Chapter 5

5. PRESENTATION OF DATA COLLECTED

5.1 Introduction

This chapter will firstly describe and analyse resource materials that were used by educators to plan and present lesson(s) on the mole. This will be followed by a detailed explanation of two models that are used to analyse data that was collected through interview and observation. The description of models will be followed by an analysis of interview and observations data that was collected. The chapter ends with conclusion and the implication of the findings from the data.

5.2 Data Sources for this study

A number of data sources were used in this chapter. Sources that were consulted and used by educators to prepare and present their lesson were used. Materials that were used by teachers to assess learners after the mole were requested. These resources include textbooks, tests, and assignments, past examination papers and learners' daily classwork activities, as presented in their note books.

Furthermore data sources for this chapter come from PaPeRs, Core and raw data consisting of field notes (for more details of field notes, see Appendix 3).

5.3 Resources Used By Educators for Preparing and Presenting Lessons on the Mole before Workshop.

For preparing his lessons, Mr Xaba used at least three sets of textbooks namely, Chemistry and Chemical Reactivity (Kotz et al., 2003), Physical Science Standard 9 (Brink and Jones, 1986) and materials obtained while studying B. Ed honours course at one of the local universities.

Like Mr Xaba, one of the textbooks Ms Simelane uses is Physical Science Standard 9 (Brink & Jones, 1986). In addition to this book, she also used Science Focus Grade 11 (Dawson et al., 2001), Chemistry Study Guide (Van Zyl et al., 1999) and notes (on the mole) that were previously prepared by the former Science Head of Department.

Despite being 20 years old Brink & Jones (1986) is one of the high school textbooks generally used by most South African educators. The textbook consists mostly of summaries of science concepts and has since its inception in the market been prescribed for Grade 11. Included also is a number of numerical activities which are intended to apply knowledge of calculations gained by means of solving calculation exercises. Mr Xaba used those exercises for preparing and extracting calculation exercises for class work, test and examinations. On the other hand, Ms Simelane used this textbook not only for class activities but also as a reference for learners to use at home for studying. According to her, the Science department at her school has got enough of copies of Brink & Jones to supply all grade 11 and 12 physical science learners in the school. Thus they are a primary source of information to many learners because most parents cannot afford to buy other (due to their socio-economic status).

There is nothing on conceptual understanding of mole in Van Zyl et al. (1999). However, there are numerous examples of calculations that need application of the mole concept for example calculations pressure volume acids and bases and chemical equilibrium.

Kotz et al. (2003) is a prescribed book for the first year at the tertiary level. It contains detailed Chemistry knowledge which an educator may need for strengthening their own knowledge. But in my view an educator needs to be selective when using this textbook because it contains information on the mole which is not necessarily important for the learners at grade 11 or 12 to know. If textbooks are not carefully used confusion and misunderstanding might be created.

From his lesson, it was evident that Mr Xaba used all the above-mentioned textbooks as references but he did not have formal lesson preparation as evidence. At his school lesson plans are done and by the Science Head of Department (HOD). The HOD did not feel comfortable to supply me with a copy of the lesson preparation for the mole. According to Mr Xaba, lesson plans considered aims of lesson, introduction to lesson, activities for learners, teaching aids and comments done after presenting a lesson.

Coming back to Ms Simelane's reference material, Dawson et al. (2001) is one of the new books introduced recently in South African high schools.

Most district Science subject specialists recommend this textbook as authors have included current issues in education which includes an outcomes based approach and different forms of assessments which are encouraged by Outcomes Based Education (OBE). Another advantage of teaching using this text book is that the style of questioning is similar to that of the nated report 550 Grade 12 examination. However, the issue of using a textbook because of examiner's influence is another debate in science education which is beyond the scope of this study.

Before the intervention, Ms Simelane indicated that she used the lesson plan which was designed previously by the HOD (See Appendix 6). The lesson plan template catered for the following issues: phase organisers, programme organisers, range statements and the type of assessment one will employ. These are technical names used in the new South African curriculum to mean knowledge area, main themes/topic, sub-themes/topic, indicators of understanding by learners and different forms of evaluation/testing respectively. For this lesson, the phase organiser was indicated to be energy and change. It is not known why the mole was taught with that phase organiser instead of including the mole under 'matter and materials'.

The programme organiser (which is the main theme) which was taught was the atom particularly the basic concepts. In the space provided for filling in information on the range statements Ms Simelane wrote 'the relative formula masses and the mole'. The critical outcomes to be assessed included processing information, solving problems and working effectively with other. (See Appendix 1 for an extract of lesson plan).

5.4 Comments on Lesson Plan

As mentioned above, Xaba was brief in explaining the mole thus this section will focus primarily on Ms. Simelane's lesson.

As an introduction to the lesson the atomic number, mass number and isotopes were revised. She indicated that in the process of teaching relative formula masses would be introduced and showed learners how to calculate formula mass. At that stage, she would explain what a mole is and Avogadro's (Av) constant and showed the calculation of number of moles using the Avogadro's number.

It was not indicated in the lesson plan how learners will be shown to calculate formula mass. But it is presumed that a procedural approach would be used. Although it was not clear what kind of explanation will be used, it is clear that the educator would presumably use the definition given in the Grade 11 prescribed book and this was confirmed during the pre-interview with the educator and also by the notes which were prepared on the mole. The follow up or conclusion to this lesson was a class work. The class work comprised mainly of exercise which involved calculation tasks. All the learners' tasks were not intended to enhance conceptual understanding of mole by learners.

I do not imply that tasks that were used by Ms Simelane for this lesson were of poor quality. The exercises were of quality standard and included more than three levels of Blooms' taxonomy of classification of questions. For example questions ranged from those that need one to find molar mass of an element given atomic numbers to those that need one to calculate molar mass of a compound and find the number of moles. Included were also questions that need one to find the mass of elements that constitute a compound. The educator's approach of solving algorithmic problems is common to most educators (in fact I also used this approach before I became aware of current science education issues when teaching for the conceptual understanding) when assessing the learners on any science concept, especially the mole.

Stromdahl (2006) points out that when he interviewed university lecturers and professors it was clear that it is not easy for them to teach a science concept which has both quantitative and qualitative dimension like the mole. They spend most of the lesson using a formula to calculate the mole. In fact he claimed that they did not even bother to conceptualise the mole themselves because it was difficult for them to explain what they understood a mole to be. Therefore, it is not unusual to see that educators use this approach frequently to teach the mole because they are not aware of other approach that they can employ.

It is probably because the approach employed is thought to be easy when assessing learners, or it is a common trend by science educators to use algorithmic procedure to teach concepts because that is the way they were taught. I think also that the educators may not have been exposed to other teaching approaches which will help to seek the understanding or the educator is just ignorant on these issues or reluctant to use the new approaches. I am making this statement because the educator (i.e. former HOD) who prepared the notes for Ms. Simelane had obtained an advanced Science Education degree in one of the recognised local universities which suggests that that educator was aware of current issues in science education at the time the tasks were prepared.

Ms Simelane's lesson plan after the workshop was different from the ones she had used before the intervention. It is obvious from the lesson plan she supplied that after the workshop on teaching for conceptual understanding of the mole, Ms Simelane seemed eager to apply the knowledge gained during the workshop because she revised the lesson plan that was presented to her by the ex HOD. She modified it to suit what she intended to teach her learners and the background information (prior knowledge) of her learners.

She used the first portion of the previous lesson plan as it was. That portion included (as mentioned earlier) phase organisers, the program organisers, range statements and critical outcomes. She changed the introduction of the previous lesson preparation by including some of the information that she learnt at the workshop. The performance indicator was that learners be able to calculate the molar mass and the number of moles and define the following terms i.e. isotopes, moles and atomic number etc. These concepts were assessed by giving learners a learning task. But for her introduction of the above mentioned concepts would be revised with learners by both learners and herself.

Resources she intended to use in the revised plan were a triple beam balance, rice grains and peanuts. For revision, learners would be shown how to calculate relative formula masses and the relationship between mass and mole using the apparatus mentioned above. Although she intended to teach for conceptual understanding, she seemed to revert to the calculation approach. At the end of the lesson, the educator planed to emphasise that molar masses of substances carry the same number of mole.

Although I did not observe Ms Simelane before she was exposed to a workshop on the mole, she was willing to give me preparation plans that she has used before the workshop. When one compares her previous lesson with the current one, it is clear that there were some differences. The first lesson plan was more dogmatic and catering for the definition in the textbooks only. The second one was at least attempting to be accessible to learners because she indicated that she intended to explain science concepts using easier methods such as employing concrete and simple demonstrations in class. She was modelling the micro process. The demonstration illustrated a macro process. The macro process (weighing of rice grain and peanut) would then be use to explain microscopic description (moles of atoms, elements, molecules etc) of what happens at macro level.

To me the modifications made by Ms Simelane on the lesson plan indicate that she was more confident with her content knowledge of the mole that and that made her to translate this science knowledge into the knowledge which will be understood by her learners. The fact that she used objects that are familiar to learners suggest that she knew the difficulties that are experienced by her learners.

> *"A mole is a very difficult concept to understand. It took me a number of years to understand*
> *this concept I a not even sure that I truly understanding it*
> *like scientists do so it is important that I start by explaining*
> *the mole by using the example of dozens*
> *of different objects."*

She knew that the learners would have not understood if she started by using the textbook definition. She was then aware that the textbook definition is difficult to understand. She probably knew that her learners' prior knowledge on the mole is not sound that is why she planned to revise the concept such as atomic mass, relative mass with them. It seemed she knew how important it is for learners to understand these concepts in order to comprehend the mole.

> *"They don't understand what atomic mass is , how to determine the MM of elements,*
> *They do no know the correct chemical formulas of compounds.*
> *For copper (II) oxide some write Cu_2O rather than CuO…………."*

Mr Xaba's lesson planning does not give an indication whether his PCK, for conceptual understanding approach in teaching, has developed because there was no formal lesson plan available. On the other hand, the above information on Ms Simelane's account gives indication that within the short period after workshop there were some traces of development of her PCK.

She became aware about her content knowledge, learners prior knowledge and some difficulties associated with teaching the mole. She intended to consider these issues in her lesson preparation and teaching but she did not have a clear strategy to employ. We cannot confidently claim that an educator's PCK did or did not developed without having captured or portrayed his or her lesson well. This brings us to the next issue in this chapter.

5.5 Description of Models used For Analysing Data

The data which were collected by observing two science educators when presenting their lessons on the mole was captured and portrayed using Content Representation (CoRe) and the Professional and Pedagogical experience Repertoire (PaP-eR) (Loughran et al, 2004). In conjunction with this method, a model called "categories of description of the mole concept model" was used to categorise the educators' understanding of content (Strömdahl et al. (1994) and Tulberg et al., 1994).

In the previous chapter CoRe and PaPe-Rs were explained as a tool used to analyse the data I collected. The method used by Loughran et al.(2004) comprises of two important elements of PCK, namely, science content knowledge and teaching practice. The CoRe is linked to the particular science content whilst PaP-eR is linked to the teaching practice (Loughran et al., 2004: 41).

In addition, in previous chapter a brief explanation of PaPe-Rs and CoRe was outlined wherein Loughran et al's explanation of both PaPe-R and CoRe is given, and prompts used to create CoRe were included. Furthermore similarities and differences between Loughran et al. (2004) and this study's CoRe and PaPe-Rs were outlined briefly. The chapter ended with a detailed presentation of CoRe and PaPe-Rs of the study.

Loughran et al. (2004) stated that if a representation of PCK is to help educators recognise, articulate and develop their understanding of that content, then it must be based on an understanding of what content the educator knows (and has come to understand) to purposefully shape the pedagogy and the associated approach to pupils learning. This statement applies to content knowledge (CK) of educators and this is what Tullberg et al. (2004) do.

From the CoRes, and PaPe-Rs units were identified which were then grouped into themes. Themes that were identified and which will be discussed in this chapter include Content knowledge of teachers, curricular saliency, Representations (analogies) knowledge of students, topic specific instructional strategies, the topics which are entertained in Geddis & Wood (1997). These topics will be dealt with later in this chapter.

5.6 Analysis of CoRes

In chapter four Loughran et al. (2004) model was used to create CoRes from the information obtained when interacting with the participants of this study. These are reproduced for analysis in table 5.1.

Table 5.1: The CoRe of the teachers

Questions	**Mr Xaba**	**Ms Simelane**
1. What you intend the students to learn about this idea?	-The mole is equal to the number of atoms, the smallest particles of matter. -To know the definition of mole in their textbook	• Definition of a mole as written in the textbook • the importance of understanding this mole in chemistry and • use the formula to calculate the number of moles. • use the formula to calculate then Avogadro's number
2. Why is it important for students know this	Makes calculating very huge number of small things like atoms of any matter easier	• To be able to distinguish quantities • The mole is related to many topics taught at Grade 11 and 12 • They need to know amount of substances to form products • Mole is one of the 7 basic SI units we use in Physical Science
3. What else do you know about this idea (that you do not intend student to know yet)	Avogadro's number. He knew about it in the interview but did not use it in class)	• The history of mole ("it confused me for years)
4. Difficulties/ limitations connected with teaching this	• Difficulties in understanding the Periodic Table.	• Lack of knowledge of symbols of elements and chemical formula

idea	• Lack of knowledge of the symbols of elements • Poor background in chemistry • Use atomic number and mass number interchangeably • Difficulties with calculation of molar mass • Algebraic difficulties, e.g. changing the subject of the formula	• Atomic number vs. mass number • Difficulties encountered in determining molar mass (MM) of elements/compounds • Poor background in chemistry • They do no know the correct chemical formulas of compounds • They cannot balance simple chemical equations • Learners confuse a mole with mass , volume and in some case with density • Their understanding of the word "number vs. quantity"
5. Knowledge about students' thinking which influences your teaching of this idea	-Maturity of students -General background knowledge	
6. Other factors that influence your teaching of this idea	❖ Responsibility by learner to do their task honestly (maturity) ❖ Chemistry background-understanding all the basic concepts such as the atoms, atomic mass relative (molar mass) mass number, isotopes etc. the concept of mass as should be understood in the concept	• Just joined the school and lacks specifics of knowledge of learners background • Learners' first group from new junior secondary curriculum • Learners were struggling with earlier tasks • Learners can do tasks on their own
7.Teaching procedure	• Doing calculations of	• Started by

(and particular reasons for using these to engage with this ideas)	different types, practice makes perfect • search for exercises from different chemistry books • do number of problems on the chalkboard • give them more homework	explaining the mole by using analogy of dozens, counting and weighing different coins, peanuts, biscuits and rice grains • Give calculation activities that create understanding but also application questions involving quantity and menu

Looking at the CoRes of the two educators, there are similarities and differences that can be identified. Both teachers intended their learners to know the definition of mole and be able to do calculations that are related to the mole (See CoRe in Chapter 4). Noticeable also is that both teachers indicated similar difficulties connected with teaching the mole. In both cases, learners had poor chemistry background. Both teachers encountered a problem of lack of subject matter knowledge for symbols of elements and chemical formulae. Their learners were confusing atomic number and mass number and learners were experiencing difficulties with calculation of molar mass. In addition both teachers made frequent use of primary language (Ms. Simelane less so). For example see field notes in Appendix 3).

From the CoRe and PaPeRs of this study, the content knowledge (CK) of the teachers, according to Stromdahl et al., seems to be at a similar level. Stromdahl et al.'s levels will be discussed in this chapter in the next section.

Ms Simelane described the mole as follows:

> *"A mole to me is a counting unit it is just a number and in their textbooks it is explained as a quantity of matter containing exactly the same number of elementary particles of which it is a knowledge I also use".*

Whereas Mr. Xaba (during interview mentioned Avogadro's number and) thought that students were to understand that the mole is:

> *"the amount of atoms or anything in a substance and this substances are small particle like for example C is made up of small particles".*

although he did not mention it during his lessons.

As mentioned above, both teachers identified common difficulties or limitations that are associated with teaching the mole. It is also noticeable that they both considered a mole to be a number and spent most time applying formula on a number of calculations. But Mr Xaba spent very little time in describing the mole as a heap or pile without even mentioning Avogadro's number and getting deeper into students' understanding of the mole. Some people may argue that he knew the curricular saliency (see 5.9) and he did not want to go beyond what he said to his learners, but in his explanation it was difficult to conceptualise "the heap or pile" definition.

Ms Simelane defined the mole as a number and also went the extra mile to explain this number using word 'dozen' to explain the concept in an effort to make her learners to conceptualise the concept by, a term that is familiar to learners vocabulary.

She was dissatisfied with development of her PCK of mole and this is evident in her reflection where in she gave an account that although she prepared her lessons well and wanted to use the strategies that were suggested during the workshop but she was panicking during a lesson. The reason for panicking could have been that she was doubtful about her subject matter knowledge development of the mole and she had to refer back to her textbooks to ascertain whether she has correctly understood the concept she intended to teach. She felt that her understanding of the mole was still lacking and needed assistance in linking of the concept to algorithms. She indicated that her teaching of the mole will improve with time:

> *"A mole is a very difficult concept to understand even now I am not sure if I understand it so well it took me more that ten years to be confident ….. but at least I have a clear understanding now….*

Researchers of PCK argue that it does not develop spontaneously, but as teachers present lessons repeatedly they find ways of dealing with problem(s) encountered before and gain experience with time. Ms Simelane reflection above confirms this. Ms Simelane said that after many years of teaching she was confident to teach the mole because she was at least sure of her own content knowledge.

A study of conceptualisation of the mole was done by Stromdahl et al. (1994) and they constructed a model which explains level of conceptualisation of mole by the teachers.

5.7 Categories of Description of a Mole

In their qualitative phenomenographic study Stromdahl et al. (1994) claim educators have different conceptions of 1mol. The way an educator has conceptualised the concept of the mole has an effect on how (s)he will teach the mole. Their study has revealed four separate fundamental meanings of the mole namely fundamentals 0 to 3 and are denoted by F_0, F_1, F_2, F_3 which are complemented by one theoretical fundamental F_4.

The categories of description summarise the individual conceptions at a collective level. By this denotion, Stromdahl et al. (1994) wanted to emphasise that the categories involve not only alternative definitions or expressions of different conceptions about the mole, but also implicitly express an ontological foundation of how matter is conceptualised. Stromdahl et al. (1994) further pointed that the meaning of the mole in one fundamental cannot be sustained in another without changing its meaning, that is, the meaning given in one fundamental is incompatible with the meaning in another. I shall now describe briefly the following categories as explained by Stromdahl et al. (1994). The table 5. 2 summarises the description of these categories of descriptions

Table 5.2: Strömdahl's Fundamental categories of description of 1 mol

Category	Description	Examples
F_0	One mole (1 mol (e)) is a portion of substance	We find out that a mole has many atoms by weighing it
F_1	One mole (1 mol (e)) is an elementary entity specific (individual) mass	It's the formula mass expressed in grams, for sure!
F_2	One mole (1mol(e)) is equivalent	I mostly think of 6, 0 2 x 10

	to Avogadro's number	23 particles, similar to a dozen. It is a certain number of particles.
F_3	The mole (1mol) is a unit of the physical quantity of amount of substance	I always want to ask, "How large is the amount" and think of the mole as a unit 1 mol
F_4	The mole (1 mol) is excluded and replaced by a number 'No' (identical with Avogadro's number), as the conversion factor between the two units of masses 1µ and 1g. Hence 1 mol is a unit of the base physical quantity *amount of substance* (SI, 1971)	Amount containing as many entities as the are atoms in 0,012 kg of Carbon 12

(Adapted from Stromdahl et al., 1994)

5.7.1 Fundamental 0 (F_0)

For this category one mole is a name for the physical, concrete portion of a substance having the property of being able to react chemically with other substances in whole value ration. In terms of this category the mole has nothing to do with physical quantities or physical units at all.

5.7.2 Fundamental 1 (F_1)

One mol is identified as individual masses (due to the actual elementary entity of the substance. One mole is equated to a mass unit since the corresponding physical quantity is mass. In this category, the concept mole is synonymous with the terms gram-atomic weight, gram-molecular weight and gram-formula weight. In this category the use of expressions molar mass or molar weight as M(C) =12.001g/mol is not logical because one mole is identical to mass.

5.7.3 Fundamental 2 (F_2)

According to Stromdahl et al. (1994) in this category 1 mol is defined as a number, Avogadro's number. This means 1 mol = 6, 023x10^{23} and so 1 mol is comparable to names of numbers like dozen, 1 score, 1 gross. Educators in Stromdahl et al. (1994) study who used F_1 and F_2) did not explicitly talk about mole as a unit of mass or as a unit of numbers thereby obscuring the factual separate meaning s of the mole in the two fundamentals. Instead, they used expressions such as 'number of moles on both fundamentals to denote measurements done by unit mole. Stromdahl et al. (1994) state that this makes use of the mole concept less incomprehensible

5.7.4 Fundamental 3 (F_3)

In this category, 1 mol is the unit of the physical quantity amount of substance ('n' which is short for amount). In this category mole is defined as a physical quantity 'amount of substance'. The term 'amount of substance' is connected with other physical quantities by the rules of quantity calculus. Those quantities are mass, volume and number. Figure 3 below shows the amount of substance is related to the quantities mass volume and number and other sub quantities as shown below.

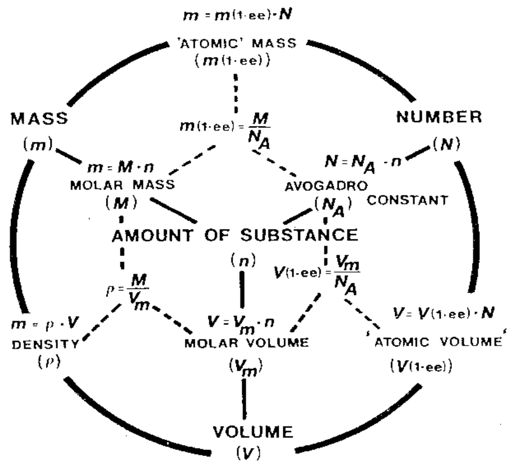

Fig 5a

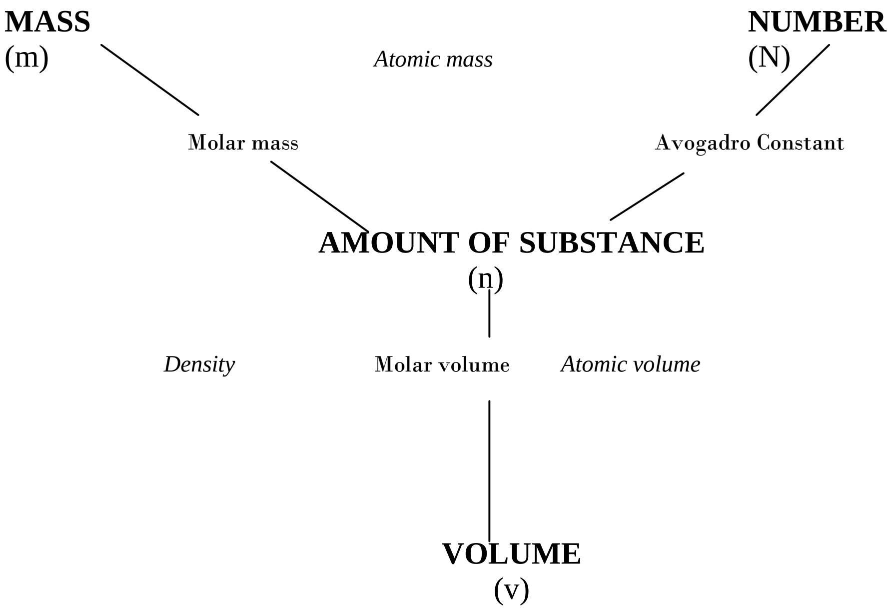

Figure 5: A graphical representation of the relation of the relationships involving the amount of substance, mass, volume, and number. Stromdahl, 1996)

The diagram is constructed around three common physical quantities used in elementary chemistry educational settings, namely mass, volume and number and the physical quantity amount of substance. The mathematical relationship between theses physical quantities is the proportionality. Mass, volume and number are connected with amount of substance through the elementary entity specific proportionality constants molar mass and molar volume and general constant Avogadro constant respectively. Mass and volume and mass and number and volume and number are connected through the proportionality constants density, atomic mass and atomic volume respectively.

5.8 Relating teachers' CK to Stromdahl's categories

It seemed to Mr Xaba that the mole is a counting unit for those smallest particles i.e. atoms as noted in the above argument and therefore his conception of the mole concept can be categorises to be within category F_2 of Stromdahl et al. (1994) and Tulberg et al.(1994).

However, when Mr. Xaba introduced the mole his conception of the mole could have been classified under category F_1 (which is the lowest form of explaining the mole) because he spent most of the time during his lesson teaching the formula and substituting on the formula. This suggests that his conception moved from category F_2 to category F1 as the lesson progressed which suggests that he was getting confused as the lesson progressed and his understanding of what he was teaching got more and more unstable.

Stromdahl et al. (1994) claims that one of the problems experienced by educators who understand the mole according to F_2 is that, they do not explicitly talk about the mole as a unit of number thereby obscuring the factual meanings of the mole in this fundamental. Instead, the talk about the expression 'number of moles' to denote measurements done by the 'unit mole' (Stromdahl et al., 1994). Stromdahl et al. (1994) warns that the identification of this obscurity makes the use of the term 'the mole concept' less understandable.

Using Stromdahl et al.'s (1994) model Ms Simelane's conception of the mole could be fitted in category F_2 because she defined the mole as the number and also used the word 'dozen' to explain the concept, a word which is said to be comparable to a number according to Stromdahl et al. (1994). However there are also traces of F_1 characteristics in her explanation because she also used the concept of weighing the 12 items by using the mass scale and spent most time on calculation exercises like Mr. Xaba.

It is surprising that she has used explanations that fit in two different categories because Stromdahl et al. (1994) pointed that the meaning of the mole given to one fundamental cannot be sustained in another without changing its meaning. However, during her lesson she referred to the mole as the amount of a substance which suggests that her conception of the mole is in line with the F_3 description of the mole.

It is not unusual that she incorporated the properties belonging onto other fundamentals and this idea reveals an important aspect of PCK of an educator, that is, CK of an educator. Stromdahl et al. (1994) and Tullberg et al. (1994) also encountered the same situation of properties of one fundamental being included into another. However, the result of doing that is that individual brings about the logically inconsistent reasoning which they are usually not aware of.

5.9 Curricular Saliency

In chapter 2 it was mentioned that curricular saliency is a term coined by Geddis & Wood (1997) to refer to the teacher's understanding of the place of a topic in the curriculum. It is observed in teachers' decisions to leave out certain aspects of the topic on either educational or logistic grounds, and in teachers' awareness of how the topic they are teaching fits in with other topics and part of the curriculum past and present.

From the CoREs of this study, and confirmed in their presentation of lessons, both teachers considered memorisation of definitions and the procedural aspects of the mole to be most important skill to place in the hands of their learners which explains why both teachers spent most of their presentation time on calculation activities and assisting learners to master them as such. For example, Ms. Simelane indicated that

> *"The kinds of activities that I give to learners to create understanding are mainly calculations I want them to master calculation on the mole because we will use the moles when we do the equilibrium rates ,Kc, acid and bases………… "*

The reason for this was given by Mr. Xaba

"You see the examiners use these textbooks to set questions if they know the definition they will pass at the end of the year"

Emphasis is placed much on performing well in examination. It is clear that their teaching is geared to final external examination. Learners are taught in mind with achieving best in examination because their fate as teachers in grade 11 and 12 depends on how learners perform at the end of grade 12. So these teachers know that by drilling algorithmic exercises (rather than emphasizing the conceptual aspect of the mole) learners will perform well during assessment, but that does not imply that they have conceptualised the mole concept.

5.10 Representations and analogies used

Tools and symbol systems have played an important role in the development of science. Schmidt (2000) indicates that progress has been associated with the creation of new representational forms that allowed scientists to think and communicate differently about scientific phenomena. In chemistry, for example, the perceptual symbolic representations that chemists created include structural diagrams, equations, and chemical formulae. Schmidt (2000) further indicates that much of what scientists do is to create an understanding from signs and symbols, which is for them often arduous and effortful activity. Teachers are very skilled in using different symbol systems and symbolic expressions in a flexible way to represent these scientific phenomena and solve problems related to them.

Ms Simelane used an analogy of a dozen to explain the mole. She said to the learner a mole is a concept like a dozen. She explained that a dozen means 12 similar items together. Different shaped dozen things comprises of 12 items. To show this analogy she performed an experiment where learners had to count the number of items of substances and also note the masses of dozen items which are the same substances as determined from the triple beam balance.

She chose items which are familiar and easily accessible to learners. The substances that were chosen as examples for this activity were rice grains, peanut beans, and biscuits and money coins. For each substance a dozen (twelve items) was taken out and weighed. Three different masses were read from the mass balance scale. She told learners that although 12 items (the same number of items) of each substance were weighed the mass total mass of 12 items for the three substances is not the same.

EDUCATOR: *"a pile of Carbon (C) has mass 12 g ………………………* ***the number of particles present in them is equal and is called a mole****. That is why I will do the biscuits* and *peanuts experiments. (On the table there was a triple beam balance, packet of sealed peanuts, packet of biscuits and rice grains in a container.* ***She opened the peanut bag and counted 12 peanuts , put them on the balance scale and measured the mass of those peanuts she called one learner to come in front to confirm the measurements. She also weighed rice ………..***

> *Note that 12 peanut beans and 12 rice grains masses are not the same but we have the same number of substances in each case. It is the same with C, S, M above they are different piles but the number of moles in each pile is the same. Number of moles does not mean mass of a substance. So 1 mol of substance is called molar mass and to get number of moles of a substance it depend on whether the substance is an element or a compound*

Further more Ms Simelane indicated to her learners that the experiment of determining the mass of dozen items warns that the mole should not be confused with the mass of a substance. She referred back to the piles of carbon, sulphur and magnesium that the mass of each substance is not the same but the number of particles in each pile is the same. She said in the case of the peanuts and rice the number of grains were counted to be twelve but in a pile of carbon, Sulphur and Magnesium it is not known. She reminded them that the number of moles of a substance depends on whether the substance is an element or compound.

Another representation she used the expanded notation of Avogadro's number. She gave learners a little bit of history of this number and wrote the number 602000000000000000000000 on the chalkboard to give a sense of how big this number is. She indicated that the particle she is referring to are atoms, ions, molecules elements etc which makes up the substance. She further told learners that this big number is known to the science community as Avogadro's constant because Avogadro discovered the number. When comparing her to Mr Xaba, this number was never mentioned during his lessons and so learners do not possibly know the number and its significance.

However, from here Ms Simelane jumped from the conceptual issues to a mathematical approach of determining the number of moles of different elements and compounds by applying the formula for determining the number of moles (n). According to Stromdahl et al. (1994) her conception of the mole best fit the description of the F_3 category, where 1 mol is the unit of the physical quantity amount of substance. But her lack of subject matter knowledge of the mole made her unable to develop the analogy she has used and link the two approaches she used, that is, conceptual and algorithmic approaches. This suggests that she was probably unsure and her conception of the mole was reverting to the original category (that she indicated before intervention) where a mole was perceived to be a number. This conception of the mole is of the lower level and fit best in the F_2 category of Stromdahl et al. (1994).

Mr Xaba on the other hand, introduced the concept of the mole after learners have explained an atom as a tiny particle of matter. He introduced the mole by writing the word "mole" on the chalkboard and then told them that the mole is the Latin word meaning heap or pile mole mean many things put together. He compared the mole to a pile of items. He went on and explained that the unit for mole is molar. He then referred the mole as a number because he said a mole equals to the 'number of atoms, the smallest particles of matter'.

EDUCATOR: *("ekee…..") "O.K". and then faced the chalk board. On the board he wrote the word "Moles" and faced the class. Mole is the Latin word meaning heap or pile (yona ke dintho tse kopaneng fela) mole mean many thing put together Unit for mole is molar It is equal to the number of atoms. The smallest particles of matter. At that moment the class was quiet and learners listening attentively.*

He was carrying white soft chalk in his hands. "(Akere tshoko e,)" You see this chalk (pointing the chalk in his hands) "(E e ntswe ka very small particles") is made up of very small particles ("Kapa ke maka") is it true?

LEARNER: *All of them "yes Meneer"*

TEACHER: *They are too many small particles in any object and we cannot count them one by one. (Bothatha ke hore re batla ho tseba hona jwale"). The problem is that we want the solution very soon. Because we need the results now we will not finish within a short time. So we use moles to calculate them. Let us calculate the number of moles. Now let us come to calculation of the moles*

He used an analogy of a piece of soft white chalk, which he carried as an example to explain the mole. A chalk is a concrete example and learners are used to seeing it in their daily lives. He told learners that the chalk is made up by very small particles of calcium carbonate and they cannot be able to count them one by one. He said if they wanted to at that time (because they needed to know within a short time) how many of those small particles make the piece of chalk it will be time consuming. He pointed that they will have to count each every small bit of those smallest particles. However, they will not finish on that day of even that week or month so how to get the actual number quickly. He told learners that they would have to calculate to particles by using the mole which suggests that a mole is a calculating unit.

In both cases, teachers used an analogy at the beginning but they did not link it to the algorithmic part of the lesson. In so doing leaving their students unable to assimilate the meaning the mole and unable to relate the meaning of the concept with calculations done in class.

In case of Ms Simelane, her efforts of teaching the conceptual aspect of the mole became fruitless because she decided to quickly go into calculation exercises without developing her dozen analogies into proportional concept and thus made it difficult for learners to grasp the meaning of the mole. Mrs. Simelane was more receptive to the idea presented at the workshop, probably because she was registered on a course of further study. However her self reflection on the lesson showed that she was disappointed with the lesson she described herself as disorganized and confused and not using the teaching approaches as she would have wished to. Her reflection demonstrated a discomfort with a new approach as she had not had sufficient time to adequately transform her knowledge. The resulting lesson had the form, rather than the substance of the new approach (Brodie & Lelliott, 2002)

5.11 Knowledge of Students

Like Mr Xaba, Ms Simelane reminded learners of concepts taught previously by explaining: the concept of atomic number in terms of the number of protons in an atom; the concept of atomic mass in terms of the number of protons and the neutrons; relative formula or molecular mass in terms of atomic mass and also indicated that molecular mass is the same as relative atomic mass.

> **EDUCATOR:** *She started the lesson by reminding them that the previous day they were talking about atomic mass, nucleons and mass number, relative atomic masses. She then asked questions. "What is an atomic number?" and pointed a learner in front." Yes"*

She indicated that relative atomic mass is compared to a particular substance's mass. But she never made it explicit which mass of a substance is this concept compared to. She gave learners algorithmic exercises to show learners how to calculate the relative mass of a substance if you are given a compound. Why she chose the example of $CaCO_3$ is not clear because she could not explain it further when she asked the reason behind using this example. She just indicated to me that it was an already prepared exercise. However it can be argued that because the question was asked immediately after observation, she was still disappointed with her lesson and could not think logically. This issue will be discussed in the next paragraph.

Both educators went step by step of how to determine molar mass (MM). In Ms Simelane's case she used $CaCO_3$ as an example. She made learners aware that MM of Ca is 40, for C is 12 and 16 for O and indicated that there are three oxygen elements in $CaCO_3$ therefore 16 will be multiplied by 3 in order to get the relative mass of O in the compound $CaCO_3$.

EDUCATOR: *"What is relative atomic mass?" pause for a second. "It is the total number of protons in a substance (wrote on the board), same as atom mass relative to a particular substance. Molecular mass is the same as atomic mass relative to the substance's mass which means molecular. If you want relative atomic mass of (writing on the board) (CaCO3) what do we do?"*

LEARNER: *"we add relative atomic mass of different elements forming CaCO3."*

EDUCATOR: *"Yes! i.e. Mr ($CaCO_3$) will be what it will be 40 for Ca 12 for C and 16 for) but how many O 's are there are 3 so*

⇨ $40 + 12 + 16(3) = 100$

Relative atomic mass has no units

She then showed them that they will have to add all the relative atomic masses of different elements forming the compound. In her conclusion, she told them that will get 100 for the compound in question. Lastly, she pointed clearly that atomic mass has no units and the number 100 is an answer to the number problem. Ms Simelane chose to do the example of $CaCO_3$ in class. She might have deliberately chosen this example to do on a board because it is simply to work out the molar mass probably because molar works out to be 100 g/mol. Schmidt & Jignéus (2003) suggested the use of easy calculations exercises in chemistry introductory study. They say that dealing with easy to calculate problems on stochiometry eliminates transmission of 'noise' chemistry classroom. Teachers who have knowledge of their students and knowledge of context would be aware of these factors and consider them in their teaching of this section. This would indicate well development of certain elements of PCK. It suggests that this teacher was aware of this and did not want to cloud learners with complicated numbers and the mole was more than enough to cause confusion.

On the other hand, Xaba explained that molar mass is obtainable from the periodic table for all elements. He went on to say on each block of the Periodic Table a number on the top left is the atomic number and the number on the bottom is the molar mass. For example the molar mass for Hydrogen is 1, 00797 g/mol. It seems to me he also knew that his learners had mathematical problem i.e. difficulty with working with decimal numbers that it why he said they shall round these numbers to the nearest whole number to make calculations easier to handle. For Hydrogen he told them that when they round of molar mass for Hydrogen would be is 1g/mol.

He then asked them to determine what will be the molar mass of different elements. For example, he wanted them to determine the molar mass of Na. He then applied a drill and practice method of determining atomic mass of 20 different elements. He corrected them when they could not correctly determine molar mass. Because learners frequently forgot to include the units g/mol he kept on reminding them that if they forget to mention those units. He further mentioned that g/mol and $gmol^{-1}$ is the same and that learners can choose the expression they are comfortable with.

EDUCATOR: *"So* ***(le seke la lebala)*** *Do not forget to include the unit g/mol and ke batla hore you should draw a table and list all the elements which we commonly use in chemistry and next to each element write down the appropriate MM.* ***(Le mpontsheng hosane)*** *Show me the work tomorrow?"*

*The unit g/mol le $gmol^{-1}$ ("**ke ntho eleng")** They are the same"**).***

Mole = $\frac{\text{Mass}}{\text{Molar mass}}$

For 12 g of C the MM(C) is 12 g/mol
Number of moles is 1.
Let us look at the convention factors:

Example 12 g/mol for C
If you are given 8 g of C then convert 8 g of C to number of moles. How are going to work out? You have to know molar mass of carbon. You then decide which conversion you will use is it g/mol or mol/g.

For 8g I use mol/g
8g x 1 mol = 8 mol
then

$$\frac{8g}{1} \times \frac{1mol}{12g} = \frac{8mol}{12g}$$

= Use your calculator 0,6 mol or 0.7 mol

5.12 Teaching Approaches Used

Going back to the lesson of Mr Xaba, he then jumped from the conceptual understanding to the calculations (mathematical approach) of the mole without forming an appropriate linking bridge between the clear understanding the concept mole and the calculations in the learners. He then solved a number of examples arithmetically on the number of moles. He gave learners the formula "Mass equals to mass over molar mass". He also showed them how to change measurement units from grams to mole. He probably realised that he did not remind them of the molar mass because he asked learners if they know what molar mass is and how to find it. He requested them to take out their copy of Periodic Table that was photocopied from Brink & Jones (1986). Because he probably knew that his learners did not know the molar mass of elements he told those learners who did not have their copy to refer to the big the chart of the Periodic Table of elements hanging on the wall.

Like Ms Simelane he then went step by step in substituting into the equation of the mole, mass of substance and molar mass the information you have and the one obtained from the Periodic Table to find the number of moles. The first example he used is the same as the one use by Ms Simelane which is finding the number of moles of Carbon, but he indicated to them the mass of 12g of C.

When he finished explaining, he gave learners the task of calculating the number of moles to the following problems: 40g of Oxygen gas; 0,45g of Cl; what mass of lead in grams is equivalent to 2,5 mol of lead (Pb)?; and what amount of tin (Sn), in moles is represented by 36,5 g? He went to spend the rest of the period at the back and joined one learner. The rest of the class worked in groups of four or five. His approach clearly indicates that his main idea was to teach learners how to substitute into the formulas of determining number of moles. The intention to teach for the conception of the concept did not come in his mind.

5.13 Content knowledge of educators and their Conceptual Problems

Ms Simelane began by giving the learners the example of the element Carbon. It is not clear why she chose the element Carbon as an example. However, she referred to the element Carbon as a substance. Researchers who have interest in the role played by language in science educations might argue that this is a language problem because Ms Simelane also used a little bit an additional language (that is, Zulu) to communicate to learners during her presentation of the lesson.

The word 'substance' in Zulu has many meanings or can be used to refer to many unknown objects. Some of the science dictionaries that are developed do not make it simpler for teachers to separate the meaning of scientific concepts. For example, a simpler direct translation of the word "substance" in Zulu is "into" (which may mean a thing in English). Young et al. (2005) describe a substance in Zulu as "ingqikithi" (meaning any kind of matter that classifies objects according to specific properties). The xhosa translation is "ulutho" which takes us back to the meaning "into" in Zulu. I therefore argue that (for a Zulu speaking person) it would not be an issue of concern to refer to an element as a substance in Zulu. In this case I think the use of the word 'substance' was inappropriate and misleading. Ms Simelane was teaching for conceptual understanding, and the word 'substance' has a particular meaning in Science. The use of the word 'substance' in this way suggest that the educator does not know the scientific meaning of the word "substance" and this might create misconception in learners.

> *When she finished <u>weighing each substance's mass</u> she went to the board and wrote the mass she recorded down.*
>
> *12 peanut mass is 8, 9 g*
>
> *12 rice grains 0, 12 g*
>
> *Note that 12 peanut beans and 12 rice grains masses are not the same but we have the same number <u>of substances</u> in each case. It is the same with C, S, M above they are different piles but the number of moles in each pile is the same. <u>Number of moles does not mean mass of a substance.</u>*
>
> *So 1 mol of substance is called molar mass and to get number of moles of a substance it depend on whether the substance is an element or a compound*

Mr. Xaba also communicated mostly with additional language with his learners because he probably knew that they had difficulties with English or it may be the case that he is used to teaching science by communicating in his home language. Possibly although the majority of learners in that class were Southern Sotho speaking there were few who do not speak the language as fluently as the other learners in the class. However, as indicated earlier on that he probably knew his learners' difficulties of language and was considering that in mind and ensuring that he clears off some factors (he was aware of) that could compound on learners' understanding of the mole lesson.

5.14 Concluding Remarks

In conclusion, in this chapter Stromdahl et al.'s model which assists in placing teachers' conception of the mole in categories was extensively described. Both teachers' conception of the mole was indicated based on their ideas they stated in class or in an interview. Their explanation of the mole influenced their lesson preparation, presentation and their approach of the lesson.

Although differences were noted on their subject matter knowledge, and there were many similarities that these teachers shared in common. In particular, their tendency to prefer the algorithmic approach to teach the mole captured the interest of this study. In the next chapter, this interest will be reflected.