lost by visiting other teachers outside my school and there were no travelling complications as well. Mrs Foster was observed teaching a class of grade 10 physical science comprising of 24 learners (14 girls and 10 boys) aged between 15 -17 years. I observed her lessons during school time within the parameters of our school timetable. The topic in the work schedule was given a total of three hours. Therefore, a total of four lessons of an average of 40 minutes each, was video and audio recorded. The entire four lessons took place during my free periods and I did not lose any my lessons or inconvenience the learners that I taught. The teacher was informed that the recordings should not affect her style of teaching neither was she supposed to change topics for the sake of research.

The teacher was the one being studied so a voice recorder was strapped on her person for clear recordings of her voice. The video was used to reinforce the capturing of data and recording learner involvement and contributions in the classroom.

3.2 Data Analysis

I used the double recordings of the video and audio that was produced from the lessons to analyse data. Field notes could not be used because I was the video recorder and could not take notes of the lesson proceedings. The recordings of the lessons were played more than three times during the analysis. Firstly, I listened and watched the four lessons for the purpose of summarising and deducing the similarities and differences of the lessons in terms of pedagogical approaches the teacher used, which were then tabulated (see Appendix A). I then listened and watched the videos of the lesson for the second time to identify and note down the times each pedagogical link-making appeared in the video in each lesson. The findings were recorded in the time line analysis table (see Appendix B).

Thirdly, I listened to each section recorded in the time line data analysis and transcribed them. During transcribing I used the audio recordings often as they provided a clear audio. Where the audio was not clear, the two recordings were then listened to. The video recordings were also used to capture pictures and drawing illustrations the teacher was using during her teaching. After transcribing particular excerpts with the relevant pedagogical link-makings, pedagogical approaches were also selected for in-depth analysis. These particular excerpts were replayed as well to get every word that was spoken in the lesson.

3.3 Coding

According to Friese (2013) the word code in qualitative research, refers to small pieces of text that are used to reference other portions of text data. In this research the word 'code' was used to mean a set of letters and numbers that denotes particular phrases found in text. The purpose of codes is to identify the occurances of particullar selected phrases for tallying and finding relationships, if any, between certain phrases. They are used as sorting devices in order to generate sets of related information parts for the purposes of comparisons (Friese, 2013). My coding was done before transcribing collected data into text so that I indentify, capture and tally the features of pedagogical link-making during the data analysis.My coding was based on the analytical framework developed by Scott *et al*. (2011). For the purposes of this case study, only one of the three main ideas of pedagogical link-making to support knowledge building was investigated and coded. The first main idea to support knowledge building has six pedagogical link-making approaches which were used to "identify specific *pedagogical tools/strategies* that might be employed in the classroom to support link-making" (Scott *et al*., 2011, p. 4). These six different categories have to be vivid in a lesson delivery for the success implementation of the pedagogical link-making approach in the science classroom (see Table 5). Where possible, each category has been subdivided, thus creating 12 subcategories that can easily be identified during lesson execution. It is these subcategories or parts that have been given code names that were tabled and compared to establish their relationships and how frequent the teacher used them in the lessons; Table 5. The frequency of these codes was tallied during the analysis of the transcribed text. The presence of each category would mean that the teacher was conscious of the pedagogical tools/strategies that promote pedagogical link-making.

Table 5: Pedagogical Link-Making Coding System

<table>
<tr><th colspan="3">Pedagogical Link-Making Approaches</th><th>Coding</th></tr>
<tr><td rowspan="14">To promote knowledge building</td><td rowspan="2">Making links between every day and scientific ways of explaining</td><td>Integration</td><td>KB1-1</td></tr>
<tr><td>Differentiation</td><td>KB1-2</td></tr>
<tr><td>Making links between scientific concepts</td><td>Linking scientific concepts</td><td>KB2</td></tr>
<tr><td rowspan="2">Making links between scientific explanations and real world phenomena</td><td>Simple phenomena</td><td>KB3 -1</td></tr>
<tr><td>Complex phenomena</td><td>KB3-2</td></tr>
<tr><td rowspan="3">Making links between different scales and levels of explanation</td><td>Micro</td><td>KB4-1</td></tr>
<tr><td>Macro</td><td>KB4-2</td></tr>
<tr><td>Symbolic</td><td>KB4-3</td></tr>
<tr><td rowspan="4">Making links between modes of representation</td><td>Pictorial</td><td>KB5-1</td></tr>
<tr><td>Diagrammatic</td><td>KB5-2</td></tr>
<tr><td>Chemical equations</td><td>KB5-3</td></tr>
<tr><td>Graphical</td><td>KB5-4</td></tr>
<tr><td>Making links between analogous cases</td><td>Analogies</td><td>KB6</td></tr>
</table>

3.4 Ethics

Through the University of Witwatersrand's ethics committee I applied for permission to carry out my research (see Appendix C). I also applied to the Department of Education requesting permission to carry out the research at one particular school in Gauteng East Educational District in Gauteng province (see Appendix D). Authorisation was granted and upon receiving the protocol number from the University of Witwatersrand, I went on to administer the consent forms and information sheets to the principal, the teacher, learners and parents (see Appendix E for consent forms). The information sheet sought permission for video and audio recording of the teacher and learners for the four lessons requested. Every participant (teacher and learners) was assured of their anonymity and the video and audio recordings were not seen by any other person other than my supervisor and me. Participation was voluntary and participants were free to withdraw at any time without being prejudiced in their education. Lessons plans from the teacher were also treated as confidential information and were used for the purposes of the research project only.

3.5 Validity and Reliability

The processes of data collection which include video and audio recordings as well as teacher's lesson plans ensured that the data collected represented as close as possible to a true reflection of what had transpired in the lessons. The use of audio and video recording and replaying them more than three times in the process of analysing data and the thorough scrutiny of the transcribed text (see sample of transcripts in Appendix F) by the researcher ensure that the existence or absence of the forms of pedagogical link-making are discovered.

Validity refers to the degree to which a method, a test or a research tool actually measures what it is supposed to measure, Opie (2004) argues that validity refers to the relationship between a claim and the result of the data gathering process. Reliability refers to the extent to which research findings can be repeated. It encompasses the way data has been gathered and how it has been analysed. It is a property of the whole process of data gathering rather than the property solely of the results (Opie, 2004). Hence, the reliability of this study is unique to the teacher and learners in the context of their school. Repeating the same study with the same sample same results can not be ensured as people change with time.

3.6 Limitations of the Study

Being a full time educator and a part time student limited my study sample due to time constraints. Therefore, the findings of this study may not be generalized because they are unique to a particular teacher and learners who participated in the study and unique to the context in which the teacher is working. In my case it was not a good idea to do the study at my work place because disturbances which I didn’t anticipate, came my way: such as being called to attend disciplinary case during a recording hence, I suggest that for an independent study without disruptions, one has to do it where the researcher is immune to external disturbance during the investigations.

3.7 Time Plan

The time plan below in Table 6 was followed for the completion of the project.

Table 6: Time Plan for the Research Project

Activity	Date of Activity
Meeting with Supervisor: Submission of project proposal to supervisor	January 2013 to February 2013
Discussion of methods to be used for collecting data	March 2013
Submission of literature review Discussion of project proposal with supervisor	April 2013
Presentation of project proposal to fellow students and lecturers	31 May 2013
Corrections of the project proposal	June 2013
Submission of project proposal to supervisor and Marang centre for external assessment	18 June 2013
Piloting of study: Video and audio taping of three lessons on a different topic, for learners and the teacher to be familiar with the second camera and my presence in the lesson.	July 2012
Gathering data	August 2012
Transcribing of data	September 2013
Analysis of results, Discussions & References Submission of draft document	October – December 2013
Corrections of the returned draft from supervisor	January 2014
Submission for examination	February 2014

3.8 Conclusion

This chapter dealt in detail with the project methodology where two research questions were addressed and how the data was collected. The pedagogical link-making to support knowledge building from Scott *et al.* (2011) was used to develop the coding system that was used to capture data for analysis, has been discussed. In the next chapter, I will report on how the data collected during the research was tabulated and analysed.

CHAPTER 4: ANALYSIS AND DISCUSSION OF RESULTS

4.0 Introduction

In this chapter, I present my analysis of the teaching methods used by Mrs Foster (pseudonym of the teacher) in each of the four lessons observed. I found that pedagogical link-making to support knowledge building in each of the lessons was done by the teacher. Transcripts of the lessons were used to examine the use of each of the six categories of link-making to support knowledge building. The chapter will end with the discussions how the teacher's approaches and the pedagogical link-makings were used to enhance learners' comprehension of the topic reactions in aqueous solutions.

4.1.0 Descriptions of Teaching Approaches

Mrs Foster used an assortment of teaching strategies in the four lessons observed and these included the transmission method, question and answer, practical work and group work. The question and answer and the transmission strategies were prevalent in all four lessons see Appendix F for the extract of verbatim transcript. In lesson 2, practical demonstrations and simulations were employed whereas lesson four was mainly group work as shown on the table below.

Table 7: Summary of teaching approaches

Lesson Number	Pedagogical Approach of Teaching		
	1	2	3
1	Question and answer		
2	Question and answer	Practical demonstration	Animation
3	Question and answer	Practical demonstration	
4	Question and answer	Group work	

Generally lesson 1 had one approach employed by the teacher, which was mainly question and answer. Lesson 2 had three approaches that were used by Mrs Foster and lesson 3 and 4 had 2 approaches each used as shown in table 7 above. More about the contents of each lesson are found under appendix A.

4.1.1 Lesson 1

The lesson started with revision of homework and Mrs Foster went on to introduce the topic Electrolytes. The teacher gave answers to the learners for self-marking with little discussion. The excerpt 1 below is at the beginning of the lesson before Mrs Foster started answering homework questions.

1 Teacher: Now guys what you need to have said is in the region of the following. Listen carefully and see what you have said is correct. It doesn't have to be word to word it needs to bring about the same concept.

Mrs Foster did not discuss the answers of the questions with the learners but she wanted them to synchronise their answers with her model answers. All the questions were dealt with in the same manner. Occasionally, Mrs Foster engaged learners to contribute but she would not allow a debate around the questions. When learners gave an incorrect answer, she gave the answer directly without probing the learners. See excerpt 2 when the class was discussing non electrolytes.

1 Teacher: ……So if I tell you the word non-electrolyte, when I say non-electrolyte what do you think that definition will be?
2 Obert: (inaudible sounds from other learners) it cannot conduct electricity.
3 Teacher: Yah, that's not a nice definition. Who thinks they can give us the whole nice definition? It's a compound that when you dissolve it in water when it's in solution cannot conduct electricity, alright.
4 Gugu: Like distilled water.
5 Teacher: Like distilled water yes. It cannot conduct so that solution is non-electrolyte or is not an electrolyte.

In turn 1, the teacher seemed to be opening a whole class discussion by posing an open question. In turn 2, Obert shared his opinion which the teacher did not agree with fully. In turn 3, Mrs Foster went on to terminate the discussion by giving the full definition of a non-electrolyte solution. The teacher has a prototype definition and any description that does not match hers would not be accepted as correct, hence she did not accept Obert's contribution. Learners come into the classroom with preconceived ideas about a particular phenomenon; the role of the teacher is to build conceptual understanding from such previous knowledge. Mrs Foster could have built the definition of a non-electrolyte solution using Obert's contribution. By so doing, she could have consolidated the learner's understanding and motivated him. To take a close look at the teacher's definition. In turn 3 line 3

Mrs Foster uses the exact phrase used by Obert in turn 2 "… cannot conduct electricity." Basically the learner's definition was a matter of omission.

The learners were keen to continue with the discussion as shown by Gugu's interruption when she gave an example of a non-electrolyte in turn 4. In turn 5, Mrs Foster agreed with Gugu but went on to close the discussion by giving the reason why it is not an electrolyte. The learners were keen to explore and have a discussion around this matter and they had a sound background on electrolytes which the teacher did not entertain. Excerpts 1 and 2 gave an insight into the teaching style of the teacher which was transmission as well as question and answer which was an initiation-response-evaluation (I-R-E) pattern.

4.1.2 Lesson 2

Lesson 2 was a double lesson where simulations on the formation of silver chloride precipitate from sodium chloride and silver nitrate at microscopic level were shown to learners. The animation was followed by practical demonstrations for precipitation reactions of halides, carbonates and sulphates. The simulations started with the formation of solutions of silver nitrate and sodium chloride from their solid state and then the formation of the silver chloride precipitate from the solutions. Mrs Foster used the transmission method coupled with questions and answers in her lesson presentation - see excerpt 3 and 4 below.

> 1 Teacher: ….there goes the sodium chloride normal salt, also gets dissolved. Now I have two aqueous solutions that have ions floating around in there. Those four different ions that we saw in the beginning, the sodium ion, the chloride ion, the silver ion and the nitrate ion.
> Now remember once we have our two aqueous solutions. We set to start our precipitation reaction. Now let's have a look how that happens. There are the two solutions getting mixed; now they are mixing, ok. They are all mixing all of them and with the water.

Mrs Foster narrated the whole video simulation to the learners. The learners were not asked to say what they were seeing on the simulations even though they had done the theory before this lesson. The teacher could have taken advantage of the learners' previous knowledge of the concept of precipitation reactions and asked the learners to narrate and explain what they were seeing. Mrs Foster could have allowed learners to discuss and ask questions about their observations so as to create a social learning environment. In my opinion, Mrs Foster could also have asked questions that sought to evaluate learner understanding of what happened at the microscopic level. Basically that was the main idea behind showing the simulations to the learners, so that conceptual understanding could be evaluated by letting learners explain what they observed. Actually the teacher chose to deliver everything to the learners on a silver platter and acted as the sole source of knowledge.

During the practical demonstrations of precipitation reactions, Mrs Foster used the question and answer method as she progressed with her lesson delivery. Just like in lesson one, the question and answer was reduced to I-R-E approach (see excerpt 4 below):

1 Teacher: I'm gonna do the sodium chloride since it is the one that we looked at on the screen here. We looked at sodium chloride and silver nitrate. I'm gonna do that first for you.
(Pouring sodium chloride solutions into a test tube)
Ok! This is my salt solution, sodium chloride. So that means in this one if we look at the ions in there will be sodium ions, which are the cations the positive ones. There will be chlorine ions in there.
Now with my silver nitrate!
(Pouring silver nitrate solution in a measuring cylinder)
You will see that my silver nitrate solution is a clear solution and my salt solution also. Both of them colourless you see. There are colourless and now I'm going to mix the two *(pouring silver nitrate into sodium chloride)*
2 Class Wow!
3 Teacher: Can you see that white, snow white precipitate powder has been formed. It looks like I added baby powder into my solution
4 Enock: It's a solid.
5 Teacher: Yes it's a solid. What's the name of this solid?
6 Gloria: Salt (*hesitating*)
7 Enock: Silver ……. (*Inaudible*).
8 Lerato: Ummm
9 Teacher: what did we have? We have sodium chloride and silver nitrate. What was the solid made?
10 Lerato: Silver Chloride
11 Teacher: Silver Chloride. Yes. Silver chloride which is nice and white.

In this excerpt, the teacher gave learners everything-even on what they were seeing and could have said without a problem if they were involved in the classroom talk. In Turn 1, Mrs Foster could have engaged learners by asking questions such as; 'What is the colour of silver nitrate?' By not engaging learners, she reduced them to non-participating observers. Turn 2 shows that the learners were very observant of every step as they were fascinated by the colour change. In turn 3, the teacher went on to give learners the results of mixing the two solutions instead of asking for their input. Enock, uninvited by the teacher, interrupted and shouted, ‘It’s a solid’ which means learners are not interested in being silent observers but they want to be involved in the teaching and learning process. Thus, Enock started a classroom discussion, which helped learners like Lerato in turn 8 and 10 to remember the name of the solid. Of course this was after hints from Enock, turn 7 and good probing from the teacher, turn 9. The interaction pattern was no longer the usual *I-R-E* but a closed *I-R-P-R-P-R-E* pattern. The later interaction pattern supports learners in expounding and making their ideas explicit (Scott *et al*., 2006).

Mrs Foster used the practical demonstrations to enhance the learners’ understanding of the microscopic level shown previously on the animations by tackling the macroscopic level of thought. She used one level of thought at a time to enable learners to switch from microscopic to macroscopic: that is from simulations to practical activity. Research literature found this to be a good practice for it helps learners explain scientific phenomena in terms of molecular level and what is observed (Chandrasegaran *et al*., 2008; Gabel, 1999; Johnstone, 1991). When Mrs Foster was doing the demonstration, she did not refer to chemical equations which are symbolic representation, but rather she referred to the simulations (microscopic). Such approach of teaching is supported by educational research as good practice for it enhances learner conception. Johnstone (1991) argued that when all three levels of thought are referred to during teaching, one will be moving in the middle of the triangle which will complicate the comprehension of scientific concepts.

4.1.3 Lesson 3

The lesson started with the teacher recapping the practical demonstration of the previous lesson on precipitation reactions. Learners were given answers on the board to mark themselves. Mrs Foster went on to introduce the topic of the day; Other Chemical Reactions in Aqueous solutions, which included, gas forming reactions, acid-base reactions and redox reactions. In this lesson, Mrs Foster did a practical demonstration of zinc and hydrochloric acid that produced zinc chloride and hydrogen gas. The greater part of the lesson was dominated by the transmission approach where the teacher related everything without the learners' involvement.

After the practical demonstration, Mrs Foster went on to balance the chemical equation for the learners.

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

The learners had done balancing of equations in grade 9 and they could be expected to balance the equation. This was a chance for the teacher to assess learners' understanding of balancing equations. The teacher even acknowledged the learners are expected to balance equations (see excerpt 5 below):

> Teacher: You guys, you are so good at balancing equations. You did so much last year ne, you are experts at balancing.

The claim could have been verified by giving learners a chance to balance all or at least one of the six equations the teacher had balanced for them during the lesson. The learners were not given the chance to even recap the concepts they had done at the beginning of the term that involved balancing equations. Later when Mrs Foster was explaining the transfer of electrons in a reaction, she reminded the learners of ionic bonding that was done in first term (see excerpt 6):

> Teacher: Guys remember when an ionic bond is formed. I wanna take you back to first term when we did ionic bonds. When an ionic bond is formed it means one of the atoms give the electrons away right? The other atom takes the electrons. Now I have two ions, the one is positive because it's lost electrons and the other atom it's negative; it's an anion because it gained an electron.

The coupling of chemical equations and practical demonstration was an excellent approach employed by the teacher. Such an approach brings about learner comprehension as they can relate symbols with what they have observed (Davidowitz *et al.*, 2010). The teacher had an opportunity to involve learners in this concept for they had covered it previously. Instead, she recapped the whole notion of ionic bonding for the learners. Hence the lesson was predominantly transmission although it started with a practical demonstration that captured learner interest.

The sole use of chemical equations as a teaching approach complicates the understanding of chemistry. Chemical equations make use of symbols to represent chemical reactions and symbolic level makes science complex (Gabel, 1999). Mrs Foster related very well the symbolic level (chemical equation) with the practical demonstration (macroscopic level) but through the transmission method. For the sake of learners' comprehension she could have let learners link the two through social interactions and mediated where learners did not agree. But the teacher did the integration herself without learner involvement. Johnstone (1991, p. 549) pointed out that

> *"…teachers unwittingly move from one level to another in lecturing, students fail to intergrate the levels which leads to a fragmented view of chemistry with many puzzling parts that do not seem to fit together".*

Learners must be helped to move between three levels as it has great potential to improve conceptual understanding (Johnstone, 1991). The understanding of learners could not be ascertained as they were not given an opportunity to discuss the concepts presented by the teacher.

4.1.4 Lesson 4

The lesson began with a recap of the previous lesson and Mrs Foster summed up the topic of Chemical reactions in aqueous solution by reminding learners of the topics which she had gone through previously with the class. The topics included; electrolytes, precipitation reactions, gas forming reactions, acid-base reactions and redox reactions. As in the three previous lessons, Mrs Foster did not involve learners in summarising what they had learned, she just narrated to learners what she had covered with them.

> Teacher: Ok, so let's go back and have a look. Remember now that we have learnt about electrolytes, which are our charged ions in solution, and we have learnt about precipitation reactions where there is going to be an exchange of ions and we will form a solid. Now we see that there is actually three other ion exchange reactions that can also occur. Formation of a gas, we can have neutralisation between a base and we can have a redox reaction where one of my ions can gain electrons and one of the ions loose electrons.

The learners were given an end of topic exercise from a text book which had questions on chemical reactions in aqueous solutions. The questions gave a summary of the reactions in aqueous solutions. Mrs Foster emphasised that learners should practise the questions so that they can be able to identify each reaction type. The learners were given this exercise as a class activity in small groups and Mrs Foster moved from one group to the other helping and answering questions from the learners. Excerpt 8 shows one of the discussions, between the teacher and Lucas on how to identify a particular reaction.

1 Lucas: Ma'am when it is like, when a reaction ne …… when one reaction has a liquid and the other one has a gas it's a redox reaction ne?

2 Teacher: No

3 Lucas: It's a gas?

4 Teacher: If there is a gas forming it's a gas. But you can check if you wanna see its redox. Check if your oxidation numbers have changed, is the change the same on both sides for the same atom. If the change is now different for the same atom then you know there is a redox. But if there is a gas forming then its driving force was a gas forming reaction.

Lucas seemed not to understand how to identify whether one particular reaction was a gas forming or redox reaction. The hints of the teacher were helpful for the learners were not only supposed to look at change of states only, but also had to look at oxidation state as well. With further discussion with other learners it was realised that one reaction can be both a gas forming and a redox reaction as well. Such discussions with learners brought about learner comprehension and eradicated sprouting of misconceptions and misunderstanding of concepts. This was evident through learner participation and discussions with the teacher as the lesson progressed. Mrs Foster had such discussions with different learners in different groups for the remainder of the lesson. When she got a common misconception or misunderstanding she rectified it by addressing the whole class.

4.2.0 Pedagogical link-making to support knowledge building

For the four lessons observed, I identified and analysed the pedagogical link-making to support knowledge building that Mrs Foster used according to code system developed in Table 5 in Chapter 3. The frequency of each link-making has been summarised in Table 8 below.

Table 8: Frequency of pedagogical link-making for the four lessons observed

	Coding			Frequency			
				L1	L2	L3	L4
To promote knowledge building	Making links between every day and scientific ways of explaining	Integration	KB1-1	0	4	1	0
		Differentiation	KB1-2	0	0	0	0
	Making links between scientific concepts	Linking scientific concepts	KB2	10	4	7	2
	Making links between scientific explanations and real world phenomena	Simple phenomena to Complex phenomena	KB3	0	10	2	0
	Making links between different scales and levels of explanation	Micro	KB4-1	0	10	0	0
		Macro	KB4-2	0	9	1	0
		Symbolic	KB4-3	1	0	4	0
	Making links between modes of representation	Pictorial	KB5-1	0	9	0	0
		Diagrammatic	KB5-2	4	5	1	0
		Chemical equations	KB5-3	3	8	4	1
		Graphical	KB5-4	0	0	0	0
	Making links between analogous cases	Analogies	KB6	0	0	0	0
Time per lesson in minutes				35	55	35	45
Total Frequency of links used per lesson				18	59	20	3

From Table 8 it is apparent that Mrs Foster used more of making links between scientific concepts (KB2) and making links between modes of representation (KB5) than any other links. Making links between analogous cases (KB6 and graphical representations (KB5-4) were not used in all the lessons at all. Lesson 2 had the most number of link-makings than any other lesson with a frequency of 59. This could be attributed to fact that the teacher had practical demonstrations as well as the animation video for it was a double lesson. Lesson 4 had the least frequency of 3. This is because very little time of teaching was done and most of the time was left to practise questions and group discussions on the class activities.

Each lesson was meant to be of 45 minutes; lessons 1 and 3 were reduced to 35 minutes as learners were released late from their previous lesson. Lesson 2 was supposed to be 90 minutes but was reduced to 65 minutes and 55 minutes of recording as there were numerous disturbances. Firstly on two occasions the researcher was requested to attend to disciplinary issues in another classroom by the deputy principal. Secondly, the principal had to call more than half of the class to the hall towards the end of the lesson due to some issues at the school and 10 minutes were lost and the teacher called off the lesson.

The information on Table 8 was represented graphically to have a clear indication of the link-makings that were used per lesson as shown in Figure 3 below.

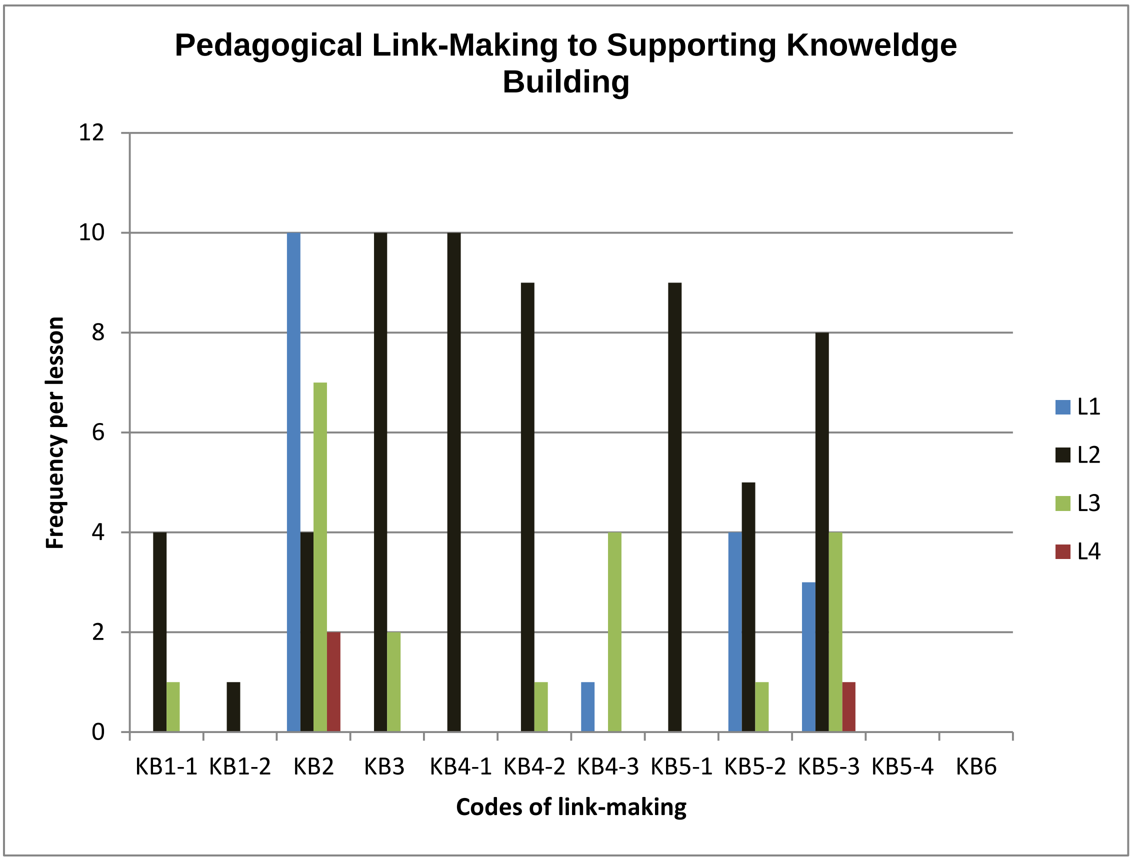

Figure 3: Pedagogical link-making to support knowledge building

Lesson 1, had four link-makings used namely KB2, KB4-3, KB5-2 and KB5-3. It is clear from the diagram that KB2 – linking scientific concepts was used the most with a frequency of 10. In lesson 2, all link-makings were used by the teacher except for KB5-4 (mode of graphical representation) and KB6; (analogous cases) which actually were never used in all the lessons observed. The most often used link-makings in lesson 2, had frequencies that ranged between 8 and 10 and these were KB3 (Making links between scientific explanations and real world phenomena), KB4-1 & 2 (Making links between different scales and levels of explanation; microscopic and macroscopic), KB5-1 & 3 (modes of representations; pictorial and chemical equations). Lesson 3 had a total of 20 link-makings used according to Table 8 and KB2 was the frequently used with a tally of 8 cases.

Although the number of link-makings used was few, most of the links were referred to in this lesson and also a practical demonstration was carried out.

The total numbers of frequencies per lesson per code and per link-making were calculated to ascertain and have a clear picture on how the links were used in the entire research. These numbers were tabulated in Table 9.

Table 9: Total frequency per code and per link-making

Coding			**Total per code**	**Total per link-making**
To promote knowledge building	Making links between every day and scientific ways of explaining	KB1-1	5	6
		KB1-2	1	
	Making links between scientific concepts	KB2	23	23
	Making links between scientific explanations and real world phenomena	KB3	12	12
	Making links between different scales and levels of explanation	KB4-1	10	25
		KB4-2	10	
		KB4-3	5	
	Making links between modes of representation	KB5-1	9	35
		KB5-2	10	
		KB5-3	16	
		KB5-4	0	
	Making links between analogous cases	KB6	0	0
Total Number of Links.			101	101

A total of 101 link-makings were used in 170 minutes of teaching time. That means Mrs Foster used approximately one case of link-making every two minutes on average. The statistics on Table 9 were subjected to graphical analysis in Figure 4 below.

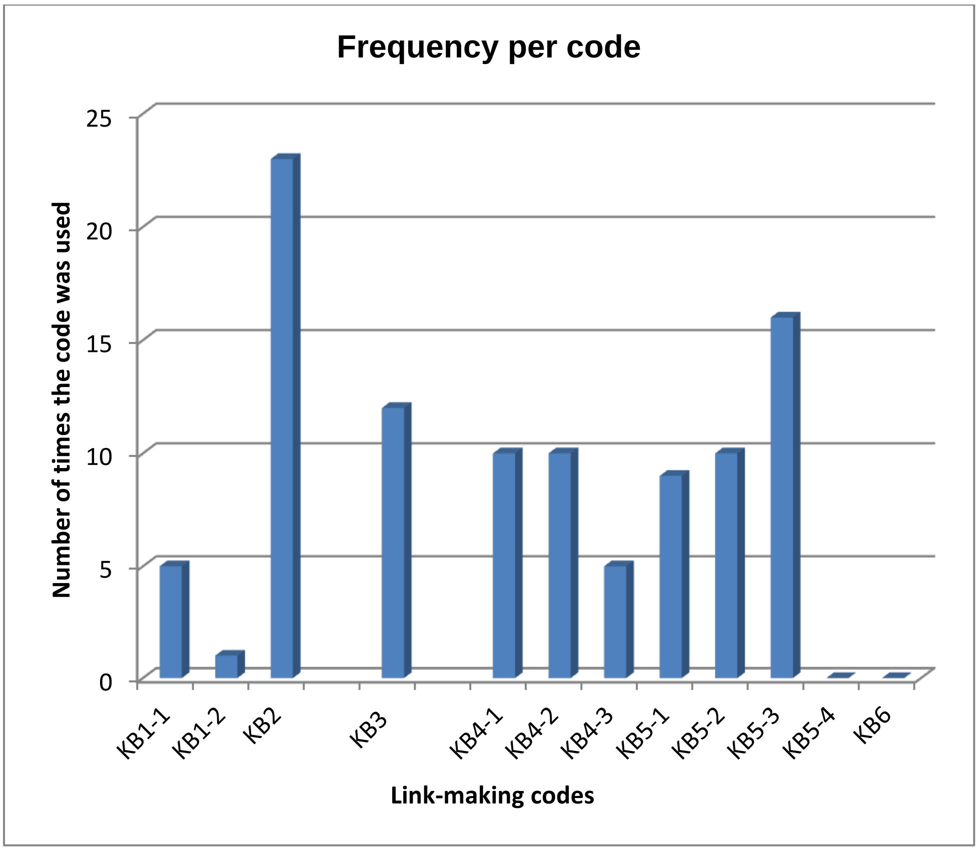

Figure 4: Frequency of link-making codes used for the four lessons

Codes KB2 and KB5-3 were the most used links whereas KB1-1 & 2 and KB4-3 were the least used with a frequency of less than 5, the rest were satisfactorily used. Figure 5 shows how the teacher made use of each link-making during the entire research.

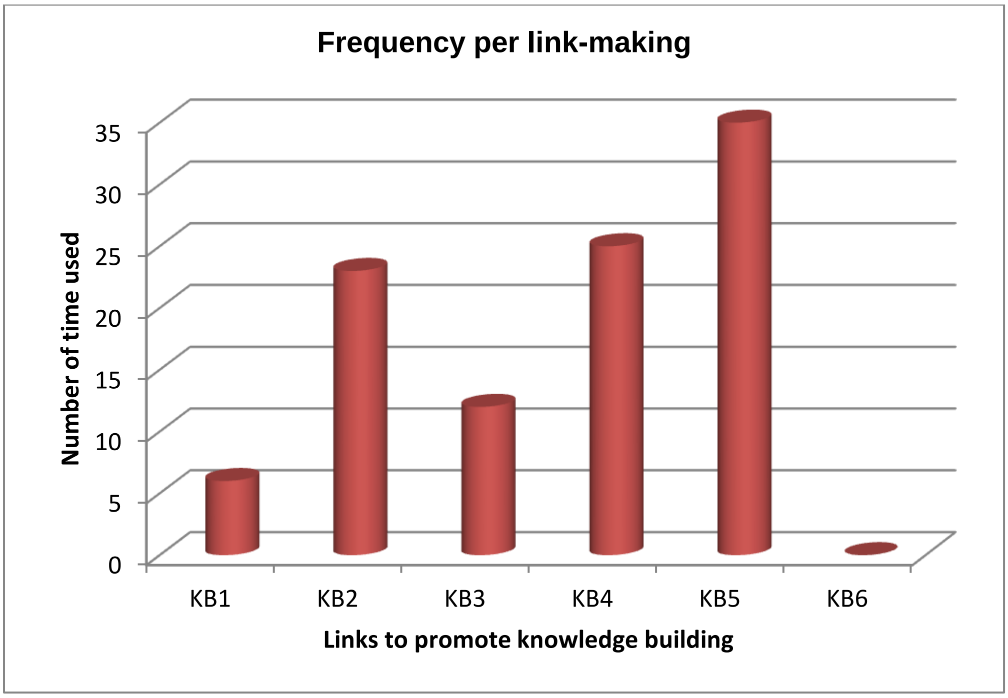

Figure 5: Frequency of the use of link-making to support knowledge building

Making links between modes of representation (KB5) was the most used link-making with a total frequency of 35 followed by making links between different scales and levels of explanation (KB4). Making links between scientific concepts was third and making links between modes analogous cases had a frequency of zero. An in-depth inquest on how these link-makings were used by the teacher during lesson delivery was done and discussed in preceding sections. Only analogous cases were not commented on since they were not referred to anywhere in the lessons.

4.2.1 Making links between every day and scientific ways of explaining

Making links between everyday and scientific ways of explaining has two categories integration and differentiation of everyday ways of explaining science phenomena with the real science explanation. In the four lessons observed there were five integration cases (KB1-1) and one differentiation case (KB1-2). Four of the integration cases were in lesson 2, one in lesson 3 and the only differentiation case was in lesson 2, as shown in Table 9.

In lesson 2 Mrs Foster was explaining how the silver nitrate solute dissolves in water to form silver nitrate solution;

1. Teacher: The silver nitrate was a solid. Let me show you again (*going back to the slide). (There was a disturbance from a learner send by the Deputy Principal to call the researcher and Mrs Foster explain that the researcher was busy*)
2. Teacher: Now let us have a look at the solid, it falls into water, and the water pulls it apart. Can you see that all the ions are pulled apart and guys we must remember that the motions in a liquid they are constantly moving can you remember that?
3. Class: Yes we remember.
4. Teacher: to us it appears like the water is lying there is very still. But they are actually moving and there you can see how they are moving, constantly moving, the water has pulled the silver ion and the nitrate ion apart.

The everyday explaining of dissolving solutes according to Mrs Foster is that the water pulls the ions apart, turn 2. The explanation has to be integrated with the actual scientific view on dissolution. Mrs Foster did ensure that learners got the scientific explanation by talking about electrostatic forces between ions and the polarity of the water molecules. She explained that the positive polar side of the water molecule is attracted to the negative anion. The nitrate ion would be surrounded by water molecules with its positive side towards the anion. Hence it would be separated from the silver ion. The silver ion is surrounded by the negative end of the polar water molecule. The electrostatic forces between water molecules and ions are greater than the electrostatic forces between anion and cation of the silver nitrate solute.

Turn 4 of the excerpt above exhibits differentiation between every day and scientific ways of explaining the status of particles in solutions. What everybody sees as calm and still solution, the teacher showed the learners that it’s not the case. With one of her slides shown on Figure 6 below, Mrs Foster managed to differentiate between these two viewpoints.

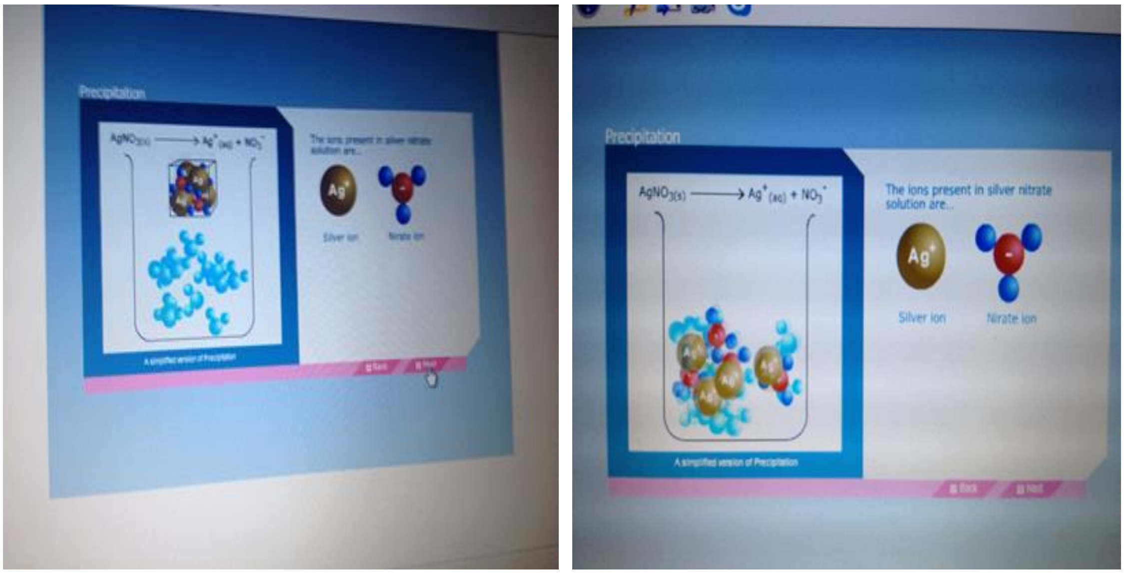

Figure 6: Animation pictures on dissolution of silver nitrate

The diagrams showed water molecules always in constant random motion before the solute was added, as well as after the solute was added. The teacher explained the microscopic level processes that could not be seen at macroscopic level. Thus successfully differentiating between, the everyday interpretation of the phenomenon of the state of water, to that of the scientific view. Learners' contributions were not sought by the teacher to establish learners' views on what they were observing on the animations.

4.2.2 Making links between scientific concepts

Linking scientific concept was one of the top three link-making to support knowledge building in Mrs Foster's lessons. The link-making was more significantly used in lesson 1 with a frequency of 10 and in lesson 3 with a frequency of 7, as shown in Table 8. In lesson one, the concept of strong and weak electrolytes was linked to the concepts of dissociation, chemical equations, acids and bases, reversible reactions and conductivity.

The existence of weak electrolytes was explained by Mrs Foster as due to poor dissociation of molecules because of their ions, which partially dissociate in solution. These are usually weak acids or weak bases, which are reversible reactions. The teacher illustrated her point with a reversible chemical equation of ammonia dissolved in water.

$$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH^{+}_{4(aq)} + OH^{-}_{(aq)}$$

She went on to explain that very few of $NH^{+}_{4(aq)} and\ OH^{-}_{(aq)}$ will be in the solution. Hence it is a weak electrolyte and poor conductors of electricity as very few ions will be available for conduction. The symbol of reversibility was explained. The teacher indicated that they will do more of the reversible reactions in higher grades.

The concept of strong electrolytes was linked to ionic compounds which completely dissociate in water and more ions would be available to be transferred to electrodes. Mrs Foster gave an example of salt (sodium chloride) in water;

$$NaCl_{(s)} + H_2O_{(l)} \longrightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$$

Unlike in ammonia, the ions in sodium solute all dissociate and all available for transfer to electrodes and facilitate conduction of electricity, hence they are good conductors. The interlinks between concepts showed that the teacher had a sound subject matter content and was comfortable in explaining all concepts to the learners. The diagram below shows how the concepts were linked by the teacher.

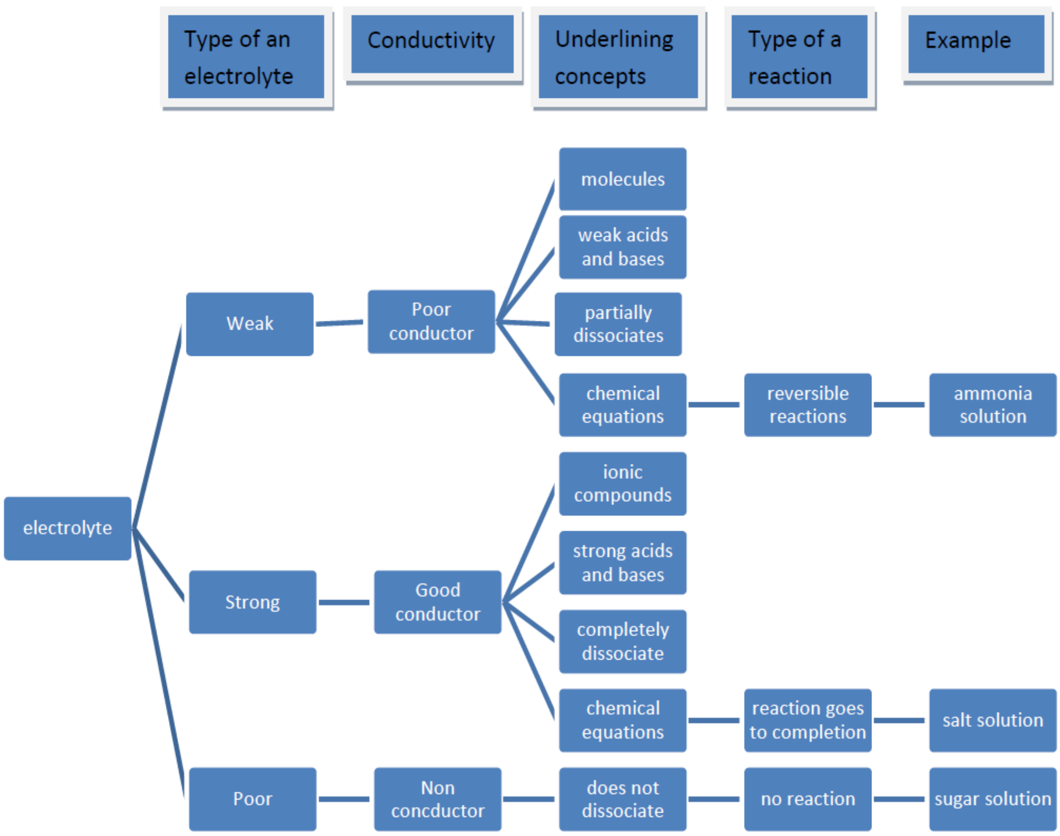

Figure 7: Electrolyte concept web

Although Mrs Foster could not come up with such a diagram as exemplified above, her lesson on electrolytes linked the above concept as deduced and illustrated on Figure 7. The only missing link was the practical activity to demonstrate strong, weak, and poor electrolytes otherwise the teacher did execute the explanation very well. The practical activity could have successfully enhanced the fact that sugar solution is a non-conductor and salt solution conducts electricity very well.

4.2.3 Making links between scientific explanations and real world phenomena

This type of link-making requires the teacher to introduce complex scientific phenomena from simple real world scenarios that learners are familiar with or that can arouse learners' interest. In observing Mrs Foster teaching, lesson 2 and 3 which had such situations with frequencies of 10 and 1 respectively. One of the scenarios in lesson 2 where the teacher made such a link is captured in the excerpt below. The teacher was doing practical demonstrations of halide precipitations as well as sulphate and carbonate precipitation reactions. In this particular scenario the teacher was about to do a practical between barium chloride and potassium sulphate.

1. Teacher: We can also test for sulphates. Sulphates in your water. Now guys this is a very important little test because this actually shows you what happens in our water at home. Sulphates and carbonates can form in your water, in the tap water, in the dam water, in your reservoir water at home. We can call it or they call it hard water, because now it makes a solid that solid goes and sits inside your pipe and you would have seen it on your kettle. Have you ever seen that on your kettle element they might sometimes be white scaly stuff that sticks to it? Have you ever seen it?
2. Class: Yes
3. Teacher: It sometimes builds up there, ok! We have many tricks to get ready of it some people used to put marbles inside it. Because the marbles when the water boils will hit against the element and actually break it off, alright! It's totally safe, it's not gonna harm you, if you ingest some of it. Its normal, it comes in our water. But our hot water pipes usually have this hard water build up, which is this precipitation of certain ions in our water. It can build on the sides of your pipe and after a while, the water won't come through the pipe real nicely. Because now the pipe has kind of being blocked. They start to get blocked and sometimes we need then to replace our pipes or are chemical treated to get ready of it, ok! To get ready of that hard water. Now let's look at one of those hard water precipitates. One of them will be a sulphate, in this case I have barium chloride, and I have potassium sulphate here.

The teacher introduces precipitation reactions of carbonates and sulphates with a real situation that happens in everyday life of hard water. She described where and how hard water is formed, and how some people deal with it in their homes. The learners were not given enough chance to show that they were familiar and really knew about the white deposits in the kettle the teacher was talking about. Although learners agreed that they know about the white stuff in the kettle, learners' prior knowledge about this concept was not solicited for by the teacher. The situation portrayed by the teacher was quite relevant and quite valuable about the scientific phenomena of sulphates precipitates. But whether it raised learner interest or helped learners understand and comprehend the concept was unclear. Learners were not given an opportunity to interact with the teacher and show their understanding on the real life phenomena under discussion.

The simplicity of the precipitates of hard water emanates from the fact that it can be identified at home in kettles and other utensils that boil water. Mrs Foster could have let the learners identify where else the white deposits are seen in the home or somewhere else. In order to determine how familiar the learners are with the concept she was talking about. Instead, the teacher just went on to relate further examples, such as deposits in hot water pipes, neglecting the power of the social plane. The social plane gives learners an opportunity to relate and discuss their experiences on the concept at hand. Without that input from learners one could not be certain that the real life example was interesting to learners or whether it was relevant to them. Whether it actually motivated learners and formed the basis for the better comprehension of the complex scientific phenomena of barium sulphate precipitation reaction, remains unknown.

4.2.4 Making links between different scales and levels of explanations

There are three scales and levels of representations, that include micro, macro and symbolic. In teaching and learning, learners need to move through all three representations for enhancement and comprehension of subject matter in chemistry. According to Table 9, making links between different scales and levels of explanations was the second highest link to be used in the four lessons observed. Among the three scales and levels of representations symbolic was the least used by Mrs Foster and micro and macro had double frequencies to that of symbolic level. These statistics showed that the teacher could move across the three scales of explanations in describing reactions in aqueous solutions.

The excerpt below is from lesson 2 in which the teacher showed learners an animation video of the reaction between sodium chloride and silver nitrate that formed a silver chloride precipitate.

1 Teacher: There goes the sodium chloride. Normal table salt also gets dissolved. Now I have two aqueous solutions that have ions floating around in there. Those four different types of ions that we saw in the beginning; the sodium ion, the silver ion, the chloride ion and the nitrate ion. Now remember once we have our two aqueous solutions, we are set to have our precipitation reaction. Now let's have a look how that happens. There is the two set of solutions getting mixed, now they a mixing ok! They are all mixing, all of them and the water they are still separate. Now what's gonna happen is those that are very electrostatically attracted to each other, those that have great electrostatic force between them. Look at that, the silver and the chlorine very attracted, and look at that! They attracted and make a solid.

2 Class: A solid (together with the teacher)

3 Teacher: they make a solid the other ones are still free, they still going on by themselves; they are not attracted to each other. The water can still keep them apart they are still surrounded and hydrated by the water. But my silver and my chlorine are not hydrated by the water anymore. They have found each other and are now attracted to each other and they make a solid and the solid goes to the bottom of the container. Let's have a look if we leave the solution this is what's going to look like; it forms the solid and the solid will sink to the bottom of the container.

The teacher was narrating and explaining what was being shown on the animation of the reaction between silver nitrate and sodium chloride. There are two levels of explanation the microscopic level, which is the theoretical explanation by the teacher of what was happening at the particulate level. Secondly, the sub-microscopic level is the particulate level that the teacher is using to describe the movement of molecules, as shown in the diagram.

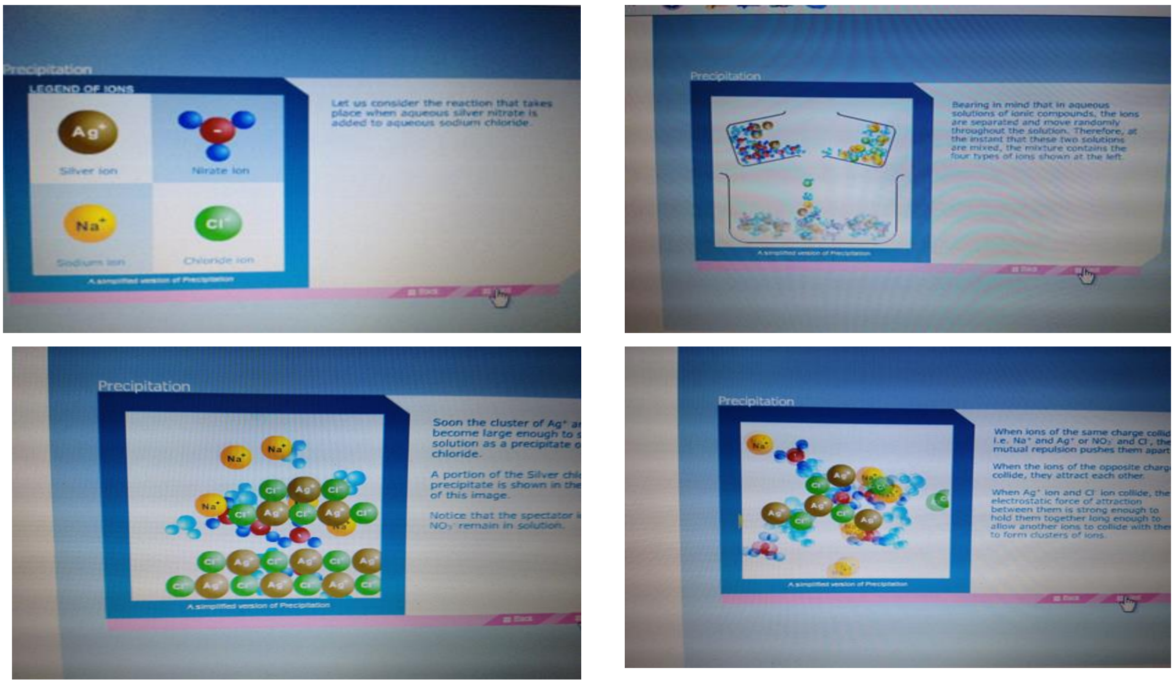

Figure 8: Moving Between different levels of explanations

The first diagram in Figure 8 shows the symbols representing the structures of sodium ion, chloride ion, silver ion, and nitrate ion as used in the animation. The whole animation showed how the silver chloride was formed from two solutions in different beakers. Silver ions and chloride ions were seen sticking together and settling at the bottom of the container. At the end of the reaction, silver chloride was seen out of solution as a solid (macroscopically it is a white precipitate) and the sodium and the nitrate ions were seen still floating around in the water (macroscopically it is clear liquid)

The teacher showed her prowess in the subject matter and in using these levels of explanation in her lesson presentation. Her explanations were explicit and exhibited her understanding of the subject content and the concepts at hand. Unfortunately she failed to involve learners and helping them to switch from symbolic to microscopic level and to the sub-microscopic level. If learners did understand that, one could not tell as evidence to that effect was not revealed through learner participation.

The macroscopic level phenomenon was illustrated by the teacher through a practical demonstration just after the animation video was shown. Mrs Foster had her apparatus and chemicals ready for four precipitation reaction experiments namely to produce silver chloride, silver iodide, barium sulphate and carbonate precipitates. The first demonstration was for silver chloride which was a continuation of the animation show, see excerpt 4 repeated below.

1 Teacher: I'm gonna do the sodium chloride since it is the one that we looked at on the screen here. We looked at sodium chloride and silver nitrate. I'm gonna do that first for you.
(Pouring sodium chloride solutions into a test tube)
Ok! This is my salt solution, sodium chloride. So that means in this one if we look at the ions in there will be sodium ions, which are the cations the positive ones. There will be chlorine ions in there.
Now with my silver nitrate!
(Pouring silver nitrate solution in a measuring cylinder)
You will see that my silver nitrate solution is a clear solution and my salt solution also. Both of them colourless you see. There are colourless and now I'm going to mix the two *(pouring silver nitrate into sodium chloride)*
2 Class Wow!
3 Teacher: Can you see that white, snow white precipitate powder has been formed. It looks like I added baby powder into my solution
4 Enock: It's a solid.
5 Teacher: Yes it's a solid. What's the name of this solid?
6 Gloria: Salt (*hesitating*)
7 Enock: Silver ……. (*Inaudible*).
8 Lerato: Ummm
9 Teacher: what did we have? We have sodium chloride and silver nitrate. What was the solid made?
10 Lerato: Silver Chloride
11 Teacher: Silver Chloride. Yes, silver chloride which is nice and white.

The demonstration by Mrs Foster illustrated the macroscopic level. Some learners were fascinated by the change in colour of substances from colours of reactants to the white precipitate of silver chloride. In this excerpt learner involvement cleared up uncertainties of learners on particular concepts. Gloria was not sure about the solid made but through probing by the teacher, she came to know the substances involved in the reaction and could answer the question correctly. Hence, learners successfully identified the compound that had precipitated as silver chloride. Mrs Foster went on to explain that the other ions; nitrate ions and sodium ions, are still hydrated (surrounded by water molecules). She referred learners back to the animation where these ions were seen floating in random motion together with water molecules.

Mrs Foster successfully linked the three levels of explanations which are, the macroscopic, the symbolic and the microscopic (that includes the sub-microscopic), for comprehension of the concept of precipitation reaction in aqueous solutions.

4.2.5 Making links between modes of representations

The link emphasises the use of different modes of representations by the teacher to help learners draw scientific meaning from scientific phenomena. From the different modes of representation highlighted in Chapter 2, Mrs Foster used chemical equations, diagrams, and pictures in her four lessons. The link-making had the highest frequency as shown in Table 9, with chemical equations topping the list, followed by diagrams, and pictures respectively. Graphical representations were not used in the four lessons by the teacher.

Lesson 2 was rich in these modes of representation; some of them also appeared in the animation video that was shown to the learners. These include diagrammatical, pictorial representations as well as chemical equations, see Figure 9 below.

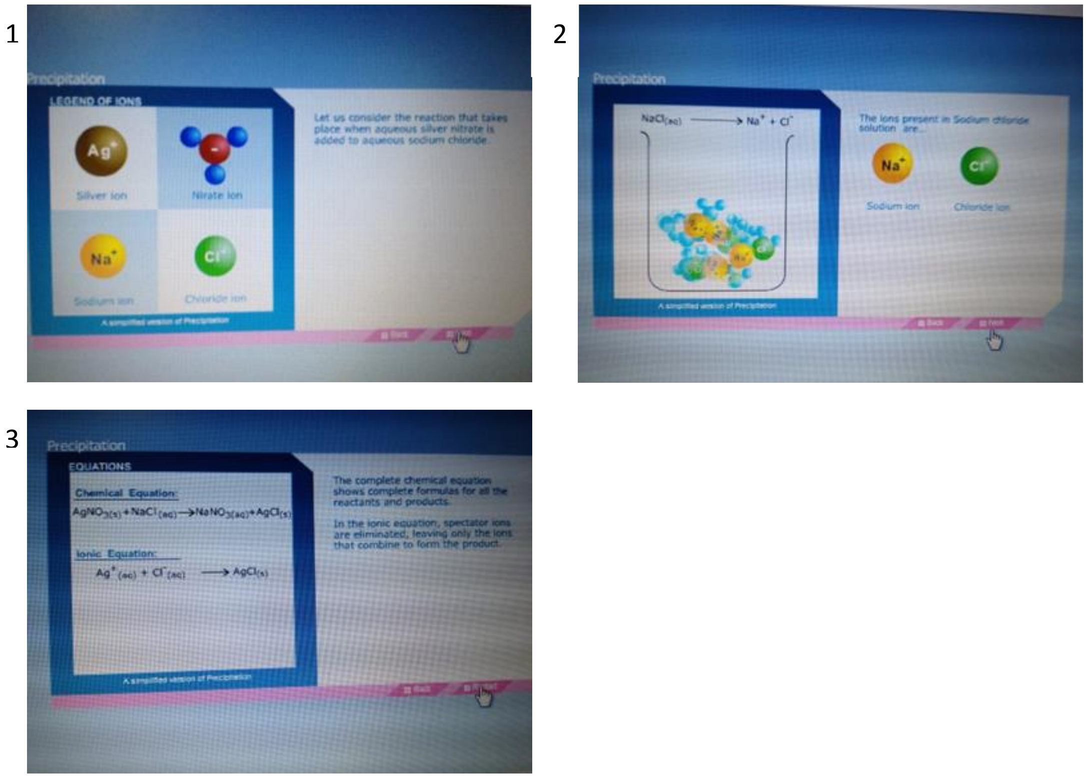

Figure 9: Modes of Representations

In Figure 9, each diagram has at least one mode of representation. Diagram 1 has pictorial representation of the different ions participating in the reaction for the precipitation of silver chloride. Diagram 2 has three modes of representation namely chemical equation, diagram (drawing of a beaker), and pictures of ions dissolved in water. Diagram three has only chemical equations, which represent full chemical equation and the net ionic equation for the reaction between sodium chloride and silver nitrate solutions. The teacher managed to use several modes of representation and in her explanations it was clear that she could move easily from one mode to the other. The purpose of using the modes of representation is to link and clarify scientific concepts to enhance learner understanding of scientific content. Some of the learners during group work in lesson 4, showed understanding by answering questions which were given to access comprehension of the reactions in aqueous.

Throughout the lessons Mrs Foster constantly wrote different equations on the white board. Some of the equations cited in Section 4.2.2, and below are how other equations have been written on the white board when the teacher was discussing redox reactions in lesson and three and part of lesson 4.

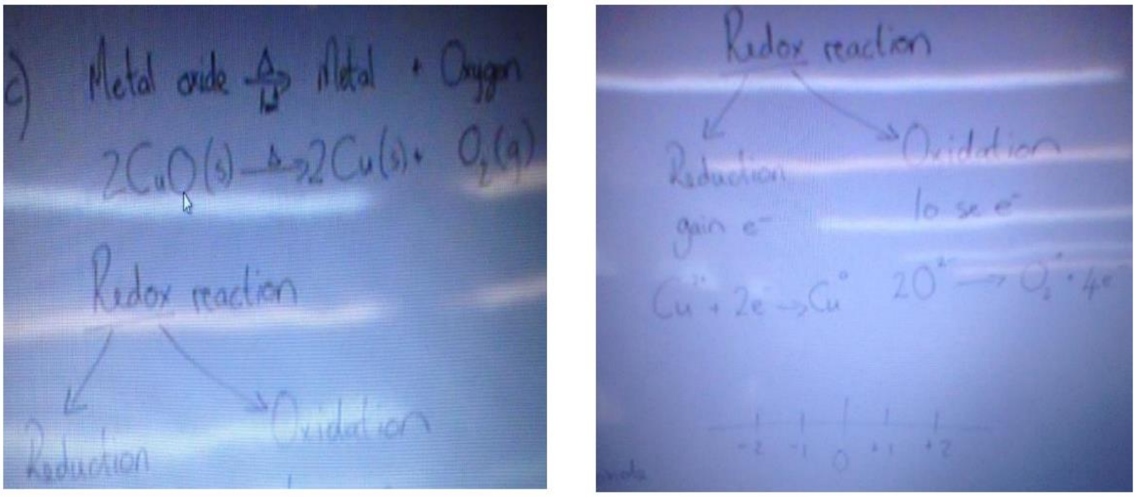

Figure 10: Chemical equation as a mode of representation

In Figure 10 a word equation was used followed by chemical equation to illustrate redox reactions. Thereafter, ionic equations were drawn to illustrate electron transfer using the number line diagram. The number line diagram was used to determine which species have lost electrons because its oxidation number will increase from left to right depicting oxidation; the loss of electrons. Reduction, the gain in electrons was illustrated by a decrease in the oxidation number represented by shift from right to left on the number line. Again Mrs foster magnificently engaged the use of multimodal representation for her learners to grasp the scientific abstract knowledge.

4.3 Discussion

The pedagogical approaches used in the four lessons taught by Mrs Foster in this case study was summarised as shown in Table 7 in section 4.1.0. It is significant that table 7 showed that question and answer was a prevalent approach to teaching and learning by Mrs Foster. The way the teacher engaged learners in her lessons showed two forms of interactive patterns and these were *I-R-E* and *I-R-P-*

R-P-R-E. The most common pattern employed by the teacher was the *I-R-E* pattern, which research has shown that is the most common approach used in science classrooms (Aguiar *et al.*, 2010; Scott *e. al*., 2006; Lemke, 1987). Usually the teacher would quickly evaluate learners' answers and move on to the next concept she wants to cover, without allowing any further debate of the concept with learners. Such a kind of teacher-learner engagement does not support conceptual understanding, rather than the *I-R-P-R-P-R-E* pattern where the teacher will be prompting and paraphrasing the questions seeking learner contribution that augment conceptual comprehension of science concept (Scott *et al*., 2006). This pattern was occasionally employed and allowed by the teacher. See excerpt 4 above that cleared learners' misconceptions about the concept which was being discussed.

The teacher was supposed to have introduced the questions to the learners for classroom discussion, the social plane of interaction and to have facilitated the debating guiding learners to the required scientific view point. The teacher is identified as an expert figure with a critical role of facilitating and passing on scientific concepts to the learner (Scott, 1998). The teacher took on this role of scientific concept mediator in lesson 4 during class activity where learners were answering questions to sum up the topic.

The importance of practical work is that of mostly 'hands on' by the learners to enhance their understanding of scientific concept and draw meaning from what they will be learning (Johnstone, 1991). In practical work, there is a need for learners to do experimental activities in the classroom and not only be observers of the teacher's demonstrations. In this study the teacher carried out all class demonstrations and only engaged learners in discussing observations made during the experiment activity.

Although time is a constraint for learners to do experiments, the teacher could at least have allowed more discussions about what had been observed during the practical demonstrations. In most cases the teacher hardly allowed discussions, instead, she explained everything to the learners including some of the observations. See except 3 and 4. The socio-constructivists argue that learning is a social matter and acquisition of knowledge and attainment of meaning learning takes place through social interactions within the social environment (Scott *et al*., 2011; Wertsch, 1985; Vygotsky, 1978).

During the animation show, the teacher adopted the narrator's role as she recounted most steps of the animations without much learner involvement. Such an approach is detrimental to the meaningful acquisition of knowledge by the learners. Learners are not blank slates where content knowledge is inscribed (Von Glasersfeld, 1991). Learners bring prior knowledge into the science classroom which the teacher must recognise and appreciate through classroom discussions. Some of the naive concepts they bring are so persistent that transmission method or authoritative discourse cannot correct and eradicate them. Therefore the teacher could at least have let the learners contribute what they were saying for her to discover learner misconceptions on the reactions in aqueous solution. In order to address those misconceptions as well as reinforcing positive contribution, she would be appreciating the fact that the teacher is not the sole knowledgeable person in the classroom (Scott, 1998).

Making links between every day and scientific ways of explaining was referred to with limited frequency in this study. The lack of learners' involvement did not give much of everyday ways of explaining how learners perceive salt dissolution. Had the teacher instituted a discussion with learners on this concept, a lot of learners' preconceived ideas would have sprouted during the discussion, such as recorded in literature that salt will disappear into nothing; it will melt; sugar dissolves into nothing; or that it eventually becomes water or changes into liquid salt (Valanides, 2000; Lee, Eichinger, Anderson, Berkheimer, & Blakeslee, 1993). In this study, the teacher provided the everyday explanation as well as the scientific explanation but the study by Valanides (2000) showed that learners as well can give plausible scientific explanations in terms of microscopic level. Hence, the teacher could have involved learners by allowing them to air their views before she provided the scientific view of explanation. Involvement of learners in classroom discussion helps the teacher to ascertain the Zone of Proximal Development of learners from which the teacher will guide them through beyond their ZPD. This ensures conceptual comprehension of the scientific concepts by the learners.

The link-making between scientific concepts was more significantly used in lesson 1 with a frequency of 10 and in lesson 3 with a frequency of 7, as shown in Table 4.1. In lesson one, the concept of strong and weak electrolytes was linked to the concepts of dissociation, chemical equations, acids and bases, reversible reactions and conductivity. These topics were linked based on whether they were within the same topic of reactions in aqueous solution or from other topic within the chemistry body of knowledge. Dissociation was in the topic of reactions in aqueous solutions, whereas the rest was from across the body of chemistry. As illustrated in figure 4.5 reversible reactions would be covered in higher grades and acids and bases was a topic that was covered earlier in grade 10.

Making links between scientific explanations and real world situation had a frequency of 12 in all four lessons and lesson 2 had the highest frequency of 10. Scott *et al.* (2011) argues that it is the learners who must link the real world phenomena to the science concept for conceptual understanding. The teacher introduces the situation and through discussion learners must be able to link it to their life experiences. That linkage of life experience and the scientific concept bring about understanding.

Mrs Foster managed to move with ease and switch between three levels of representation in her lessons. She showed complete mastery of content and understanding of the science concepts and could tell her story with ease. Her prowess in the subject matter is of vital importance to the teaching and learning of science and it should benefit learners. In this study on the levels of representation, the learners observed the teacher moving from one level to the other as spectators. It is not only the teacher that must be able to navigate between macroscopic, microscopic and symbolic but also the learners. Chandrasegaran *et al*. (2008) argue that students should be able to traverse between the levels of representation and should be able to use each representation at the right stage of reasoning. For learners' conceptual understanding of the three levels of representation, there was need for the teacher to invite learners to describe and comment on the animations and practical activities that were shown and demonstrated respectively in lesson 2. Gabel (1999) argues that learners have difficulty to see the interconnectedness of the microscopic, symbolic, and macroscopic hence the teacher has to facilitate the integration of the levels through teacher - learner dialogic interaction.

During the execution of making links between different scales and levels of explanation, it was eminent that the teacher did not present all three levels at once to learners. This was a quite remarkable pedagogical approach which simplified the abstractness of the reactions in aqueous solution to a certain extent. For research did find out that simultaneous reference to microscopic, symbolic, and macroscopic renders the comprehension of molecular chemistry difficult (Gabel, 1999; Gabel, 1998 & Johnstone, 1991). This notion is supported by the findings of Chandrasegaran *et al*. (2008, p 294) which states that

> *"the aquisation of knowledge by students without a clear understanding may be attributed to the confusion caused in having to deal with simulatneously with macroscopic, submicroscopic and symbolic worlds of chemistry"*

Mrs Foster referred to two levels of thought (levels of representations) at a time and covered all three as she was moving from one level to another. For example in lesson three she concentrated on macroscopic level and microscopic thought and placed much emphasis on the symbolic. During the first half of lesson 2 symbolic and microscopic were emphasised and the last half of lesson 2 dealt with practical activities and emphasised macroscopic and symbolic, see Figure 11 below.

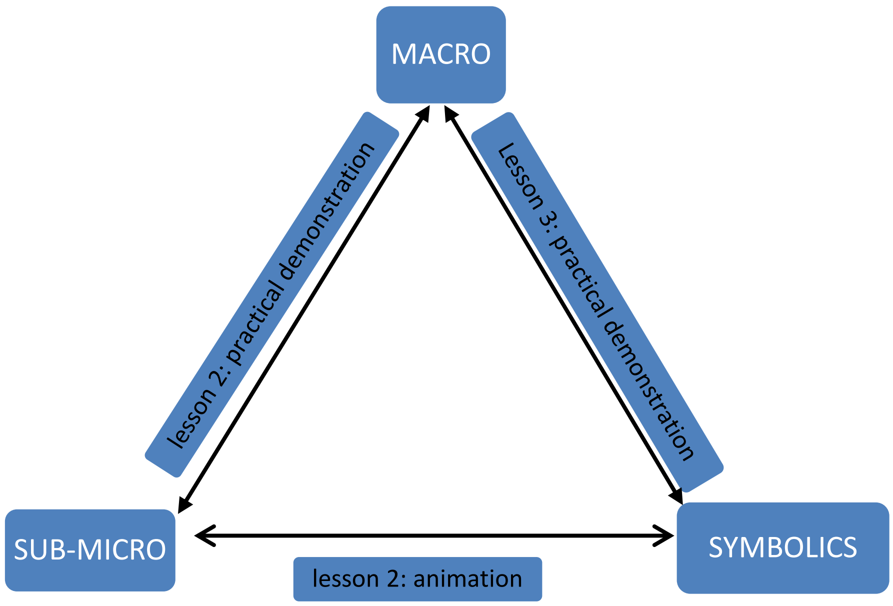

Figure 11: Triangle of thought and pedagogical approaches

Mrs Foster never tried to move to the centre of the triangle consistent with the argument of Johnstone (1991) that moving at the centre of the triangle, is overloading learners thereby complicating the understanding of the science concepts.

The inclusion of the animation in Mrs Foster's pedagogical instruction was consistent with scientific research recommendations when teaching abstract topics such as reactions in aqueous solutions. Kelly and Jones (2007) argue that the nature of reactions in aqueous solutions are concepts learners have difficulty to understand and the incorporation of animations of chemical processes at molecular level neutralises the complexity of the concepts. By reducing the abstruseness of the concepts, animations offer a comprehensive model for construction of conceptual representations that also reduce mental processing load (Cook, 2006). Animations become useful when learners are interacting and involved in the discussions of what they are observing. In this study, the teacher was supposed to let the learners narrate what they were seeing and probe them to explain why silver and chlorine were attracted to each other as an alternative to explaining everything to learners.

The narration by the teacher and the minimum class discussions of the animations reduced the benefits and purpose of screening animations in this case study. For research asserts that animations foster conceptual understanding when learners are given an opportunity to explain or/and question their observations during the show (Cook, 2006; Kelly & Jones, 2007). Nevertheless, the teacher effectively used the power of playback invested in animation as she occasionally replayed the animations, to emphasis her presentations and arguments.

Mrs Foster could have made her lessons more beneficial to learners had she solicited learners' prior knowledge and built on it as she progressed with her demonstrations as well as animations. Cook (2006) argues that prior knowledge influences perception, attention, as well as conceptual learning. When Mrs Foster was informally asked why she would not allow learners to participate in the practical demonstrations, she bemoaned the time constraint and as well as the time frame given by the department of education through their prescribed work schedule. She indicated that there was less time to cover the content in the work schedule and learners need more time to do experiments. Her argument was that it is of no use to rush learners in doing experiments for they will not benefit much so she resorted to doing the demonstrations to save time.

The topic 'Reactions in aqueous solutions' has limited modes of representation since there are no geometric and algebraic calculations as well as no graphical representation. But it is reach in chemical equations and one will expect the teacher to deal only with equations throughout the lesson. Mrs Foster did overcome that shortcoming by choosing an animation which was rich in pictures, diagrams and she further illustrated her explanations by drawing her own diagrams. For example, in explaining redox reactions and how learners can check the oxidised and reduced species, she employed the use of the number line which she drew on the board. This mathematical tool proved to be useful to learners during their discussions and class activity as they used the number line to predict whether the reaction was redox or not.

Figure 8 above shows how Mrs Foster intelligently paraphrased the simultaneous reduction and oxidation processes of decomposition of copper oxide. Beginning with word equation which learners were mostly familiar with from grade 9 natural science, she took the learners through all the steps on how copper would gain electrons and skilfully used the number line to show how it was reduced. The type of such pedagogical approach was approved by Cheng and Gilbert (2009) when they argued that scientific understanding is generally made by amalgamation of several modes of representation within a lesson, for one mode is not adequate to bring about meaningful comprehension of scientific concept. Stand-alone chemical equations do not show much as they lack the reaction mechanism (Davidowitz *et al.*, 2010). But through her paraphrasing Mrs Foster tackled the reaction mechanism of the decomposition of copper (II) oxide. Hence the teacher showed her prowess in conveying her subject matter content for the benefit of the learners.

4.4 Conclusion

The general findings of this study are that the teacher did make use of the pedagogical link-making to support knowledge building in the teaching of reactions in aqueous solutions. This chapter also discussed in detail how the five features of knowledge building have been fused with the teaching approaches employed by the teacher. Conclusions and recommendations would now be alluded to in the next chapter.

CHAPTER 5: CONCLUSION

5.0 Introduction

The results of this study show that Mrs Foster was able to use and incorporate the five features of pedagogical link-making to support knowledge building in the teaching and learning of reactions in aqueous solutions. This chapter provides some concluding remarks on how these features of pedagogical link-making were used in Mrs Foster's lessons in conjunction with her other pedagogical approaches. Lastly, recommendations for further study will be discussed.

5.1.0 Summary of findings from Mrs Foster's lessons

5.1.1 Teaching and Learning Approaches

Mrs Foster employed not only the question and answer approach in her teaching but also used practical demonstrations and animations to diversify her teaching and learning methods. The question and answer method was the most prevalent approach to teaching and learning in lessons observed. The teacher mostly used the class discussion and group discussions in the last lesson when she was concluding the topic. It seems that the power of mediation was mostly ignored or reserved for the concluding lesson. However, literature records that it should rather be the main focus of the teaching and learning for comprehension of the subject matter (Leach & Scott, 2003; Wertsch, 1985).

The diversity of methods of teaching and learning shown in chapter 4, Table 7 ensured learner attention and interest was kept high as repetition of one teaching approach is monotonous and discourages and dampen learners' attentiveness. The diversity of approaches involved the use of animations in the teaching of precipitation reactions. These animations became an integral approach in the teaching of abstract phenomena such as reactions in aqueous solutions for they are highly interactive and can be relied on to focus learner attention on particular concepts (Kelly & Jones, 2007; Cook, 2006).

However due to time constraint teachers are in away forced to use traditional ways of teaching, which are transmission method in order to cover syllabus as eluded to by Mrs Foster during our informal discussion. Nevertheless, teachers also tend to fall back to easier ways of teaching (transmission approach) which does not need a lot of preparation unlike other approaches that calls for intense preparations. Although Mrs Foster used transmission method in all her four lessons, she managed to embark on other approaches like animation, group work and demonstrations. Considering the abstractness of the topic under which she was observed, she would be commented for her efforts to engage herself to other approaches to enhance her learners' comprehension of the physical science. Such efforts, to some extend can be due to the postgraduate course she attended with UNISA, where pedagogical approaches have been emphasised. As a researcher, I could not ascertain if Mrs Foster's approaches have helped her learners' to understand the topic better for I did not administer any tests to come to such conclusions. Her use of different approaches to the teaching of science even with abstract topics such as Reactions in Aqueous Solutions could also be attributed to her improved performance to the school's physical science matric passed rate.

5.1.2 Pedagogical link-making to support knowledge building

Mrs Foster managed to link scientific concepts in her lessons very well. The links were within the lesson; between lessons; between chemistry topics and between different grades. The teacher successfully linked the chemistry concepts during the lessons and recognised that scientific concepts cannot be treated in isolation but are interlinked. Lemke (2000) argued that science concepts cannot be used one at a time for their usefulness emanates from their interconnectedness. Scott *et al*. (2011) argued that the teacher and the learners make the links of the science concepts for meaningful learning and for learners' comprehension of the subject matter. However, in most cases it was only the teacher who made the links; the learners were passive recipients of the teacher talk. The teacher could have facilitated dialogic interaction with learners to manage conceptual development and foster understanding. The teacher could have done this by introducing the link-making to the social plane and let learners discuss it. Meaning-making can best be achieved through collaboration among learners on the social plane (O'Loughlin, 1992).

The teacher in this study successfully drew scenarios which were appropriate and relevant to learners' experiences, for example with hard water. The real world phenomena referred to in the teaching context should have bearing of life experience of the learner (Gabel D. L., 1998; Scott *et al*., 2011). Mrs Foster managed to do that in her examples of hard water in kettles and water pipes. The only problem was that learners were not afforded an opportunity to present their views and understanding of the world situation introduced by the teacher. In this regard, there was a lack of learner expressions about their understanding of the world phenomena hence one cannot predict or conclude if conceptual learning took place.

The coupling of animations and practical demonstrations strengthened the teacher's pedagogical approach to achieve learner understanding. It has been seen that teaching at macroscopic level arouse learners' interest and their involvement in the class discussions facilitate learner comprehension of science concepts (Kelly & Jones, 2007).

The teaching approaches used by the teacher were relevant and appropriate in seeking and fostering meaningful acquisition of scientific knowledge. The lessons had only a few instances of learner participations, hence the classroom discourse was predominantly authoritative dialogic interaction instead of being balanced with dialogic discourse. The authoritative dialogic interaction only fosters scientific point of view and disregard learners' perception of concepts at hand as well as societal view about science. Such an approach to teaching and learning concentrates on the development of the scientific story (Scott *et al.,* (2011). The approach does not recognise and incorporate learners' ideas and hampers meaningful comprehension of abstract scientific concepts.

Teachers, who do not seek learners' prior knowledge on most of the concepts taught in the classroom, regard learners as without much knowledge of the concept at hand or just the need to cover the syllabus so as to be at par with the work schedule. In this case the assertion above cannot be conclusive unless the researcher had further interviewed the teacher after the lessons as a follow up and not relying solely on informal discussions with the teacher.

The key features of the socio-constructivists approach such as, group discussions, teacher-learner interactions and relevant real world situations were observed in this study. But the lack of intense classroom discussion of the *I-R-P-R-P-R-E* pattern supersedes such features and labels the teacher's approach as authoritative dialogic discourse. Research has it that authoritative dialogic discourse does not support meaningful learning (Mortimer & Scott, 2003; Gabel, 1998; Johnstone, 1991).

Mrs Foster effectively used the pedagogical link-making to support knowledge building that teachers are encouraged to use by Scott *et al*. (2011) in their study of the fundamental aspect of teaching and learning scientific conceptual knowledge. Although the topic understudy was very abstract, the teacher used her sound chemistry background to effectively use the pedagogical link-makings.

5.2 Recommendations

The study focused on only one aspect of the three pedagogical link-making and the other two aspects namely; to promote continuity and to encourage emotional engagement were not covered for pragmatic reasons in this study. I recommend that further studies should integrate all three aspects for a more holistic understanding of the teacher's practice. It would be interesting as well, to broaden the case to be also an experimental research also and investigate how learners who are taught without the use of the pedagogical link-making, perform compared to those learners taught using the full pedagogical link-making approaches.

5.3 Conclusion

The chapter discussed how Mrs Foster used different teaching approaches in her four lessons that were observed and these were question and answer, animations, group work and transmission approaches. Section 5.1.2 dealt with the pedagogical link-makings that were used by Mrs Foster and last some recommendations were highlight to conclude the study.

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Appendix A: Differences and similarities of Lessons

	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Lesson topic	Electrolytes	Precipitation reaction. Slide show and practical demonstration.	Other reactions in aqueous solutions	Consolidation
Summary	The teacher started with revision of homework, she was quick and gave answers to learners, no discussion of questions because of time. Definition of Electrolytes was discussed with the whole class. Thereafter the teacher went on to explain good, weak and bad electrolytes in a transmission method. Promised to do a demonstration of conductivity but couldn't do it because of time. The teacher ended the class with a class exercise on the discussed concepts. Homework was then given. The teacher move around checking and helping learners. She dealt with individuals as they asked questions and discussed with the teacher.	Teacher checked homework but did not discuss with the learners. Instead she checked if all learners had done homework from one learner to the other which she didn't do in the previous lesson. Her argument for not revising was the time was limited since it was test day hence periods are shorter and in that double she needed to do some practical demonstrations. The activities included learning answering questions given to learners as homework. She did a recap of precipitation reactions.	Lesson 2 was disturbed when some of the learners were called to the hall by the principal. Hence the teacher started the lesson by reminding the learners of the previous lesson and their homework. Homework was revised and the lesson of the day was started. The lesson dealt with redox reactions; acids and bases and gas forming reactions The lesson was in transmission method again and it ended with homework.	The teacher finished the topic on redox reaction which could not be completed on the previous day. She went on to discuss homework given to learners. Thereafter learners did an activity in class which included all the reaction in aqueous solutions except electrolytes. Learners were allowed to discuss in pairs or in a group of three pupils. The teacher was moving from one pair to another or one group to another discussing with learners. The lesson was not that transmission any more but teacher learner interaction mostly on an individual basis.
Major linking making approach	The major link-making apparent in this lesson was making links between scientific concepts. With limited modes of	Almost all pedagogical link-making approaches were represented in this lesson but the most prominent ones were	In this lesson linking scientific concepts was prominent as well as chemical	No major link-making was recorded.

	representations which were only reduced to chemical equations.	making links between different scales and levels of explanation and making links between modes of representation	equations.	

Appendix B: Time Line Data Analysis

	KB1-1	KB1-2	KB2	KB3	KB4-1	KB4-2	KB4-3	KB5-1	KB5-2	KB5-3	KB5-4	KB6
L1			01:10 02:06 02:40 05:25 18:05 18:25 18:45 21:45 22:35 25:00				21:45		07:15 11:00 15:45	09:10 19:35 21:17		
L2	10:00 14:41 25:03 27:40		15:40 20:46 21:45 28:05	14:41 14:47 1527 15:37 17:55 21:54 23:45 25:45 26:45 27:20	06:55 08:21 08:52 09:05 09:34 09:41 10:00 10:30 10:56 12:06	14:41 15:27 16:07 18:39 19:25 21:35 22:40 23:00 26:45		08:21 09:05 09:18 10:00 10:30 10:49 10:56 11:30 12:02	08:21 08:52 09:05 10:00 10:30	09:05 12:31 12:27 13:14 21:02 30:04 31:36 32:30		
L3	04:22		03:20 04:00 08:18 09:01 10:25 15:10 24:00	01:37 04:15		11:45	14:36 15:25 19:25 23:20		28:55	01:25 14:25 15.16 18:35 23:45 28:11		
L4			02:25 05:26							01:22		

Appendix C: University of Witwatersrand Ethics Clearance Letter

Wits School of Education

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

Student Number:
509419

Protocol Number:
2013ECE082M

Date: 22 July 2013

Dear Brighton B Mudadigwa

Application for Ethics Clearance: Master of Science

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

Teacher use of pedagogical link-making in the teaching of chemical change.

The committee recently met and I am pleased to inform you that clearance was granted. However, there were a few small issues which the committee would appreciate you attending too before embarking on your research.

The following comments were made:

- In the Information Letter to learners there is a small error which you need to correct before proceeding with the research. The error occurs in the paragraph beginning

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

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

All the best with your research project.

Yours sincerely

MMabeta

Matsie Mabeta
Wits School of Education

011 717 3416

Cc Supervisor:

Cc Supervisor: Ms. A. Msimanga

Appendix D: Gauteng Department of Education Approval Letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2014/129

GDE RESEARCH APPROVAL LETTER

Date:	3 July 2013
Validity of Research Approval:	3 July 2013 to 20 September 2013
Name of Researcher:	Mudadigwa B.
Address of Researcher:	P.O. Box 430
	Nigel
	1490
Telephone Number:	011 814 8185 / 083 295 3226 / 076 902 4835
Fax Number:	011 814 1396
Email address:	bbmudadigwa@yahoo.com
Research Topic:	Teacher use of pedagogical link-making in the teaching of chemical change
Number and type of schools:	ONE Secondary school
District/s/HO	Gauteng East

Re: Approval in Respect of Request to Conduct Research

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

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

Makhado
2013/07/04

1

Making education a societal priority

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

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Dr David Makhado

Director: Education Research and Knowledge Management

DATE: 2013/07/04

2

Making education a societal priority

Office of the Director: Knowledge Management and Research

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

Appendix E1: Information for the School Principal

Protocol Number: 2013ECE082M

Information for the School Principal

University of the Witwatersrand, Johannesburg, South Africa
School of Education

SCIENCE EDUCATION MASTERS RESEARCH PROJECT

Brighton Mudadigwa
Wits school of Education
Marang Centre for Mathematics & Science Education
27 St Andrews Road
Parktown, 2193

Cell: 0769024835

E-mail:bbmudadigwa@yahoo.com OR Bbmudadigwa@gmail.com

The Principal

Dear Sir/Madam

Re: REQUEST FOR PERMISSION INTO YOUR SCHOOL AS A RESEARCH SITE

I am a student at the University of Witwatersrand. I am currently studying for an MSc degree in Science Education. As part of the requirements of the programme, I am proposing a research study in the area of teaching and learning of science. I am requesting permission to use your school as a research site. The research aims at firstly, illuminating and elucidating South African secondary school teachers' and learners' classroom interaction during a science lesson. Secondly, the study seeks to explore how teacher makes use of the pedagogical link-making in the teaching of chemical change.

My research focuses on Grade 10 teacher's and learners' classroom engagement. The specific activities will be to audio and video record two lessons of the teacher teaching on the topic of aqueous solutions of chemical change. In these activities, I will be working with the teacher as a facilitator. In the research, I will be focusing on how the teacher's and learners' classroom interaction relate to the development of learners' understandings of the scientific concepts. I will be working with one Grade 10 Physical science teacher at your school and I propose to meet her two times during the period the teacher will be dealing with the section on aqueous solutions during term three.

I am aware of the ethics of human subject research and I have put in place a number of provisions to safeguard both the teacher and learners in this project.

For example, I do not intend to disrupt any school activity. Lessons will be observed the way they are being conducted within the normal school timetable. Other ethical considerations include:

- Data collected will be used strictly for the purposes of the research, and will be reported in the thesis to be submitted to Wits and in papers for conference presentations and publications.
- Written consent will be obtained from the teacher and learners (see attached)
- I will make the final report available to your school after its examination by the University of Witwatersrand.

Please feel free to contact me at any time if you have questions or concerns about the research.

Yours sincerely

________________________ _____________

Mudadigwa Brighton Date

Researcher

Appendix E2: Information for the Teacher

Protocol Number: 2013ECE082M

Information for the Teacher

University of the Witwatersrand, Johannesburg, South Africa
School of Education

SCIENCE EDUCATION MASTERS RESEARCH PROJECT

Brighton Mudadigwa
Wits school of Education
Marang Centre for Mathematics & Science Education
27 St Andrews Road
Parktown, 2193

Cell: 0769024835

E-mail:bbmudadigwa@yahoo.com OR Bbmudadigwa@gmail.com

Dear Teacher,

RE: INFORMATION AND REQUEST FOR PARTICIPATION CONSENT

Introduction

I am a student at the University of Witwatersrand. I am currently studying for an MSc degree in Science Education. As part of the requirements of the programme, I am proposing a research study in the area of teaching and learning of science. I am requesting permission to use your school as a research site. The research aims at firstly, illuminating and elucidating South African secondary school teachers' and learners' classroom interaction during a science lesson. Secondly, the study seeks to explore how teacher makes use of the pedagogical link-making in the teaching of chemical change.

Description and Invitation

You are hereby invited to participate in the study. The proposed research will be carried out in your school. It involves you doing your normal everyday teaching of Grade 10 Physical Science but I will only be involved when you are teaching aqueous solutions in the Chemistry section. My research focuses on Grade 10 teacher's and learners' classroom engagement. The specific activities will be to audio and video record two lessons of the teacher teaching on the topic of aqueous solutions of chemical change. In these activities, I will be working with the teacher as a facilitator. In the research, I will be focusing on how the teacher's and learners' classroom interaction relate to the development of learners' understandings of the scientific concepts. The research will cover two periods in the third quarter of 2013.

I will make copies of lesson plans for all the observed lessons. The research does not seek to evaluate your performance as a science teacher. It will not affect your regular teaching as lesson observations will be done during your normal class times.

If you give me permission, data collected will be reported in the thesis to be submitted to the University of Witwatersrand. The data will also be reported in papers for conference presentations and publications with your permission. Video clips of your lessons with you in them will be shown at conferences and may also be used for purposes of research and teacher-education and training.

Risks and benefits of Being Part of this Research Study

There are no foreseeable risks involved in participating in the study. No remuneration will be due to you for participation in this study. Benefits will be in terms of contribution to knowledge and understandings of the Teaching and learning of science. You are also likely to improve understanding of the intended new curriculum and possible learner misconceptions in science and particularly in the teaching of aqueous solutions in chemical change in grade 10 physical science. Should you have any concern about participation or questions to ask about the proposed study, please contact me? My contact numbers are provided at the top of this information sheet.

Volunteering to Be Part of this Research Study- Participant rights

Participation in the study is completely voluntary. You are free to participate in this research study or to withdraw at any time without any consequences. If after reading this information, you decide to participate in the study and give consent to that effect; your participation will be voluntary. You will have the right to answer any question and/or withdraw from part of the study without any penalty. Any information obtained during this study, which could identify you, will be kept strictly confidential and anonymous. Your privacy and research records will be kept confidential to the extent of the law. Unless you request otherwise, your name will not be used in my thesis and other academic writings about the study. Only pseudonyms will be used.

Video and audio recordings

You may agree to participate in the study but if you so wish not to allow video clips with you in them to be shown to any audience, and then your wish will be respected. Just indicate your wish on the attached consent form. Once tapes are no longer needed for research and teaching purposes (probably after five years of this study), they will be destroyed.

Consent

Please complete, sign and return the attached forms. An extra copy of each form is for your own records.

Thank you

Yours sincerely

____________________________ ___________

Brighton Mudadigwa Date

Researcher

Appendix E3: Information for Parents/Guardian/Learners

Protocol Number: 2013ECE082M

Information for Parents/Guardian/Learners

University of the Witwatersrand, Johannesburg, South Africa
School of Education

SCIENCE EDUCATION MASTERS RESEARCH PROJECT

Brighton Mudadigwa
Wits school of Education
Marang Centre for Mathematics & Science Education
27 St Andrews Road
Parktown, 2193

Cell: 0769024835

E-mail:bbmudadigwa@yahoo.com OR
Bbmudadigwa@gmail.com

Dear Parent/Guardian/Learner

RE: INFORMATION AND REQUEST FOR PARTICIPATION CONSENT

Introduction

I am a student at the University of Witwatersrand. I am currently studying for an MSc degree in Science Education. As part of the requirements of the programme, I am proposing a research study in the area of teaching and learning of science. I am requesting permission to use your school as a research site. The research aims at firstly, illuminating and elucidating South African secondary school teachers' and learners' classroom interaction during a science lesson. Secondly, the study seeks to explore how teacher makes use of the pedagogical link-making in the teaching of chemical change.

Your child's school has been selected as the place for the research. The Principal has granted permission to conduct the study in your child's school and your child's Physical Science teacher has given her consent to participate in the study.

Description and Invitation

You/your child is hereby invited to participate in the study. As part of the study, I will observe about two physical science lessons during the tenure they will be aqueous solutions in Chemistry section. I will audio and video record the two lessons. You/ your child can voluntarily participate if you/he/she so wishes. The research will not have anything to do with your child's performance report in Physical Science.

Confidentiality

Unless you request otherwise, you/your child's name will be kept confidential at all times and in all academic writings about the study. If you give permission, video clips of Physical Science lessons with your child in them will be shown at conferences and used for purposes of research, teacher education and training as well as curriculum reform activities.

Risks and benefits of Being Part of this Research Study

There are no foreseeable risks involved in participating in the study. The study will have no effect on your child's Physical Science marks. You/your child will not be paid for participating in the study. Benefits will be in terms of contribution to knowledge and understandings of the Teaching and learning of science. You are also likely to improve understanding of the intended new curriculum and possible learner misconceptions in science and particularly in the teaching of aqueous solutions in chemical change in grade 10 physical science. Should you have any concern about participation or questions to ask about the proposed study, please contact me. My contact numbers are provided at the top of this information sheet.

Volunteering to Be Part of this Research Study- Participant rights

If you/your child have read through this form and have decided to participate in this project, kindly understand that you/your child's participation is voluntary and you/your child has a right to withdraw consent or discontinue participation at any time without penalty. You/your child have/has the right not to answer particular questions. Your/your child's individual privacy will be maintained in all published and written data resulting from the study. Pseudonyms will be used always.

Video and audio recordings

If you/your child may agree to participate in the study but so wish not to allow video clips with you/him/her in them to be shown to any audience, and then you/your child's wish will be respected. Just indicate you/your child's wish on the attached consent form. Once tapes are no longer needed for research and teaching purposes (probably after five years of this study), they will be destroyed.

Anonymity and confidentiality

The anonymity and confidentiality of your/your child's participation is guaranteed at all times.

Consent

Please complete, sign and return the form below, indicating whether you agree or do not agree to participate.

Thank you.

Yours sincerely

____________________________   __________
Brighton Mudadigwa   Date
Researcher

Appendix E4: Audio and Video-Recording Consent Form for the Teacher

Protocol Number: 2013ECE082M

Audio and Video-recording consent form for the teacher

I,……………………………………………………of…………………………………
…….
(School) have read and understood the procedures involved in the study and what is expected of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to participate in the study.

☐ Yes ☐ No

I give consent to being video recorded while teaching Physical Science lessons

☐ Yes ☐ No

I give consent to being audio recorded while teaching Physical Science lessons

☐ Yes ☐ No

I give consent for videotapes with me in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for audiotapes with my voice in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for audiotapes and videotapes with me in them resulting from this study to be kept for up to five years

The extra copy of this form is for you to keep

Thank you.

____

Signature of teacher

____

Date

____

Please print your name

Appendix E5: Lesson Plans Consent Form for the Teacher

Protocol Number: 2013ECE082M

Lesson plans consent form for the teacher

I,………………………………………………of……………………………………. (School) have read and understood the procedures involved in the study and what is expected of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to participate in the study.

☐ Yes ☐ No

I give consent for my lesson plans and other material pertaining to Chemistry practical investigations to be photocopied

☐ Yes ☐ No

The extra copy of this form is for you to keep

Thank you.

______________________________ ____________

Signature of teacher ***Date***

____

Please print your name

E6 E6: Audio and Video Recording Consent Form (Parent/Guardian)

Protocol Number: 2013ECE082M

Audio and Video recording consent form (Parent/Guardian)

I,…………………………………………………………of …………………………………………………………………………………………… (address) have read and understood the procedures involved in the study and what is required of my child as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing to allow my child to participate in the study.

☐ Yes ☐ No

I give consent for my child being video recorded during Physical Science lessons

☐ Yes ☐ No

I give consent for my child being audio recorded during Physical Science lessons

☐ Yes ☐ No

I give consent for videotapes with my child in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for audiotapes with my child's voice in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for videotapes with my child in them resulting from this study to be kept for up to five years

☐ Yes ☐ No

The extra copy of this form is for you to keep

Thank you.

____
Name of learner

______________________________ ______________
Signature of parent/guardian ***Date***

____
Name of parent/guardian *(Please print)*

Appendix E7: Audio and Video-Recording Consent Form for the Principal

Protocol Number: 2013ECE082M

Audio and Video-recording consent form for the principal

I,…………………………………………………of……………………………………. (School) have read and understood the procedures involved in the study and what is expected of me as a participant. I willingly give the following consents:

Please put a tick in the appropriate box

I am willing for my school to participate in the study.

☐ Yes ☐ No

I give consent to the video recording by the researcher in the Physical Science lessons

☐ Yes ☐ No

I give consent to the audio recording by the researcher in the Physical Science lessons

☐ Yes ☐ No

I give consent for videotapes with the teacher and learners in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for audiotapes with the voice of the teacher and learners in them resulting from this study to be used for purposes of research, publications, teacher education and training programmes

☐ Yes ☐ No

I give consent for audiotapes and videotapes with teachers and learners in them resulting from this study to be kept for up to five years

The extra copy of this form is for you to keep

Thank you.

______________________________ ____________

Signature of Principal ***Date***

____

Please print your name

Appendix F: Lesson Transcripts

Lesson 1:

I entered the class earlier to remind the teacher of the expectations of the research. The teacher had done some topics on this topic 'Reaction in aqueous solutions.' The learners entered the classroom and the teacher settled them down and began with the revision of the homework given in the previous lesson. Due to the 1-hour test period in the morning, lessons were 35 minutes long.

Teacher: I need you to keep quiet and sit still, because otherwise we can't hear what I am trying to say here, ok!. Let's start with question number 1 … activity 7 page 283.

They say, explain why structure of water molecule enable water to dissolve ionic compounds is?

Now guys what you need to have said is in the region of the following. Listen carefully and see what you have said is correct. It doesn't have to be word to word nut needs to bring about the same concept.

So let's see, as a result of uneven sharing of the electron pairs and the shape of the water molecule. One side of the water molecule has a slightly positive charge that's the hydrogen side and one side will have slightly negative charge that's the oxygen side. For this reason water is called the polar substance and they say because of its polar nature the forces of attraction between these molecules are strong. Also this polar nature of water enables the water to dissolve ionic compounds.

Alright now basically what you need to remember it's not that because it has polar bonds. It's not because it's uneven sharing between the hydrogens and oxygen's. It's also because of its shape. I told you that if two hydrogens were sitting next to the hydrogen it will not have a positive and negative side. (illustration: the teacher stretches out her hands on the shoulder height sideways).

…..positive, because the two hydrogens are next to the oxygens. We need to remember that because it has got this big v-shape. (illustration: teacher stretches her hands forward forming an angular shape). Angular shape to the hydrogens point in one direction and oxygen is exposed in one direction. So that is why we have the polar molecule. One side being positive and one side being negative and that's what gives it its ability to dissolve the ionic compounds, because it's polar, alright! You guys know that by now.

Now they wanted us to discuss for question 2 (a) the process of sodium chloride being dissolved. But describe in words they didn't ask for diagrams or equations. So I'm gonna say it to you in words. Make sure that your answer sounds the same. So we know that aah when sodium chloride gets dissolved I the water, as soon as it is in the solution. My water molecules, the negative side which is my oxygen will immediately be attracted to my sodium because it's the positive cation in that compound. The sodium is my positive cation all oxygen will go and surround it on the outside will sit around it. It will be attracted to it. And when the hydrogens which are the positive parts, they will be attracted to the chlorines immediately.
Now because there is so many of the water molecules the electrostatics forces of attraction between the water and this different ions becomes greater than the electrostatic forces between the original ions, the sodium and the chlorine. Those water there are so many of them. Their forces are now greater than the original forces that kept my sodium and chlorine together, right! And therefore the water can actually pull them apart and surround them.
Now the actual process of being attracted to the ions and pull them apart is called dissolution process. To dissolve as soon as they pull them apart and surround that ion we call this hydration. Now that ion is completely surrounded by water molecules so its now a hydrated ion. So we can show it in chemical reaction because it is a chemical change. We changing the compound was sodium chloride now its sodiums and chlorines on the other hand right!
So basically the process which you should have told me about the negatives and the positives being attracted and pulling the two ions apart. That's what supposed to be aid here. It was three marks so you can give me one sentence. You need to give at least three lines for three marks and not three lines of nonsense. Three lines that actually discuss what we have just said.

Question number two (b). Why can a solution conduct an electric current whereas solution of sugar in water cannot? The easiest one is to start with sugar; the sugar water, the sugar is a molecular compound. So when you put sugar in water it dissolves but it does not form ions, it does not form ions. The sugar stays together right because we know that the bonds between the sugar atoms are covalent bonds not ionic bonds.so that water isn't strong enough to pull the sugar molecule apart. So sugar does not form ions and therefore it cannot conduct it's not any electrolyte.

Our salt on the other hand, when it dissolves the water dissolves it in such a manner that it becomes to ions in the solution. The two the positive cation and the negative anion are in the solution and why can it conduct because the ions are able to move. The positive are attracted to the negative side and the negatives are attracted to the positive side. We know that a battery has positive and negative sides, right! Now that is why ions can conduct but molecular molecules can't. The molecular structures or molecular compounds cannot conduct. It's on page 278 of this orange books and I will hand them out to you again. So that you make some notes for yourselves at a later time not today.

Question number 3, Let's look at question number three, what you are supposed to say there. We went through quickly precipitation reactions but we gonna come back to it to do it a little bit more in depth. …..you are given silver nitrate as an insoluble salt. I here (pointing to the board) I still have a table that you were supposed to copy on the board and they say silver and chlorine when they meet they make an insoluble salt, correct. When they meet they make an insoluble salt. Now they say you know that so 3 (a). Explain what will happen when you mix a clear silver nitrate solution with clear solution of table salt. So the silver nitrate solution contains two ions silver and nitrate and the salt solution contains sodium and chlorine.

Now we know that when the silver and the chlorine meet. What's gonna happen (clapping and clinging hands together), they gonna bond strongly and make a solid precipitate, alright. They are very attracted to each other. And even though the waters are there, the attraction between my silver and chlorine is so great. It overcomes the polar or the electrostatics of the water and they actually bond and make this solid silver chloride.so what you were supposed to say is to explain what will happen. You will see a precipitate forming, silver chloride. When you add those two colourless mixtures there is gonna be a colour change. You gonna see something forming you will see a solid forming. Now we know the colour of the solid as well. We said chlorines are, when its silver chloride its

Learner 1: White.

Teacher : White. Silver bromide with a creamy colour and when we get to silver iodide its gonna be a nice yellow colour, yes.

Alright a balanced chemical equation for this reaction its on page 282 of your book but let us quickly write it down here. We have the silver nitrate which are aqueous and colourless. We add it to the sodium chloride which are aqueous and colourless. Remember that when you put the aqueous in brackets nest to your compound it means that its been dissolved. The two ions are floating around ok, or separated from each other. What we gonna form is the silver chloride which we know is a solid. So we have to put solid in brackets next to it. And we will form what is left is my odium and my nitrate and there will be there. We write them as a compound but we put in brackets that there are still aqueous, which means they stilled dissolved. The ions are still floating around in the solution separate, alright.

$$AgNO_{3(aq)} + NaCl_{(aq)} \longrightarrow AgCl_{(s)} + NaNO_{3(aq)}$$

That was 3 (b), question 4. You add silver nitrate solution to unknown clear solution and you find a yellow precipitate, what anion was present and how do you know?

Which one makes yellow?

Class: Iodine.

Teacher: Iodine. So the anion present is iodine. How do you know that because silver iodine is yellow? We know that silver iodine is yellow. So if I added the silver cation in that solution and a yellow precipitate forms I know silver iodide was formed and that's yellow precipitate.

Question 5. What anion are we testing when in the reaction, that's the last question, there we had barium chloride we added it to magnesium sulphate and look what formed barium sulphate. Now between or in the compound barium sulphate that's the solid that form. What is our anion? Is the barium the anion or the sulphate the anion?

Learner 2: Sulphate

Teacher: Yah we still …. you can you can look at your table if you have forgotten. Remember metals make cation ions so it can be the barium. So we must have tested for?

Class: Sulphate

Teacher: The sulphate ion (pointing on the table on the board), which is the white precipitate that will form there. Alright guys lets close our book and continue with today's work.

I want you to open your work book write today's date.

At this moment the class is disturbed by other learners who were outside and not coming into class. They are reprimanded by the teacher and asked to sit down at their positions in class. Others handed in the consent forms and one who did not have was asked to sit at the back beyond the camera view.

Teacher: Alright today's date is the 24th of July 2013 (writing on the board). It's important to put the date down, please let's date our work. And we gonna visit electrolytes (writing the topic on the board): ELECTROLYTES.

We are just going to talk about electrolytes which a… who can remember what an electrolyte is? We quickly touched on that before. Today we are going to now write down what exactly it is but who thinks that they know?

Learner 3: Inaudible sound

Teacher: Yes! It's something that must be able to conduct electricity. That's where the word comes from. I can already see electricity in that word, electrolytes, ok. It is a compound that conduct electricity when it's in solution. Then we say it's an electrolyte ok.

Now let us write down the definition of an electrolyte. I will like you to write down the definition of an electrolyte. Now you could open your textbook your Platinum textbook if you have that one with you, or your Siyavula as well under electrolytes conductivity aqueous solutions. Open over there if you have it with you. Both of these because in both of them you will find a good definition.

Page 170 in Platinum and if someone open for us in Siyavula I don't have Siyavula textbook right in front of me, it's on page what? Electrolytes may be they talk about electrolytes let's have a look.

The teacher and learners check for the page where electrolytes in dealt with in Siyavula.

Learner 4: 312

Teacher: 312 thank you very much ok. So let's write down the definition of. So I have given it to you in words. I have told you what is an electrolyte but I you need to put down the whole definition in your book and so that you can go back and actually study that definition.

So we said an electrolyte is a compound that when one dissolves it into a liquid it can conduct electricity. Then we call it an electrolyte. So if I tell you the word non-electrolyte, when I say non-electrolyte what do you think that definition will be?

Learner 5: *(inaudible sounds from other learners)* it cannot conduct electricity.

Teacher: Yah, that's not that not a nice definition. Who thinks they can give us the whole nice definition? It's a compound that when you dissolve it in water when it's in solution cannot conduct electricity, alright.

Learner 6: Like distilled water.

Teacher: Like distilled water yes. It cannot conduct so that solution is non-electrolyte or is not an electrolyte. I'm gonna give you quickly a table but I will like you to copy it into your books about electrolytes.