Exploring a professional learning community's knowledge for teaching stoichiometry

A research project submitted to the Faculty of Humanities, University of the Witwatersrand

By

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Student Number: 1766031

In

Partial fulfilment of the requirements of

Master of Education (Science Education)

Ethics Protocol Number: H20/60/37

May 2023

Declaration

PLAGIARISM DECLARATION

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Supervisor: Dr. Mpho Mosabala Research Topic: Exploring a professional learning community's knowledge for teaching stoichiometry

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Dedication

This report is dedicated to two special souls in my life, my late father, C.R. Pillay, a teacher himself par excellence and my late daughter, Dipti, who is a source of light in my darkest hour.

Acknowledgements

Firstly, I would like to thank my supervisor, Dr Mpho Mosabala, for refining my thinking. This report is a product of my interaction with lecturers from the Wits School of Education, who have enlightened me on my journey of post graduate academic studies. Thank you to all the lecturers at the Wits School of Education for their guidance and support. Thank you to the teachers for participating in this project amidst a global pandemic. This report would have not materialised were it not for my family, Sundeepa, Suriyan and Kheyuran – thank you for your love and support. Finally, I thank my mother Sarasvathy, my Goddess of knowledge, for being my first teacher.

Abstract

Content knowledge and pedagogic content knowledge for teaching of stoichiometry is seen as essential knowledge for teachers to possess to ensure high standards of learner achievement in stoichiometry. In recent years, the results produced by matriculants show that questions involving stoichiometry is the most poorly answered in the Grade 12 National Senior Certificate examinations. Vygotsky (1978) social cultural theory on learning is used to explain how teachers can work in collaboration through a professional learning community to help learners gain deeper knowledge on the topic stoichiometry. This study considers teacher discussions on stoichiometry and its role in developing teacher knowledge for the teaching of stoichiometry. The role of teacher discussions in professional learning communities is explored. This research uses a qualitative methodology in which the researcher analyses transcriptions of meeting discussions to find pedagogical reasoning of teachers through reflective practices. Pedagogical reasoning by Shulman (1986), and reflective practices by Schon (1983) are shown to work together to assist teachers gaining pedagogical content knowledge. It was revealed that teacher discussion stimulates reflections in action and on action (Park & Olivier, 2008). Through these reflections, teachers became aware of gaps in their subject matter and pedagogic content knowledge. Teachers became aware of the importance of change in orientation to teach associated with change in instructional strategies moving from a didactic teacher-centred approach toward an activity-driven or academic rigor approach (Magnusson, Krajcik & Boroko, 1999). The findings of this research show and concurs with other academic studies (Newman & Wehlage, 1993; Seashore & Helen,1996) that professional learning communities can create space for thinking of authentic activities and authentic pedagogies through teacher interaction by discussions. However, it remains unknown in this study how the participants enact their change in thinking of practice in the classroom situations. Further studies are recommended to see how teachers move from PCK gains in PLC discussions to enacting PCK in the classroom context. The impact of PLC discussion on the improvement of learners understanding of the topic stoichiometry needs to be established through further research.

Abbreviations / acronyms

CAPS- Curriculum and assessment policy statement

CPTD- Continuous professional teacher development

CoRe- Content Representations

DBE- Department of basic education

NSC- National senior certificate

IEB- Independent Examination Board

OBE- Outcome based education

PaPeR- Pedagogical and Professional- Experience Repertoires

PCK- Pedagogic content knowledge

PLC- Professional learning community

RCM- Refined Consensus Model

SACE- South African Council of Educators

TRA- Teaching and research activities

TSPCK- Topic specific pedagogic content knowledge

ZPD- Zone of proximal development

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Chapter 1

Introduction to the study

1.1 Background

My study explores teacher discussions of stoichiometry within a professional learning community and how these discussions can influence teacher pedagogic content knowledge through a process of pedagogic reasoning and teacher reflections. Professionals have the skill of knowing that operates through reflective practice (Schon, 1983). This study reveals teachers learning through reflective practices from each other as they discuss the teaching of stoichiometry.

Stoichiometry is the quantitative study of the relationship between reactants and products in a chemical reaction. The 'mole' is a central concept to learners understanding of this topic. The idea of mole is abstract and difficult for learners to understand. A good grasp of the topic stoichiometry is necessary for learners to understand other topics in the grade 12 CAPS curriculum including, acids and bases and chemical equilibrium. In addition, the Independent Examination Board (IEB) grade 12 examination problems applies stoichiometry to the topic electrochemistry. Therefore, a poor understanding of stoichiometry prevents learners from solving examination problems on three other topics in grade 12 physical science paper taken at South African high school.

Pedagogic content knowledge (PCK) was identified as the blind spot in teacher knowledge (Shulman, 1986). Since Shulmans seminal paper on teacher knowledge 36 years ago, there has been a flood of research on the topic of pedagogical content knowledge (Magnusson et al., 1999; Loughran et al., 2003; Bishop & Dentley, 2007; Park and Olivier, 2008; Padilla et al., 2008; Hume and Berry, 2011; Park and Chen, 2012; Mavhunga and Rollnick, 2013; Anney & Hume, 2014; Malcolm et al., 2014; Malcolm, 2015; Lucenario et al., 2016; Ndlovu, 2017; Budiasih et al., 2018; Mu et al. 2018; Borowski, Cooper & Hume 2019; ; Carlson & Daehler, 2019; Cooper & Hume, 2019; Neumann et al., 2019) . Shulman's model of pedagogical reasoning (Shulman, 1987) is powerful in that it shows a process happening in the minds of teachers in developing their pedagogic content knowledge. This model is definite in the context of classroom instruction. The maxim that teachers learn by teaching embodies Shulman's model. My study shows how teachers develop pedagogical content knowledge by a process of pedagogical reasoning in the context of a professional learning community.

The concepts reflection-in-action, reflection-on action and knowing in action was first introduced by Schon, (1983). Park & Olivier (2007) make use of the concept reflection-in-action in their model of PCK. Moghaddam et al. (2020) identify reflection-in- action in their study. My research analyzes teacher discussions from transcriptions looking for points of knowledge transfer. These points of knowledge transfer are found to occur at moments of reflections- in- action. Much of the discussions itself which are reflections on action stimulate reflection in action. Teachers at moments of reflection in action make shifts in thinking. Teacher discussions become a stimulus for teachers to reflect in action.

One of the attributes of pedagogic content knowledge is its domain specificity (Shulman, 1986). The domain is a particular area of study with its characteristic knowledge structure. As an example, we talk about the domain science. Physics, chemistry, biology, geology all fall within the domain science. Another attribute of PCK is its topic specificity, (Mavhunga and Rollnick, 2013). Different topics within a subject have its own PCK. For example, in the subject chemistry we can talk about PCK for the topic electrochemistry or PCK for the topic stoichiometry. I have chosen the topic 'stoichiometry' as a topic for discussion.

In a qualitative study, researchers (Anney & Hume, 2014) have seen growth in PCK of unqualified licenced teachers in Tanzania through professional development efforts of working in professional learning communities. There was a shift in instructional strategies of unqualified teachers with a move towards a student-centred approach moving away from a teacher centred transmissive mode of instruction. A quantitative study (Mu et al., 2018) in China reveals that teachers participating in professional learning communities increase their PCK and the working of PLC's eradicated regional inequalities in Chinese education.

A study on the development of teachers' reflective practices within a professional learning community over a two-year period show that the participating teachers' levels of reflection increase over time (Woolway et al., 2019). This study showed that reflection on practice in a PLC resulted in improvement in teaching practice. The study looked at "reflection on action" (Schon,1983 P62) bringing about change in teaching practice in which teachers become more engaging with learner prior knowledge. My research also exams teacher reflective practices in a professional learning community. However, my research shows how "reflection in action," (Schon, 1983 P62) leads to teachers' critical evaluation of their practice, growing PCK. Reflection in action, reflection on action and "knowing in action," (Schon, 1983 P50) are characteristics of a reflective practitioner.

Researchers suggest that an important goal of professional development programs is the development of PCK as it includes teachers' understandings of how students learn (Van Driel & Berry, 2012). PCK is shown to have positive outcomes on learning indirectly through motivating learners (Senjaya et al., 2021). My study shows a professional development program of a subject specific professional learning community of which the goal is the development of PCK at the grain size of topic level.

My research has its influence in the social cultural theory of cognition (Vygotsky, 1978). The social cultural theory of cognition deems that knowledge is socially constructed and an individual learns through social interaction. Vygotsky (1978) contended that since cultures vary, the knowledge an individual possesses cannot be a result of maturation alone. All knowledge is rooted in the social cultural context. A professional learning community of Physical Science teachers of high school learners will therefore be unique in their culture stemming from a shared experience of teaching high school learners' physical science, interactions with district offices, parents and community. Physical science teachers of varying number of years' experience teaching stoichiometry to high school learners are chosen for this study as the intention is to identify transfer of knowledge to teach stoichiometry between teachers of different levels of experience and qualification investigating pathways of knowledge transfer and viability of teacher discussion on stoichiometry to improve teacher knowledge.

Most research papers and reports on PCK for teaching of stoichiometry (Okanlawon, 2010; Malcolm et al., 2014; Mashamba,2017; Ndlovu, 2017; Makhechane & Qhobela, 2019; Aziz et al. 2020; Lee, 2020) do not engage with PCK for stoichiometry as a function of a PLC of physical science teachers. Mudzatsi (2017) investigates how a lesson study helps teachers improve PCK for teaching of stoichiometry. A lesson study is when teachers view each other's lessons and discuss afterwards. This involves collaboration and shows the workings of a PLC. Since there are limited research papers dealing with PCK for stoichiometry within a PLC, my research adds to the body of knowledge on PCK for teaching of stoichiometry within a PLC. The findings of this research will therefore contribute to the body of existing knowledge.

The national policy framework for teacher education and professional development makes provision for continuous professional development (Department of Education, 2006). Teachers need to accumulate continuous professional teacher development (CPTD)points, 150 points in a three-year cycle (Department of Education, 2006). Educators are required to log in their CPTD points to the South African Council of Educators (SACE). The policy framework allows for teachers to choose the kinds of professional development programs that they would want to participate in. However, many professional development programs are not effective in teacher learning that can enhance teacher practice because their purpose is not towards the development of professional practice for organised systematic learning, and they are not founded on the knowledge that teachers require and how best to acquire such teacher knowledge (Bertram, 2011).

The licenced unqualified teachers of Tanzania felt empowered and appreciated the support provided by the PLC that supported their growth in teacher knowledge (Alsharari, 2016). In the context of this study, novice teachers felt that their professional education to teach received from the tertiary institutions did not prepare them well for the workplace. (Alsharari, 2016). My research findings can show the value of PLCs in developing PCK, especially in novice teachers.

Researchers reveal learners' difficulties in understanding stoichiometry (Chandrasegaran, et al 2009; Gauchon & Meheut, 2007; Pekdag & Azizoglu, (2013); Schmidt, 1990). Ways to improve teacher knowledge for the teaching of stoichiometry can aid in improving learner understanding and performance in stoichiometry. A study conducted shows a positive relationship between increased teacher knowledge and learner achievement (Lucenario et al, 2016). In this study, a guided "lesson study" approach was followed. (Richardson, 2004 as cited in Lucenario et al. 2006, P1) Teachers' observations of lessons followed by reflections on observations improved teachers PCK and showed gains in student learning. My research focusses only on teacher knowledge. More longitudinal studies, in PhD research can investigate development of teacher knowledge withing a PLC and its relationship to student learning. For this study, the focus is on teacher knowledge and its development within a PLC.

In a pilot project studying novice teachers' changes in PCK in their first years of teaching, it was found that teachers' PCK for knowledge of students' learning showed changes with experience (Lee et al., 2007). A teacher could have two years of experience repeated ten times (Bishop & Denley, 2007), but generally, it is accepted that tacit knowledge develops through experience. Tacit knowledge is knowledge that is not easily made explicit. Tacit knowing is embodied in the expression "You know than you can tell" (Polyani, 1966, p.4.) It is a knowledge that even the knower is unaware of possessing this knowledge. Tacit knowledge can be captured and transferred through close interactions. Experienced teachers rich in PCK retire and leave the system with all this valuable knowledge that remains inaccessible to those teachers entering the field. I hypothesise that one way to ensure PCK transfer from the old to the new is by having teachers of varying levels of experience and qualifications to meet to discuss their teaching of topics. In this way, PCK skills in the teaching profession can be transferred.

This study investigates the feasibility of having such discussions. The department of basic education in its policy document contained in clause 13.9 suggest ways in which school management can schedule time for professional learning communities to meet (Department of Basic Education, 2015). The PLC is the context in which PCK, which is domain specific, can be transferred between teachers. This research looks at the workings of a PLC in discussing the topic stoichiometry and how such a community can aid in teacher knowledge transfer.

1.2 Rationale

The findings of my research can reveal the effectiveness of topic specific discussions by a PLC as a professional development program. Having more research on professional development programs to see what works and what does not, can guide teachers and school management teams to prioritise those programs that work. The research problem in this study is three-pronged and framed around the domain, PCK and a PLC.

The domain hones in on the topic stoichiometry as this topic is particularly challenging to learners. Learners find this topic difficult to understand (Shadreck and Ennunuwe, 2018) I base this assertion on the question by question and topic diagnostic analysis of the South African National Senior Certificate (NSC) examinations and educational research on the topic.

Students have performed poorly in questions on stoichiometry in the Grade 12 NSC examinations. (Department of Basic Education, 2018; DBE, 2020). The 2018 diagnostic report for the NSC Grade 12 Physical Science examinations, under the section overview of learner performance in paper 2, stipulated that Grade 11 work on stoichiometry is poorly understood (Department of Basic Education, 2018). According to the graph in figure 1-1 below, stoichiometry in question 5 and question 7 were poorly answered with an average of 48% and 44% respectively.

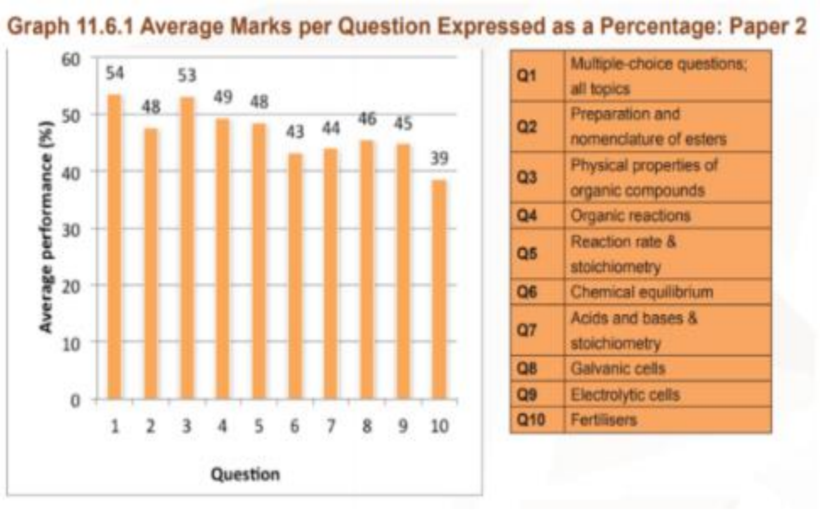


Figure 1-1: Average marks per question expressed as a percentage paper 2 (NSC 2018 Diagnostic report part 1, DBE, P170)

Graph 11.6.1 Average performance per question in Paper 2

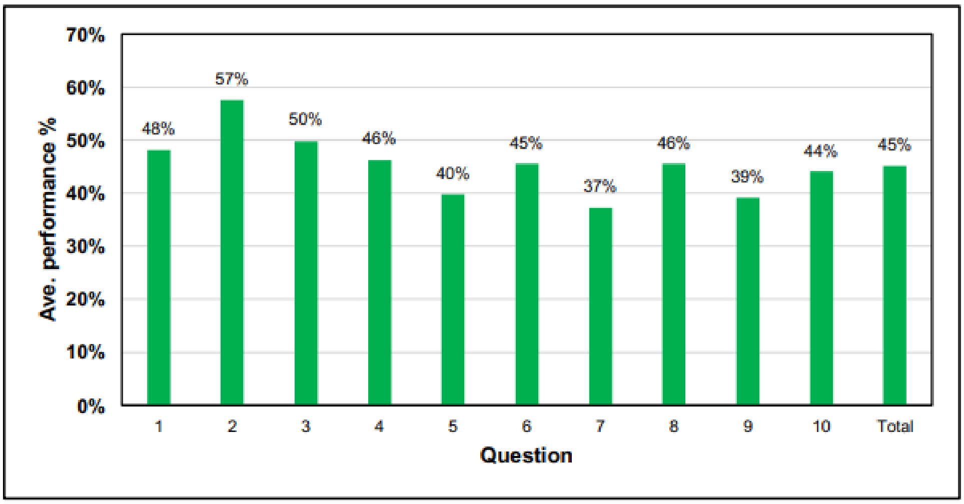


Figure1-2: Average mark per question expressed as a percentage, paper 2 (NSC 2020 Diagnostic report, Part 1, DBE, P209

Figure 1-2 shows the performance of learners in the 2020 National Senior Certificate Examination in South African schools. Question 7 of the year 2020 was the most poorly answered question with an average of 37%%. This question was therefore selected for discussion in the professional learning community meeting of this research and appears in the second meeting discussion. I have chosen stoichiometry as the discussion topic of teacher discussions as this is the topic that is most challenging to learners in the NSC Paper 2.

1.3 Research Problem

While PLCs have been widely studied and implemented in various educational contexts, including science education (Woolway, Msimanga, & Lelliott , 2019), there is limited specific research on the application of PLCs in teaching stoichiometry.

Research suggests that PLCs provide opportunities for teachers to collaborate, share best practices, and develop a deeper understanding of content and pedagogy (Marks & Louis, 1997). Investigating the PLC's knowledge for teaching stoichiometry can help identify effective instructional strategies, teaching resources, and assessment methods that support students' learning in this challenging topic.

Stoichiometry is a complex topic in chemistry, and students often hold misconceptions that hinder their understanding (Talanquer, 2011). By investigating the PLC's knowledge, researchers can identify common misconceptions and develop targeted professional development initiatives to address them, leading to improved student learning outcomes.

PLCs encourage teachers to engage in collaborative activities such as lesson study, peer observations, and reflective discussions (Vescio, Ross, & Adams, 2008). Investigating the PLC's knowledge for teaching stoichiometry can promote a culture of collaboration and reflective practice, allowing teachers to refine their instructional approaches and develop a shared understanding of effective teaching strategies.

Studying the knowledge of teachers within a PLC can inform the design of relevant professional development programs that cater to their specific needs in teaching stoichiometry. Ongoing professional growth is vital for teachers to stay up-to-date with current research, advancements, and innovative teaching approaches, ultimately benefiting their students (Darling-Hammond, Hyler, & Gardner, 2017).

1.4 Aims and objectives

The aim of this research is to determine whether teacher discussions on the topic of stoichiometry within a PLC can lead to growth in teacher PCK.

The objectives include:

1.4.1 Locate within the discussions teacher reflections and changes in thinking as a result.

1.4.2 Identify the more knowledgeable other and his influence in the thinking of others in the professional learning community.

1.5 Research questions

What is the PLC knowledge for teaching stoichiometry?

1.5.1 What is the role of teacher reflective practices within a PLC discussion in the way teachers critically evaluate their knowledge for teaching stoichiometry?

1.5.2 How does the more knowledgeable other within the PLC contribute to others in the group moving through the zone of proximal teacher development of teacher knowledge for the teaching of stoichiometry?

Chapter 2

Literature review

My research considers how teachers through discussions in a professional learning community develop pedagogic content knowledge by reflective practices. The backdrop to this research is Vygotsky's perspective of learning occurring within the social cultural context. I am looking at the ways teachers learn from each other through discussions. The activity of teacher focused discussions on the teaching of stoichiometry within a PLC is deemed as an effective professional development program.

2.1 Theoretical framework

Vygotsky's (1978) theory provides the psychological foundation that puts forward the basis of development of higher order thinking as being primarily a result of social interactive processes occurring historically within a social cultural context. He looked at early learning of the child, showing how the act of grasping at objects, an external process, through interaction with the adult is internalized as a sign of pointing. "An interpersonal process in transformed into an intrapersonal one", (Vygotsky, 1978, p. 57). In this way, Vygotsky explains the ways in which higher psychological functions are internalized (Vygotsky, 1978). My research uses Vygotsky's theory as its framework, where social interaction of teachers becomes the learning ground for teacher development of PCK. Taylor (2014) describes social constructivism as a learning theory in which knowledge is constructed by individuals through social interaction. Discussions between people allow for metacognitive process in which participants think about their thinking, (Taylor, 2014).

Mediation through tools and signs is revealed by Vygotsky (1978) as the mechanism of developing higher order cognitive functions. In this sense, the use of language in the form of conversations between teachers that share a common culture of teachers of science becomes the tool in developing teacher knowledge. The study of chemistry and stoichiometry has its own forms of signs and symbols used to make the abstract concepts concrete and communicable.

There are three theoretical positions on the interaction between learning and development, (Vygotsky, 1978). First, learning precedes development. Developed mental structures are a prerequisite for learning to happen. Second, learning is developmental. The third position is that both learning, and maturation are developmental processes with maturation necessary for learning and learning pushing forward maturation. After presenting the three viewpoints, Vygotsky (1978) explains the concept zone of proximal development (ZPD) that provides for a new viewpoint on interaction between learning and development.

"The zone of proximal development is the distance between actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky,1978, p.86)." I have taken this idea of Vygotsky and used it for my research by looking at learning and development as a lifelong process not necessarily limited to school children and formal learning in schools.

Piaget (1972) provided a model for cognitive development with stages of development at different ages that end with the formal operational phase at complete maturation when adulthood is reached. However, the postmodern view of cognition sees its development into adulthood (Despotovic, 2014). Complete maturation cannot be possible and as human beings are continuously engaging in personal tasks (Riegel, 1975). Contextualist theorists of development see cognitive development into adulthood as adults face situationally complex problems (Despotovic, 2014). It follows that adults stretch their thinking in developing knowledge for teaching by interaction through teacher discussions (Coenders and Verhoef, 2019).

2.2 PCK and PCK models

Shulman (1986; 1987) in his succinct essays, “Those who understand: Knowledge Growth in Teaching,” and “Knowledge & Teaching: Foundations of a new Reform,” sought to professionalise teaching to occupy status that medical doctors and lawyers hold. In doing so, Shulman categorized knowledge bases for teachers and created the construct, PCK, what he referred to as the blind spot in understanding teacher knowledge.

Shulman metaphorically describes PCK as being an amalgam of content and pedagogy. It is powerful in its meaning. From material science we know that the alloy steel made from iron and carbon is stronger than its individual constituents. In a comparable way, PCK is more than the sum of content and pedagogy, the blind spot in teacher knowledge that has eluded teacher research in the decade preceding the 1980’s.

Shulman (1986) reminds us of the ancient world of learning in the practice of teacher and students at universities, acknowledging the value of teachers in society. The highest university qualification, “doctorate” translates to teacher or masters meaning teacher. Once the candidates graduate in any field by mastering the subject matter, they are then able to teach others. Today, we hold onto the same rituals of graduation recognising the importance of teachers in society. From this language of titles at universities we see the pedagogue, rich with content knowledge able to teach others.

Schulman (1986) recognised at the time of writing “Those who understand knowledge growth in teaching,” (Shulman, 1986, p4) the heavy focus of pedagogy and little emphasis on content by policy makers, a marked difference from a century earlier where the focus was heavily on content knowledge in teaching board exams. As Schulman (1986), puts it, “the pendulum has now swung in both research and policy,” (Shulman, 1986, p 7)”. The merging of content knowledge and knowledge of pedagogy creates a new category of teacher knowledge “pedagogic content knowledge” (Shulman, 1986, p 9). . Since the time of Shulman’s papers in 1986 and 1987, the research programs have seen an abundance of research into PCK.

Loughran et al., (2003), published a paper titled “Frameworks for representing science teachers pedagogic content knowledge.” Here, Loughran makes use of Schulman’s, idea of propositional knowledge in teachers developing content representations (CoRe’s) looking into the central ideas within a particular topic. Shulman described three forms of knowledge, propositional, case, and strategic (Shulman, 1986).

In the CoRe’s developed, teachers are prompted on each idea with cues as quoted:

> Why do you intend learners to learn about this idea? Why is it important for students to know this? What else you may know about this idea that you don’t expect students to know yet? What are the difficulties or limitation with teaching this idea? What knowledge about students thinking that influences your teaching of this idea? What are the other factors that influence your teaching of this idea? What are your teaching procedures and particular reasons for using these to engage with this idea? What are your specific ways of ascertaining student understanding or confusion about this idea? (Loughran et al*.,* 2003, p7.).

Probing into the minds of teachers can occur by getting teachers to have the discourse about their practice. It is an attempt to make explicit PCK. Teachers can articulate their thoughts by speaking to other teachers. Teachers talking about their teaching to other teachers can provide the researcher with information of the thinking of teachers on teaching.

The questions identified in the study of Loughran et al., (2003), as alluded in the previous paragraph, probe into the thinking of teachers and reasons behind this thinking. In this way, PCK is documented. The CoRe as Loughran et al., (2003) pointed out lack the aspect of teacher experience as it is propositional in nature. To compensate for this, and provide a more wholistic representation, Pedagogical and Professional- Experience Repertoires (PaP-ERs) are produced. PaP-ERs are narratives of teachers' experiences when teaching a topic. These narratives are documented reflections of teacher experiences on teaching particular aspects of a topic, a form of case knowledge (Schulman, 1986).

Loughran et al., (2003), show what they call a PaP-ER of teachers on the topic 'chemical reactions'. Before starting the topic on chemical reactions, the teacher in the narrative of Pap-ER reveals her knowledge of learners identifying a problem with learners' knowledge of what a substance means. When a substance reacts and bubbles are produced, the teacher reveals that learners cannot see that the bubbles are indication of a new substance. These narratives provide the pedagogical reasoning behind the pedagogical action of the teacher.

At the centre of the Refined Consensus Model of the PCK graphic representation (Borowski & Cooper ,2019), is pedagogical reasoning represented by the innermost circle or core of the illustration as shown in Figure 2-1 below.

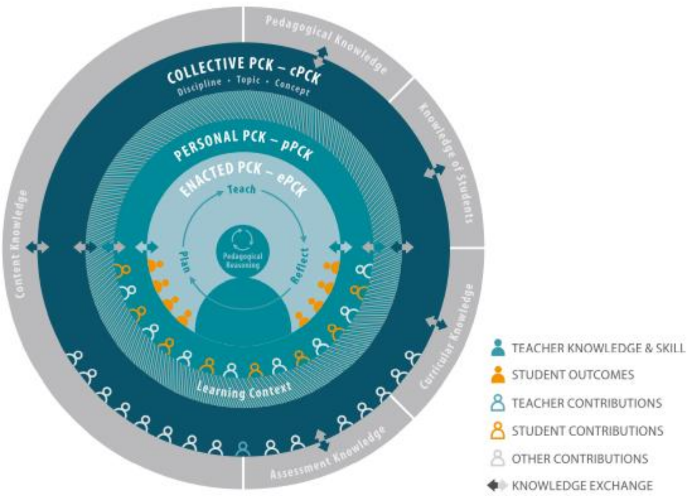


Figure 2-1 Refined Consensus Model (Borowski et al., 2019, p.83)

Shulman (1987) created a model of pedagogical reasoning (See Figure 2-2). He shows the five stages that teachers go through in the process of pedagogical reasoning.

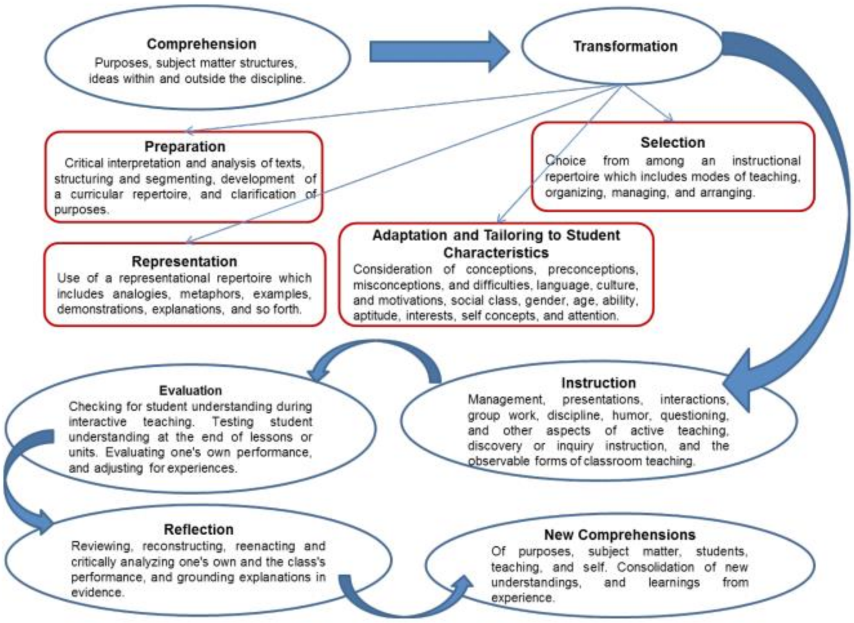


Figure 2-2 Model of Pedagogical Reasoning and Action adapted from Shulman 1987 P15 & Salazar 2005 as cited in (Fernandez, 2014 p 82)

At the beginning, a text in the form of an activity or question is shown or will be shown in the classroom context. Comprehension of the text by the teacher is the first stage of the process of pedagogical reasoning. Comprehension is followed by transformation in which the teacher engages with rephrasing, using metaphors, various representations so that the text becomes accessible to the learner. Transformation is followed by instruction, then evaluation, reflection, and finally new comprehension. It is notable that transformation does occur not necessarily preceding instruction but can occur in the act of teaching itself as indicated in the refined consensus model. This view of reflection in the act of teaching is incorporated in the pentagon model of PCK (Park & Olivier, 2008) as reflection in action. The Park and Olivier (2008) pentagon model is elaborated upon further in this report.

Mavhunga & Rollnick (2013) investigated PCK at the topic level considering PCK of 16 pre-service teachers in training who underwent a 12-session program of 100 minute per session delving into components of PCK relevant to the grain size of topic level.

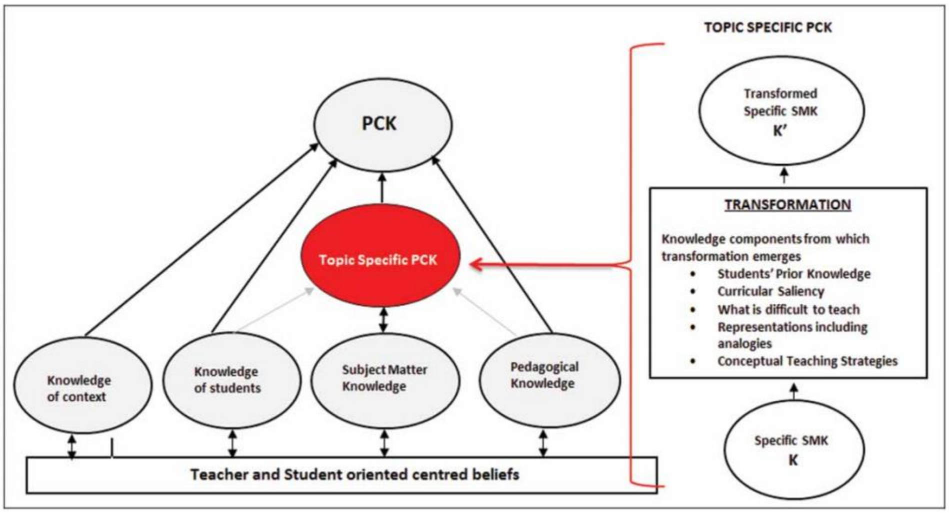


Figure 2-3 Model of Topic Specific PCK by Mavhunga & Rollnick (2013, p.115)

As shown in figure 2-3 above, the five components are pertinent to transformation of subject matter knowledge used in the study include: student prior knowledge, curricular saliency, what makes a topic easy or difficult to understand, conceptual teaching strategy and representations including analogies. The participants in this study were given the opportunity to explicitly think about PCK and its components in relation to electrochemistry.

An intervention of pre and post explicit discussions of topic specific - PCK and components in the form of a validated instrument of questions provides quantitative data in addition to online text discussions providing qualitative data enabled the researcher to draw conclusions (Mavhunga & Rollnick, 2013)They concluded that all participants gain PCK at the topic level and attributed these gains to the explicit inclusion of topic specific PCK and its components that enable transformation on content on electrochemistry in the structured course work of these 16 students.

An earlier study, like Mavhunga et al. (2013), considers PCK and its components (Park & Chen,2012). They use the pentagon model of Park & Olivier (2008) as a conceptual framework in their study which is shown in Figure 2-4.

Figure 2-4 PCK Pentagon Model by Park & Olivier (Park & Chen 2012, p.925)

Park and Chen (2012) show the importance of connections between the knowledge components of teacher knowledge in determining quality of PCK. The knowledge components of teacher knowledge that they considered based on the pentagon model, figure 2-4, is the same as those highlighted by Magnusson, Krajcik & Boroko (1999) in a model of PCK shown in figure 2-5. However, the difference in both models (figure 2-4 & figure 2-5) is the pentagon model is a cyclic representation showing equal connections between knowledge components and PCK. Magnusson et al., (1999) shows a linear model where connections are between orientations to teaching science and the other components as shown in figure 2-5.

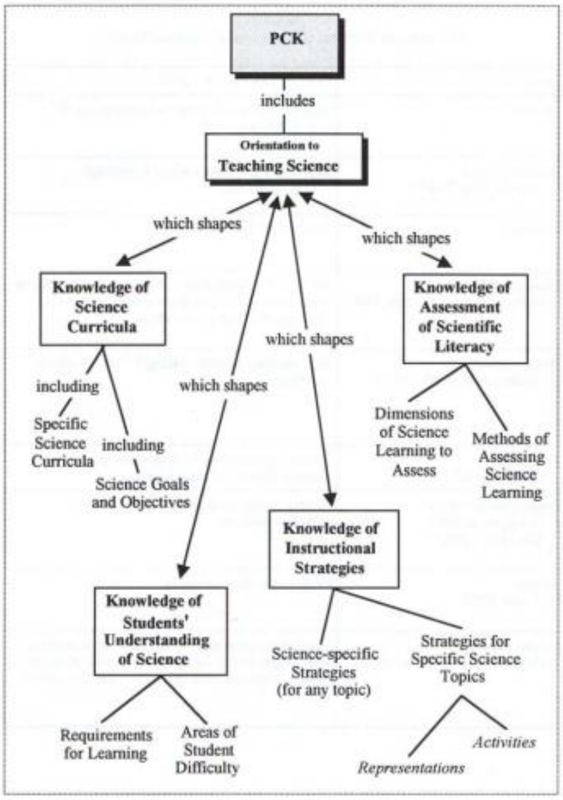


Figure 2-5 Magnusson Model of PCK & its components (Magnusson et al.,1999, In J. Gess -Newsome & N. Lederman (Eds.) p.99)

Park and Chen, (2012) mapped the connections between teacher knowledge components on the pentagon for four experienced biology teachers from the same school exposed to the same curricula material and teaching the same topics, photosynthesis and hereditary. Their results showed that PCK was idiosyncratic and topic specific. They further found that the knowledge components- knowledge of student understanding and, knowledge of instructional strategies and representations, had the greatest connections between knowledge components and with other knowledge components. For one of the teachers observed, they found that the knowledge component orientations to teaching science limited connections with other knowledge components. This teacher was orientated with the didactic approach believing in transmission mode of learning unlike the other three who's approach followed the constructivist view of learning. The teacher orientated to the didactic approach inhibited his connections with the other knowledge components. Knowledge of science curriculum had the least connections with other knowledge components for this study. Knowledge of assessment had the most connections with knowledge of students understanding and knowledge of instructional strategies and representations. Park et al. (2012) advocate finding ways of strengthening connections between knowledge components to enhance the quality of PCK.

Neumann, Kind and Harms (2019) provide a rationale for the consensus model of teacher professional knowledge and skills including PCK. The consensus model is shown in Figure 2-6 below.

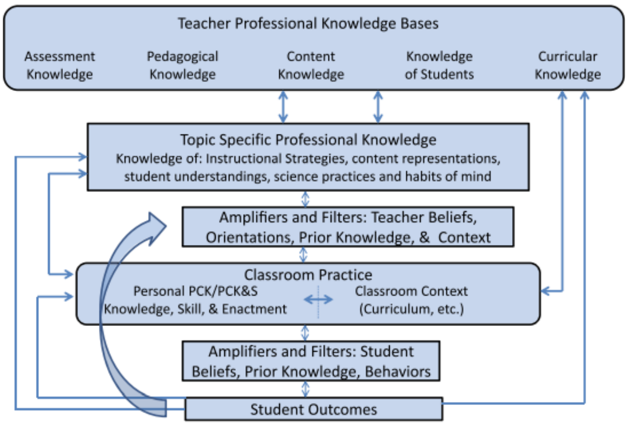


Figure 2-6 Consensus Model of Teacher Professional Knowledge and Skills including PCK Model by Gess- Newsome (2015) as cited in (Borowski et al., 2019, P79.)

The model reconciles the coexistence between the transformative and integrative approaches and lines of research into PCK. The pentagon model (Figure 2-4) represents an integrative model in which PCK integrates knowledge from the different teacher knowledge bases. The Magnusson Model (Figure 2-5) in which PCK is viewed in a transformative manner.

Neumann et al. (2019) explains topic specific pedagogical knowledge (TSPK) below teacher professional knowledge base as the point of integration whereas personal PCK and PCK & Skill occurring lower down in the classroom practice box by virtue of its position in the model is indicative of transformative view of PCK.

Magnusson et al. (1999) shows the transformative linear model of PCK and how it relates to its components. Park & Oliver (2008) reveal the pentagon model of PCK, Gess -Newsome (2015) show the Consensus Model and Borowski et al (2019) highlight the Refined – consensus model. What follows is a comparison of PCK Models looking at similarities and approaches toward understanding PCK by the various models.

All the models show PCK drawing upon the professional knowledge bases of teachers. Shulman (1987) identifies seven categories of professional knowledge that forms knowledge required for teachers. These include content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, knowledge of educational ends, values, and purpose. Park and Oliver (2008) and Magnussen et al. (1999) included teacher knowledge and beliefs of orientations to teach science, teacher knowledge of instructional strategies to teach science and teacher knowledge of assessment in addition to knowledge bases listed already. The models show knowledge exchanges between PCK and other domains of knowledge. The discussion that follows will unpack the knowledge bases briefly.

Subject matter knowledge can be seen as the specialised body of knowledge containing concepts within topics and between topics of the subject. For this research, the subject matter 'knowledge' refers to that body of knowledge of the subject of chemistry. The history of science reveals how this body of subject matter knowledge has seen a paradigm shift since the time of early concept formations by John Dalton who introduced atomic theory to chemistry in 1808, what Gess-Newsome and

Lederman (1999) refer to as cannons of evidence. For the purposes of this study the subject matter knowledge of teachers that is probed into at a topic level is that of stoichiometry. To teach a subject it is then necessary to have knowledge of the subject matter. Gess-Newsome and Lederman (1999) go further by incorporating an understanding of the nature of the discipline as being part of the subject matter knowledge for teachers. They group knowledge of the nature of science as being part of the subject matter knowledge required for teaching science.

When reading Schulman (1986), one needs to be careful not to confuse subject matter knowledge with content knowledge. Schulman (1986) explains three categories of content knowledge required by teachers to include, subject matter knowledge, pedagogical content knowledge and curricular knowledge. Subject matter knowledge has two branches substantive subject matter knowledge and syntactic knowledge. He goes on to explain substantive knowledge as the knowledge of central concepts and knowledge of the structure of the way in which this knowledge is organised and built upon. Syntactic is what makes the knowledge of the discipline acceptable, the rules that govern acceptability of concepts within the discipline.

Schulman (1987) refers to general pedagogical knowledge as the overarching principles of classroom organisation and management moving beyond content knowledge. The repertoire in the teachers' toolbox creating a classroom environment conducive to teaching and learning will therefore form part of general pedagogical knowledge. All teachers of different subjects can share this kind of knowledge. However, Physical Science teachers do work with learners in a science laboratory and, therefore, there would be some aspects of this kind of knowledge peculiar to science teachers.

Knowledge of curriculum is expanded to include curricula material, horizontal and vertical curriculum as shown in the PCK model in Figure 3 (Park & Olivier,2008). The South African curriculum has been through changes form Outcome Based Education (OBE)to Curriculum Assessment and Policy Statements (DBE,2011). As the curriculum changes, it is therefore imperative for teachers to expand their knowledge of curriculum to meet these changes. Some of the changes involve either removal or addition of topics to the curriculum. In the South African context, the recent removal of spheres of the Earth, hydrosphere in Grade 10, lithosphere and mining in Grade 11 and chemical system and fertilizer industry in Grade 12 is a case in point of changes in curriculum showing differences in what is required to be taught from 2021 in the Physical Science CAPS curriculum.

The two categories of knowledge of science curriculum as identified by Magnusson et al., (1999) include (i) knowledge of goals and objectives of the curriculum and (ii) knowledge of specific curricular programs that are either domain specific or topic specific. The curriculum is a national document that is mandatory for teachers to have knowledge off. Teachers should have knowledge of the topics across the curriculum as concepts merge across topics. Knowledge of the vertical curriculum in a subject includes knowledge of topics done in previous years and those topics that are to be covered in future years. The horizontal curriculum includes those aspects dealt with across subject at a particular grade. Knowledge of topics dealt with in Mathematics becomes relevant for teachers to know as these topics aid problem solving in the Physical Sciences.

Teachers' understandings of the cognitive development levels of learners that they teach is part of knowledge component, knowledge of learners. Shulman (1986) writes on the research done on the conceptions and misconceptions that students bring with them to the classroom. Shulman (1986) reminds us at this point in his article "Those Who Understand Knowledge Growth in Teaching," (Shulman, 1986, p4) that learners are not coming into the classroom as blank slates, they have their own conceptions which likely is different from the science worldview. Understanding of how learners think is a part of the teacher knowledge component, knowledge of learners.

Magnusson et al., (1999) provide a two-fold categorization of teacher knowledge of students understanding to include teacher knowledge of learner prior knowledge required to understand content being taught and teacher knowledge of learner misconceptions or difficulties in understanding science concepts. In chemistry, learners can have difficulties visualizing molecules in reactions at a sub-microscopic molecular level (Davidowitz, Chittleborough & Murray, 2010).

Magnusson et al*.,* (1999) categorize teacher knowledge of instructional strategy as subject specific strategies and topic specific strategies. Some subject specific strategies include, for example, the learning cycle which comprises a three-phased strategy including discovery, term introduction and concept application. Conceptual change strategies involve confronting misconception and creating mind conflict. Argumentation and scientific debate fostering scientific critical thinking is subject specific instructional strategy. Topic specific strategies as explained by Magnusson et al*.,* (1999) can be categorized as representations and activities. Representation includes analogies, illustrations, symbols and so on used to transform knowledge making it understandable to learners. Activities include demonstrations, practical, simulations, assignments, project, and tasks engaged by learners that help them to understand science.

Orientation to teaching science is regarded by Magnusson et al., (1999) as being the overarching component of PCK as can be seen by the schematic representation of PCK in Figure 2-7 below.

ORIENTATION	CHARACTERISTICS OF INSTRUCTION
Process	Teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills.
Academic Rigor	Students are challenged with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena.
Didactic	The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science.
Conceptual Change	Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates discussion and debate necessary to establish valid knowledge claims.
Activity-driven	Students participate in "hands-on" activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as a consequence omit or inappropriately modify critical aspects of them.
Discovery	*Student-centered.* Students explore the natural world following their own interests and discover patterns of how the world works during their explorations.
Project-based Science	*Project-centered.* Teacher and student activity centers around a "driving" question that organizes concepts and principles and drives activities within a topic of study. Through investigation, students develop a series of artifacts (products) that reflect their emerging understandings.
Inquiry	*Investigation-centered.* The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions.
Guided Inquiry	*Learning community-centered.* The teacher and students participate in defining and investigating problems, determining patterns, inventing and testing explanations, and evaluating the utility and validity of their data and the adequacy of their conclusions. The teacher scaffolds students' efforts to use the material arid intellectual tools of science, toward their independent use of them.

Figure 0-7 The nature of instruction associated with different orientations to teach science (Magnusson et al.,1999, In J. Gess-Newsome & N. Lederman (Eds.) p.101)

Grossman (1990) describe orientation as the purposes of teaching a particular subject at a particular grade level," (Magnusson et al., 1999, In J. Newsome & N. Lederman (Eds.) p. 96) and therefore a component that influences other components with a strong influence on teacher instructional strategies. We see this influence of orientations to the nature of teacher instruction in Figure 2-7.

Magnusson et al., (1999) and Park et al., (2008) draw focus to teacher knowledge of dimensions of assessment and methods of assessments. Dimensions of science learning important to assess include conceptual understanding, nature of science, interdisciplinary themes, scientific investigations, and practical understanding. Knowledge of methods of assessments considers knowledge of instruments, activities, and approaches (Park et al., 2008). Dimensions of science goes beyond subject matter knowledge that is status quo focus by teachers and leaners in the classroom. Science is more than a body of factual knowledge. Assessment strategies that can mirror the things that scientist do forms a dimension of science known as nature of science. Methods of assessment include written tests, laboratory notebooks, rubrics, portfolio files, and interviews.

Teacher efficacy refers to teacher confidence in teaching (Park et al., 2008). Teachers will pursue what they are confident in and avoid that which stirs uncertainty or lack of confidence. The willingness or unwillingness to tread unchartered waters falls in the realm of teacher efficacy. According to Park et al., (2008), the PCK model included teacher efficacy as a component of PCK in a hexagon model and subsequently removed teacher efficacy in the pentagon model.

Veal and MaKinister (1999) produced a general taxonomy for PCK as shown in Fig 2-8 below. General PCK occurs within disciplines. Veal et al., (1999) reveal similarities of general PCK in different disciplines using the example of inquiry-based learning in science. Figure 2-8 illustrates how stoichiometry fits in a taxonomy. Stoichiometry occurs at the topic specific level within chemistry.

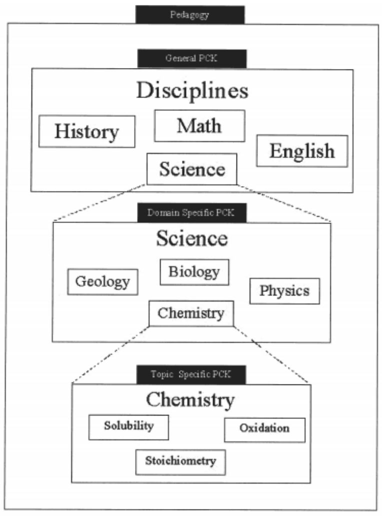


Figure 0-8 General Taxonomy for PCK (Veal & McKinister,1999, p.7)

PCK models are useful in that they help describe PCK and can be used to track PCK growth in teachers (Mavhunga and Rollnick, 2013; Park and Olivier, 2008). This part of the literature review outlines the different PCK models that conceptualize PCK in different ways.

2.3 Teaching and learning of stoichiometry

Padilla & Garitz (2008) used Loughran's (2003) CoRe representation to capture PCK of four university professors' teaching of stoichiometry. The chemistry professors together with the researchers agreed upon the main ideas when teaching stoichiometry to be ratio and proportions, purity of substances, composition, empirical and molecular formulae, balancing chemical equations and expressions of concentration. The professors were then asked to answer the CoRe prompts for each main idea. From this data, the researchers can categorise the professors as being representational, procedural, conceptual, or contextual in their approach. Although all the professors displayed the conceptual approach in their teaching style, this was not the predominant style for everyone.

CoRe is used by a pre-service teacher to develop PCK for stoichiometry through a process of scaffolding (Hume & Berry, 2010). In doing so, they used the approach of social constructivism in learning. The pre-service teacher in the study designed a program that provided the opportunity for her students to explore learner prior knowledge with respect to the topic atomic structure and chemical bonding. Next, they were asked to find out what learners needed to know given the age group on the same topic. Students were provided with directions of sources for the materials needed to undertake the tasks. Thereafter, students had to draw up a CoRe for a different topic, Redox reaction. This they did with guidance of the teacher. Finally, the students had to work a CoRe for the topic stoichiometry independently of the teacher. Students were working in groups. The findings of this study revealed that scaffolding pre-service teachers strengthened their ability in drafting CoRe with the possibility of strengthening PCK in future. Here we see the researcher using the idea of Vygotsky's (1978) ZPD.

Like Hume & Berry (2010), Driver et al., (1994) base their ideas on social constructivism in arguing for teachers to create a classroom that mirror the kinds of discursive practices of scientists. Scientific Knowledge is viewed as being socially constructed with claims of being made based on evidence which is argued with counterclaims to fight for its place as being accepted by the community of practice of scientists. The point that Driver et al., (1994) make is that learners come into the classroom with their own naïve ideas that they use to explain observations in the world. These ideas are mostly conflicting with the science worldview. Teachers need to understand what the learners are understanding first before creating cognitive conflict by presenting different view for learners to see the plausibility of the science worldview. Teacher discussions within PLC's should be modelled around social constructivism in which an environment becomes conducive for different perspectives to be expressed with the notion that there is no one way of thinking.

Ndlovu (2017) examined the topic-specific pedagogical content knowledge in stoichiometry of preservice teachers. This was a longitudinal study that used a methods university course as an intervention in which topic specific PCK components as exemplified by Mavhunga (2013) are explicitly taught alongside developing a CoRe for stoichiometry. A pre-intervention topic specific PCK validated instrument, by Malcolm (2015), was used as a diagnostic to determine quality of topic specific PCK pre and post intervention. The findings of this study show positive gains in quality of PCK measured after doing the post diagnostic a year after the intervention. The study recommends that the component conceptual teaching strategy be given more attention for pre-service teachers' methods course as this component proved challenging for the participants.

Makhechane and Qhobela (2019) undertook a study on topic specific PCK pertaining to stoichiometry for a group of teachers from different schools in Lesotho. They based their study on the topic specific PCK model of Mavhunga and Rollnick (2013) as represented in Figure 2-3 and using content representations (CoRe's) introduced by Loughran (2013) in determining PCK of teachers where extensive ideas are made explicit by the participants. The researchers focus on some of the knowledge for teaching including teacher orientation and beliefs of the purpose and goals of science teaching and role of prior knowledge (knowledge of learners). The study revealed the predominance of a teacher centred or lecture teaching strategy reasoned by teachers that stoichiometry is abstract and therefore, requires more explanations by the teacher. The teachers have not considered the ways in which children learn as explained by the social constructivism theory of learning and therefore require a shift in teaching strategy. Insights into learners' own conceptions means a move towards involving learners more, changing the lecture method thereby tapping into the thought of learner, working with their ideas. Knowledge of learners, therefore, becomes one of the knowledge bases of teacher professional knowledge necessary for the advancement of learning. This aspect seemed to require more emphasis by the teachers in this study.

Chemical reactions are represented by chemical equations. Davidowitz et al. (2010), in their study show the usefulness of students using sub-micro diagrams in teaching and learning of chemical equations and stoichiometry. Davidowitz et al., (2010) argue that diagrams of sub-micro level provide a more complete picture of the chemical reaction leading to a deeper understanding. In this study, students had to construct sub-micro diagrams and relate these to the chemical equations to improve their understanding of chemical equations and stoichiometry. Their findings show that sub-micro level drawing to be useful in teaching and learning introductory chemistry. Furthermore, the study reveals the difficulty for some students to make the link between sub-micro and symbolic representations.

Literature shows learners have difficulty in determining the limiting reagent in stoichiometry problems. Chandrasegaran et al. (2009) in their study discovered that students displayed limited confidence during problem solving to determine the limiting reagent and perform calculations related to limiting reagent. Even though learners could properly define the limiting reagent as that which gets finished first, they were not able to apply the concept to problems involving stoichiometry in new and unfamiliar situations. This became evident when solving problems involving percentage composition of binary compounds. The students did not find a need to write a chemical equation to find the stoichiometric mole ratio. In this study, some student failed to get the molecular mass of hydrogen and oxygen correct as they did not realize that in the gaseous phase these molecules are diatomic. Gauchon and Meheut (2007) concluded in their study that most learners had the view that both reactants get used up completely when they are in the same physical state and that one reactant, reacts completely when the reactants are not in the same physical state.

Literature shows much confusion around amount of substance as used in chemistry. Schmidt (1990), in their study of students reasoning patterns in solving stoichiometry problems, found that many students arrived at their answers by mixing up amount and reacting mass or molar mass and reacting mass. In their article, Schmidt (1990) suggested that teachers be aware of learner ideas before they enter the classroom so that teachers will know how to use these ideas. It is recommended in the paper for teachers to avoid chemical formulae of type AB and molar masses of elements used should be different.

A study conducted by Pekdag and Azizoglu (2013), shows that the confusion around "amount of substance" in stoichiometry is exacerbated by the semantic mistakes found in textbooks. They found that textbooks use amount of substance as equivalent to mass, Avogadro's constant, molar volume, and molar mass. Schmidt & Jigneus (2003) argue that Swedish learners use non-mathematical methods to solve simple stoichiometric problems. These researchers recommend that non-mathematical strategies be used to solve simple stoichiometric problems.

Refining the conception of mole as a standard international (SI) unit for amount of substance is the thrust of the paper presented by Malcolm, Rollnick and Mavhunga (2014). In this article, the authors discuss the error in conception of the mole by teachers, learners and in textbooks. Using the view of the mole as an SI unit in linking the macroscopic visualization to the sub microscopic visualization is what the authors refer to as being curriculum salient. The confusion around mole stems from falsely thinking about amount of substances in terms of mass and volume. They emphasise that mole is the amount of substance that connect to mass and volume by proportionality relations.

Malcolm et al., (2014) create awareness that the lack of subject matter knowledge of teachers defining the mole is a barrier to learners understanding of reaction stoichiometry. They argue that *n* (mole) is a macroscopic measure of the amount of substance that relates at an atomic level of representation to the number of entities of elementary particles, atoms, ions, molecules, or formulae units. They show that questions asked by teachers and those found in textbooks creates a misconception of the meaning of mole. For example, instead of asking how many moles are there in 40 grams of water, the question should be phrased as what is the amount of substance in 40 grams of water?

The mole is defined as an amount of a substance that is equivalent to the number of atoms found in 0.012kg of carbon 12. The mole as in the definition is not a number (Kind,2014; Malcolm, 2014). The argument by Kind (2014) and Malcolm et al., (2014) is using "amount of substance" and "number of particles" as meaning the same thing, creates much confusion and deviates from the meaning of mole as define as an SI unit.

The representation used by Silberberg (2006) gives a clear picture of where the mole fits within the three levels of representations used in chemistry. Figure 2-9 depicts the mole as amount of substance at the macro level of representation. Also indicated in this pictorial representation are the sub micro level of representation in the form of molecules and the symbolic representation in the form of a balanced chemical equation.

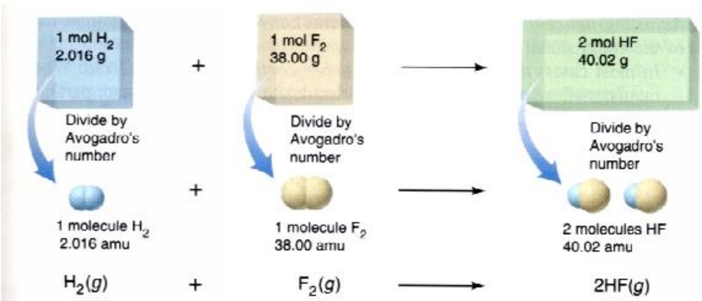


Figure 0-9 Three Levels of Representation (Silberberg,2006.)

Sunyono, Yuanita & Ibrahim (2015) provide evidence in their study that show learners develop more coherent mental models of chemical reactions after intervention of instructional strategy incorporating use of all three levels of representation, symbolic, macroscopic and sub microscopic. A mental model is an internal construct of an external reality, and these models can be unstable (Sunyono et al.,2015). Learner connecting all three levels of representation can understand the chemistry stoichiometric problem by developing a mental model of the phenomena. This helps learners with conceptual understanding as shown in this study, learners become better able to deal with problems in stoichiometry.

Budiasih et al., (2018) links misconceptions in stoichiometry to misconceptions is chemical equilibrium. Learners hold the view that number of moles is proportional to number of atoms and therefore incorrectly conclude that increasing the volume of the gas in a system in equilibrium, then the shift the equilibrium in the direction of a greater number of atoms. This misconception according to the researchers arise from the learners not realizing the difference between the reaction coefficients and the subscripts of an element. The symbolic representation of a balanced chemical equation is not understood.

Some researchers show that stoichiometry and mole concept are abstract concept introduced to learners before development of the formal operation stage in mental development (Pillay & Huddle, 1996; Kind, 2014). There is a sound reason for teachers to use more concrete examples and allow learners to work in small groups when these abstract ideas are first introduced (Pillay & Huddle, 1996).

To show the limit to learning, Piaget (1966) reveals how children for example in the pre-operational stage are unable to conceptualize conservation. Children at this stage will say that there is more plasticine when a ball is rolled into a sausage shape. When the sausage shape is made thinner, they will say the plasticine is less. This is a result of the development of the structure dealing with changes in width versus length is not developed yet at the preoperational stage. They cannot see that an increase in length results in a decrease in width and therefore conservation of substance.

Piaget (1966) indicates the four factors involved in development to include maturation, experience, social transmission and equilibration or self-regulation. He shows that the first three factors mentioned cannot be exclusively used to explain development on its own. For example, in maturation it is found that the stages of development occur at different ages of the child for different countries. No amount of social transmission can result in learning if the operational structures are not formed yet within the mind of the child. Equilibration is explained in rolling the ball of plasticine into a sausage shape. As it gets longer, the child thinks there is more of the plasticine and as it gets even longer, he will say there is less. Equilibration is reached when he or she can see a relationship between width and length in that as the length increase the width decreases. The child will need to equilibrate at one level before moving to the next. Equilibration involves compensation and reversibility. In the example, the length compensates for the width.

Piaget concludes that learning is a process of assimilation which he says is the "integration of any form of reality into the structure" (Piaget,1964, p.185). According to Piaget, learning cannot be a process of accommodation within stimulus -response of the behaviourist theorists. Development results when complete structures form whereas learning involves specific activities that are assimilated within the developed structure. Learning comes after development.

Some learners lack the mathematical skill of understanding ratio and proportion due to not reaching the formal operational stage of development as defined by Piaget (1964), Shayer (1970, cited in Kind, 2014). This becomes an hinderance to understanding mole and its application to stoichiometry. However, Rowell, Dawson, and Nelson (1991, cited in Kind, 2014) disagrees with Shayer (1970), in that providing the learners with a step-by-step scheme will enable them to follow through stoichiometric problems using the mole concept.

Kind (2014) suggests bringing the mathematics later when teaching stoichiometry. She argues for using concrete ways to develop conceptual understanding. Using objects such as formulae cards to show ratios in which molecules react helps develop conceptual understanding. She suggests demonstrating chemical reactions in front of the learners' measuring amounts and showing what happens when an excess of a reactant is used. Avogadro's number being so huge is abstract for learners to understand just how huge it is. Kind (2014) suggests giving learners a feel of the bigness of the number by relating it to size that they are familiar with. The example that she gives is that of one mole of the sweet marshmallows will cover a depth of 1000km of the entire United States of America Kind,2014).

The literature on teaching and learning of stoichiometry provides a diagnosis to the difficulties in teaching and learning of stoichiometry and maps solutions for both teachers and learners to overcome barriers of teaching and learning the topic. It is evident from the literature that many of the difficulties encountered in the topic of stoichiometry are unique to the topic. There is much for teachers to discuss on the lived experienced challenges of teaching and learning this topic creating grounds for teacher knowledge for teaching stoichiometry to be socially constructed.

2.4 Teacher professional development

Effective teacher professional development is a "structured professional learning that results in changes to teacher knowledge and practices and improvements in student leaning outcomes," (Darling-Hamond, Hyler & Gardner, 2017, p v). This research involves a structured program to facilitate teacher discussions on stoichiometry. The impact of the teacher discussions on teacher knowledge for teaching stoichiometry is gauged within this research. There is, therefore, a potential for teacher professional development because of the teacher discussions.

Darling-Hammond et al., (2017) show that even with large monetary investments in professional development of teachers, studies reveal low levels of professional development of teachers which is gauged by teacher assessments and learner performance. The authors, therefore, have identified seven design elements to be considered when designing programs for effective professional development.

Firstly, there needs to be a content focus. Professional development focusing on curriculum content of a discipline is seen to have a positive effect on learner achievements. Professional development programs for teachers are deemed productive when there is a classroom context and less productive when issues not relevant to actual teaching and learning is the focus. The content focus design element is incorporated in this research with discussion on the topic of teaching of stoichiometry.

The next design element of importance is active learning. Active learning involves teachers engaging in activities based on classroom teaching and learning context. This could involve engaging with authentic artifacts, interactive activities as opposed to sit-and-listen lectures. The principle of active learning manifests itself in meeting 3 of this research orientated towards being activity driven. Meeting 2 of this research involves discussion of problem 7 of 2020 as an activity, where teachers first solve the problem and then discuss ways of teaching problems of this nature in stoichiometry.

Collaboration as a design element of professional development could be one on one, small groups, whole school or with other professionals outside the school. This research involves collaboration of a small group of physical science teachers from different schools.

Models and Modelling of effective teaching has shown to enhance teacher development and learner achievement. Modelling could include video or written cases of teaching, demonstration lessons, unit and lesson plans, observation of peers, curriculum material including assessment samples and students work. The PLC of this research discuss an assessment sample in the form of a question that learners nationally found difficult, that is problem 7.2 of 2020 NSC (Fig 4.6, p.40 of this report). The teachers' own solutions become a sample of teacher responses to this question. Darling – Hammond et al., (2017) provide a vast range of modelling that can be used to form a framework of discussion by PLCs.

Coaching and expert support is the fifth design element supporting professional development. Coaches who are often teachers make use of modelling and share expertise on practice that is based on evidence. Geddis and Wood (1997) have shown that experienced teachers have higher quality topic specific PCK than younger teachers. This research has the potential for teachers with less experience in teaching the subject to draw on the experience of teachers in the profession for a long time. The idea of coaches or expert support ties in with Vygotsky's (1978) "more knowledgeable other" who stretches the learners' thinking; enabling the learner to move across his/her ZPD. My research attempts to show teachers as learners, learners of knowledge to teach.

Feedback and reflection are seen to be a powerful tool for adult learning. Time should be allocated to reflection in the professional development program. Reflection is the thrust of meetings in this project.

Finally, Darling-Hammond et al. (2017) identified sustained duration as the seventh design element of effective professional development. These authors say that fragmented and episodic professional development programs cannot allow for "rigorous" and "cumulative learning" of adults, (Darling-Hammond et al, 2017, p.15). My research provides a limited view as it investigates just 3 meetings. This is a master's degree project with limited time and resources. A longitudinal study, a PhD, can investigate the functioning of a PLC engaged for a sustained duration.

The teacher development summit held in South Africa in 2009, led to the Integrated Strategic Planning Framework for Teacher Education and Development in South Africa, 2011–2025 (Department of Basic Education and Department of Higher Education and Training, 2011). This document acknowledges the need to develop teachers' subject matter knowledge and PCK by teachers identifying their needs for development and for them to access opportunities for their professional development needs.

Given the high demands on high school science teachers with limited resources and time, prioritizing effective professional development programs that show teacher professional development resulting in improved learner performance is necessary. Data and research in this area allows informed decisions to be made on the kinds of professional development programs to invest in.

2.5 Professional Learning Communities

According to Vescio, Ross & Adams (2008), the notion of professional learning communities (PLCs) in education has its roots in the business sector in which the idea of capacity of an organisation to learn was founded. Hord (1997) writes on the value of turning schools into professional learning communities in which teachers together with administrators of schools collaborate and engage in continual learning through inquiry and reflexive dialogue, at the heart of which is student learning.

Reflexive dialogue is a feature of professional learning communities (Hord,1997; Vescio et al.,2008). Teachers engage in reflective dialogue when they have a conversation on the ways that they teach and through reflection, new ways of doing what they normally do emerge. They continually discuss matters pertaining to, curriculum, instruction, and student development. A shared lived experience is an essential common ground of a professional learning community. Teachers in such a learning community work towards a common goal to improve learning of students. Vescio et al., (2008), further point out that such a learning community should add value to teaching practice for improved learner achievement.

Vescio et al., (2008) did a literary review of 11 studies and discovered that professional learning communities do in fact support teaching practice. Strahan (2003) showed that developing professional communities of three schools of low income and previously underperforming was significant in improving learner achievement. Liang, Lu, & Huang (2018) considered the Chinese teaching and research system and the teaching and research activities (TRA's) which is part of this system as a professional learning community. They undertook a large scaled quantitative study to determine whether those participating in the PLC had improvements in their pedagogic content knowledge. They also wanted to determine if this PLC could help irradicate the inequalities faced in the Chinese educational system. The results from this study revealed that the PLC contributed to positive gains in PCK irrespective of the subjects taught and help level the plain field in providing equal quality of education in the Chinese educational system.

Seashore and Helen (1996) probed into the effectiveness of PLCs and de-privatisation in education on learner achievement. The researchers identify two schools that show the effectiveness of teachers working in teams. In the one school, there is co-teaching. Teachers observe each other's lessons and discuss better ways of instruction to enhance student achievement. The teachers enjoy the elevated level of collegiality. One of the teachers remarked that it was great to have another adult involved. Teachers work collectively rather than in isolation. They have intimate discussions on pedagogy, instructional strategies, curriculum, and assessment.

Teachers working in teams, create grounds for authentic instruction (Newmann & Wehlage,1993). Professional communities complement authentic instruction and provides support for authentic student achievement (Seashore & Helen, 1996). Authentic instruction activates higher order thinking with meaning making that connects with the real world leading to authentic learner achievement. Higher order thinking involves moving beyond recall of information towards synthesis, evaluation, and application of knowledge (Newmann & Wehlage., 1993). Professional learning communities therefore promotes authentic pedagogy through substantive conversation by peers.

The Department of Basic Education (2015) outlines the guidelines to establish professional learning communities in all South African schools. PLCs is seen as an effective way for teacher professional development. The establishment of PLCs in schools is part of the Departments "Integrated Strategic Planning Framework for Teacher Education & Development" (Department of Basic Education,2015, p.). Professional learning communities as seen in the framework document are communities of teachers, school managers and subject advisors that create their own professional development trajectories creating activities that drive these development paths (Department of Basic Education and Department of Higher Education, 2011).

Ten characteristics of professional learning communities are discussed in the guideline document to establish PLCs (Department of Basic Education,2015). Mutual trust and respect are seen as a characteristic that takes time to establish in a PLC and determines the effectiveness of the PLC. Constructive challenges and criticism is a characteristic that is resonates with argumentation to learn. Debate and different points of views are encouraged in the learning community for learning to happen. A shared vison and focus on learning of students is a characteristic that provides direction for the working of the group. Collective and reflective inquiry as a characteristic resonates with Seashore & Helen (1996) that call for a de-privatisation of education. Teaching is no longer seen as an individual's task but a collective responsibility in which team teaching and peer review of classroom teaching allows for a reflexive discourse. Inclusive membership and openness allow for a transparent community. Outside experts are welcome to share their knowledge expertise without losing focus on learning of learners. Shared leadership as characteristic of PLC's allows for authority to be distributed across members. Leaders of different task groups or committee within the PLC utilizers expertise of members, professionalising their contributions where ownership is taken. A collective responsibility for learners learning occurs when teachers come together to understand how learning takes place in different classrooms. A coherent and responsive change to practice results from discourse of PLC's. The penultimate characteristic is regular meetings to be effective and finally the tenth characteristic identified in the document is rigorous and systematic enquiry into practice. This characteristic aligns to teachers being ongoing researchers bringing evidence into the discussions.

My research collects and analysing data on the functioning of a PLC. The PLC in this research is subject specific, teachers of Physical Science, and the discussion and activities are topic specific. The rationale is that PCK can be located within the domain and is idiosyncratic in nature.

Situated cognition provided a new paradigm of learning (Lave, 1991). Studies in social and cultural anthropology specifically in the workings of apprenticeships (Lave & Wengner, 1991), has thrown light into the ways in which learning takes place through a community of practice. These workings of a community of practice extends beyond that of apprenticeships of artisans to other professions.

Lave & Wenger (1991) describe a community of practice. A community of practice has a boundary. Those entering the community of practice initially participate on outskirts within the community. They are referred to as the newcomers. The newcomers are encultured into the ways of the community and gravitate towards the core of the community at which point they become the old timers well versed in the practice of the community. Learning within the community is situated in activities of the community that has a social, historical, and cultural basis. One must learn the workings and adopt its cultural, social, and historical principles to become part of the community of practice.

Teachers are part of a community of practicing teachers. Two teachers who have never met before can have a lot to talk about. They are engaged in similar lived daily activities. Groups of physical science teachers forming a professional learning community will have a lot to talk about as they are part of a community of practice and share the historical, cultural, and social common grounds.

A study by (Coenders and Verhoef, 2019) shows how teachers critically evaluate their practice through reflective practices in the context of a lesson study. This collaborative process shows how the more knowledgeable others within the group contribute to teachers within the group moving through the zone of proximal development as a result of teacher discussions. Teachers collaboration, participatory involvement and discussions in this study resulted in positive growth in teacher knowledge for teaching stoichiometry.

Chapter 3

Methodology

My research methodology is qualitative in nature. My epistemological orientation leans towards a "constructivist" approach (Stake, 1995; Merriam, 1998 as cited by Yazan 2015, p137), in which knowledge is constructed by the researcher as opposed to knowledge being discovered. The researcher influenced by his experience interprets the data, finding meaning, constructing, and presenting a view amongst multiple views, (Yazan, 2015)). The readers of this report will construct their own knowledge, offering criticism, adding to the multiple perspectives on the subject.

The topic of this research, "Exploring the effect……," gives a sense of a qualitative researcher becoming the instrument in receiving data from natural settings constituting a case study in which findings emerge from the researcher interpretations through the exploration.

The rigor of conventional research is determined by internal validity, external validity, reliability, and objectivity. Guba and Lincoln (1985), advocate trustworthiness which is an analog to rigor for real world naturistic inquiries. For naturalistic research to be trustworthy it must show credibility, which is an analog to internal validity, transferability an analog to external validity, dependability an analog to reliability and confirmability an analog to objectivity (Guba & Lincoln, 1985).

3.1 Research design: Case Study

A case study according to Baxter and Jack (2008) express a constructivist approach in which knowledge is constructed by collaboration of researcher and participants. The case study is a qualitative study in a bound system over a period in which the researcher gathers data through multiple sources to understand the phenomena investigated (Creswell et al., 2007).

The bounded system in this research consists of a group of three teacher (including the researcher) that have discussion on stoichiometry over a period which in segmented into three meetings on the online platform, ZOOM.

Creswell et al., (2007) identify three kinds of case studies that include, single instrument case study, collective case study and the intrinsic case study. The selection of the case study depends on the intention of the research, what the research wishes to reveal in answering the research questions. This project is a single instrument case study where the researcher investigates an issue to show the case. A collective case study is useful in that it could show any patterns across cases for the same treatment, in this case meeting discussions. However, a collective case study would have been too time-consuming for a master's program and will better suite a longitudinal study or a PhD program running over a longer period. The third, an intrinsic case study, investigates a case, for example the value of an existing program.

A case study can have a logical design with the researcher having worked out before starting the research, the data collection, and data analysis methods (Yin, 2009). Furthermore, Yin (2009) suggests that the theory used in the case should be identified along with any rival hypothesis that can be used to explain the data. It is suggestive that internal validity will improve by taking this into consideration. Yin (2009) leans towards a positivist epistemology. My research departs from Yin (2009) as this study is embedded in constructivism. This allows for a greater flexibility in design. The design is altered as the research proceed as knowledge is constructed along the way. Unlike the positivist paradigm, it is not the intention of this case study to discover a fact but to construct a reality.

The unit of analysis is important to ascertain in determining what the case is (Baxter et al 2008). Chenail (2012) suggests using word insert comment to identify the unit to analyse in transcribed text. As, Chenail (2012) suggests, a unit of analysis is not necessarily a line or word. The author defines a unit of analysis as a single entity to which the researcher focuses on within the text.

The unit of analysis are reflections and can be one of two kinds: reflection on action and reflections in action. Reflective practices are well described by Shoen (1993). The ideas of reflection are incorporated in the models of pedagogical reasoning (Shulman,1987; Park & Olivier,2008).

In summary, the research design adopted is a single instrument case study of the constructivist paradigm.

3.2 Sampling and sampling techniques

The two types of sampling than can be used in research include probability and non-probability sampling Acharya et al., (2013). A random sample selected in a study can allow the researcher to generalize on the population of study. All entities or participants in a random sample have an equal opportunity of being selected (McLeod, 2019). The sampling used in this research is non-probability sampling. It is not the intention of this research to make a generalization on a population of teachers but to investigate how a particular group of teachers can operate through meeting discussions.

The samples in my research are purposively chosen (Suri, 2011) as they are focus groups of experienced Physical Science teachers who would have a developed PCK through their wisdom of practice. Shulman (1986) has identified PCK as a kind of knowledge that develops through experience of teaching a subject. My interest is in capturing this knowledge through discussions on stoichiometry and determining any transferability of this knowledge amongst the participants through the focus group discussions. By default, teachers in the meeting discussion teach the topic stoichiometry to high school learners in the further education and training phase (FET – Grade 10, 11 and 12).

Participant named Teacher N, is a 52-year-old male teacher who has been teaching Physical Science for 28 years. In addition to his extensive experience as a science teacher, Teacher N has recently obtained a PhD in science education from the University of Northwest. He also completed his post graduate studies in term of a Bachelor of Science Honours in Science Education and a Master's degree in Science Education through the University of Witwatersrand. Teacher N holds a Bachelor of Science degree majoring in Chemistry from a University in Zimbabwe and a post graduate certificate in education.

Participant named Teacher A, is a 33-year-old male who has been teaching Physical Science for 10 years. He holds a four-year teaching Diploma from a college in Zimbabwe majoring in Physics, Computer Science and Mathematics.

Teacher R, who is also the researcher for this study is a 48-year-old male who has been teaching physical science for 20 years. He holds a four-year teaching diploma from Springfield College of Education, a Bachelor of Science – Environmental Management, chemistry stream degree from the University of South Africa, Honour in Science Education from the University of Witwatersrand and is currently completing a master's degree in science education through the University of Witwatersrand.

Besides being Physical Science teachers that have taught stoichiometry in the FET phase, the sample of teachers had to have access to the online platform of ZOOM which means having access to the internet. The sample of participating teachers were therefore conveniently selected (Taherdoost, 2016) as research participants. Convenient samples are easily and readily available (Taherdoost, 2016)

3.3 Trustworthiness

Thick descriptions (Geetz, 1973) are detailed information that makes the experience real and credible to the reader, (Creswell et al*.,* 2000). The meeting discussion is video recorded, and transcriptions verbatim provide thick descriptions. Detailed accounts of how the meeting discussion took place, the meetings situated in its context provide for a detailed description that qualifies as thick description. Such detailed accounts allow the reader to make judgements of transferability of the account (Creswell et al., 2000).

Researcher reflexivity is a way to ensure credibility. The researcher explains his/her role in the research, bringing his/her beliefs to the forefront. The researcher acknowledging bias or providing the reader with all information that the reader could make judgement on researcher bias. Researcher reflexivity falls into the critical research paradigm, (Creswell et al., 2000). Haynes (2012) describes reflexibility as when the researcher is aware of his role and influence in the research outcome. The researcher's role in this research is one of a participant observer, (Kawulich, 2005). The researcher participates in the discussion.

A discussion of teachers who teach stoichiometry at high school unfolds. The researcher, like the two other research participants is a teacher of physical science at high school. The researcher who is referred to as teacher R in the transcripts, worked very closely with both participants in the education community. The researcher worked together with participant N is the marking of the Grade 12 NSC Physical Science paper 2. Teacher N and the researcher had previous memorandum discussions as part of a team of matric markers. The researcher belonged to the same district of cluster group of teachers as teacher A. Teacher A and the researcher had previous discussion as part of the district cluster group meetings. Teacher A was the examiner for the cluster group Grade 12 common term 1 cluster test for which the researcher was the moderator. Thus, there is a close professional relationship shared between the researcher and research participants.

The researcher being a part of the community, steps out of the community and analyses the data permeated with his value system following the framework of reflective practice and PCK. It is important to note that the researcher is not regarded as an outsider to the community and is very much a part of the community. The case is a natural setting of teachers talking to each other about how they teach stoichiometry. Teachers are asked open ended question on their practice so that they could share their experiences.

The researcher acknowledges that he controls the meetings as coordinator and probes discussion as if chairing the meetings. There are times when the researcher steps back allowing for the discussion to flow freely. The reflections in action of participants are natural and uncontrolled. In analyzing the transcriptions, the researcher qualifies his selection of reflection in action and reflection on action. The researcher does create an easy-going atmosphere for teachers to engage in conversations naturally.

Prolonged engagement in the field is another way to ensure credibility (Creswell et al., 2000). Geetz (1973) explains the importance of the researcher understanding backstage culture due to prolonged exposure in the field. In this sense, the researcher is a science teacher himself sharing the work culture experience of the participants day to day over many years.

Creswell et al*.* (2000) explain diverse ways of ensuring validity that can be suitable to the paradigm of researcher or the viewpoint of the researcher. Peer debriefing or peer review is a procedure which ensures validity. The authors suggest that peer debriefing best suits the critical paradigm. A peer debriefing is when some other person who is familiar with the phenomena questions the researcher's methodology. Through this discourse the researcher can ensure that the procedures are valid. The researcher's work is constantly reviewed by a supervisor from the University of Witwatersrand.

Audit trail is described by Creswell et al. (2000) as a process of checking by external persons. The method of data capture, analysis and the conclusions drawn is investigated by somebody external to the project. This project being as part of a Master's program at the University of Witwatersrand is to be reviewed by an external examiner. The researcher provided all information required for an audit trail in the research report. This process required by the university ensures validity of procedures. All video recording and transcriptions are submitted to the researcher's supervisor at the University of Witwatersrand. The research report has transcriptions and analysis of transcriptions as annexures. The audio video recordings can be requested by the external examiner from Dr. Mosabala, the research supervisor.

Triangulation is when the researcher converges information across various sources to obtain categories or themes. Creswell et al. (2000). and Denzin (1978) identify four kinds of triangulation. These include triangulation across data sources, triangulation across theories, triangulation across methods and triangulation across investigators. Triangulation is a procedure that makes validity and reliability of the research processes (Golafshani, 2003). This research achieves triangulation across investigators. The findings of this research show and concurs with other academic studies (Newman & Wehlage, 1993; Seashore & Helen,1996) that professional learning communities can create space for thinking of authentic activities and authentic pedagogies through teacher interaction by discussions.

Some pertinent issues around use of triangulation in this research project is looking at how the intervention or treatment affect different research participants (data sources). The intervention or treatment in this project is the meeting discussions. Searching the literature for other investigators doing similar research and obtaining similar results will aid in triangulating the research methodology ensuring transferability. Some other researchers may see similar patterns to this research. Hence, this research adds value to the body of knowledge in this area of study.

3.4 The researcher as participant observer

In meeting 1 and 2, the researcher takes on the role of participant observer. The role of a participant observer refers to a research method in social sciences where the researcher actively engages in the observed setting while also maintaining an observational role. This approach allows the researcher to gain first-hand experience and insight into the social phenomena being studies by immersing themselves in the culture, activities and interactions of the group being observed (Jorgensen, 1989).. The researcher asks questions that probes into teacher knowledge for teaching stoichiometry. These questions are asked in a natural conversational manner and not as a predetermined set of questions. An example of a probing question from meeting 1 is given by the extract below from meeting 1:

Turn 1 R: …and eh, I'm looking at that and having a discussion on how to go about teaching the topic. Of course, each teacher is individual in their approaches and may share some common traits as well.

Turn 2 N: That's true.

Turn 3 R: I need to capture that, to capture how you doing it and to look at how other members in the group do it and to kind of exchange and interchange and see if we can influence each others thinking. That's the idea. So we want to look at what you do in the classroom. I put it on *multiple. You can access the screen and you can show us what you do. Stoichiometry, what would you consider to be the central kind of concept?*

The researcher in the above extract probes into what teachers consider to be the big idea when they teach stoichiometry. The researcher analyses the response of teacher N's response from which the researcher produces a concept map shown in fig. 4-17, page 64. In this way, the researcher generates data in which he converts into information from which judgements can be made about teacher knowledge.

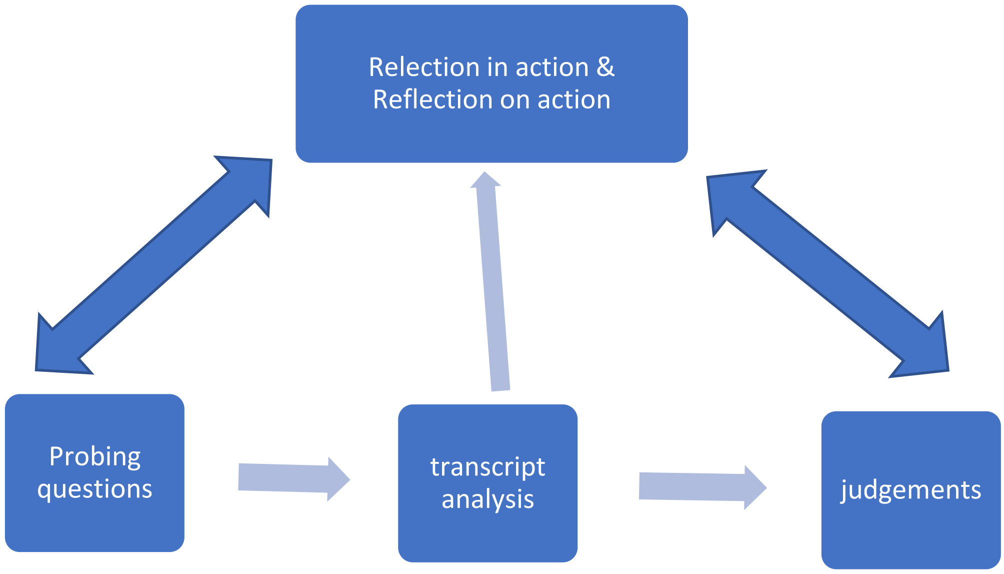


Figure 3-1Researcher as participant observer process diagram

A probe is used as an instrument to measure something in the environment, example a thermometer is a probe that measures environment temperature. In the same way, the researcher probes by questioning, reflecting in action and again questioning. In this way the researcher is trying to find out teachers thinking about teaching of stoichiometry. Teachers articulate their thoughts through speech. The researcher then analyses the talk and conversations in the form of transcriptions and reflects on action looking for teacher pedagogic content knowledge, shifts is teacher pedagogic content knowledge, subject matter knowledge and shifts in subject matter knowledge. As part of the probing and measuring processes, the researcher reflects in and on action within the meetings, therefore the double arrow in fig. 3-1, showing a two-way process.

3.5 Data collection

Three meetings to discuss the teaching of stoichiometry involving three teachers including the researcher took place on the Zoom online platform on 26/11/2020 (Start Time 21:20), 16/03/2021 (20:49) & 24/03/2021 (20:53) respectively. The meetings took place during the Covid pandemic lockdown period. The meetings lasted 58 minutes, 40 minutes & 74 minutes respectively. All the teachers reside in Johannesburg East Rand and teacher physical science in different coeducational high schools on the east rand. All teachers work in schools that are part of the Johannesburg East District. In the first two meetings, teachers were given tasks before the meeting to complete. These tasks are questions on stoichiometry. For meeting three the researcher revealed and undertook a practical task at the meeting. At the start of meetings two and three the researcher reflected on what transpired in the previous meeting so that the members of the meeting remember the context of the discussion.

What follows is a brief synopsis of the three meetings to provide the reader with the gist of the discussions.

Three meeting were held over the Zoom online platform. All meetings were held in the evenings. The meetings were convened with the researcher as host. All meetings were recorded.

The meetings discussions were transcribed verbatim.

The data “generation”, (Mason 1996, p36) process took place between 26 November 2020 and 24 March 2021.

The first meeting starts off with a discussion between the researcher, Teacher R and Teacher N. Teacher A arrived eight minutes into the discussion. The meeting lasted 58 minutes. The discussion centred around teaching the topic stoichiometry. There are three focus area for discussion viz turn 1-turn 72 focuses on the mole concept in stoichiometry related to chemical reactions and balanced chemical equations; turn 72 – turn 124 focuses on discussion around limiting reagent and the confusion of learners that think the smaller mass is the limiting reagent or smaller number of moles is the limiting reagent and turn 124 – turn 249 the focal point of discussion being focused on the concept concentration.

The second meeting is focused on discussing question 7 of the 2020 NSC Physical Sciences paper 2. This question asked for the percentage impurity of 1,2 grams calcium carbonate that reacts completely with excess ethanoic acid in 25ml vinegar with 4.54% ethanoic acid. The excess ethanoic acid is neutralized in a titration with 14,5 cm^3 of sodium hydroxide of concentration $1mol.dm^{-3}$. The density of vinegar is given as $1g.cm^{-3}$. All participant worked the question out before the meeting. The meeting aimed to discuss how teachers can break down such a problem so that learners could find meaning in the problem at hand. The meeting lasted 39 minutes.

The third meeting was aimed at taking the second meeting further upon reflection on action by breaking down the question 7 in doing a practical task designed to meet the challenges of the problem and the challenges of lack of apparatus. The third meeting was in response to a trigger (turn 84 -turn 97) of the second meeting in which the researcher had an aha or Eureka moment. The third meeting focused on determining the mass of calcium carbonate that reacts completely with ethanoic acid in vinegar that contains 5% ethanoic acid. The excess ethanoic acid is neutralized by around 35 cm^3 sodium hydroxide of concentration 0,1 $mol.dm^{-3}$. The density of vinegar found by internet search to be $1,01g.cm^{-3}$. 0,3 ml of solid sodium carbonate was used in the reaction. The internet value for density of calcium carbonate is 2,711 $g.cm^{-3}$. The theoretical value of the mass of calcium carbonate is 0,81g. The calculated value on the video was 0,93g. However due to mistakes in recording of volume of sodium hydroxide used and this error being picked up by the researcher on viewing the video recording, the calculated value of calcium carbonate is 0,875 grams. The end point was not reached due to insufficient sodium hydroxide available. We were close to end point as there was a prolonged colour change which dissipated after two minutes. A few more drops of base would have enabled complete neutralization.

3.6 Data analysis

The transcripts were analysed looking for reflection in action and reflections on action. Pieces of conversation were linked to the five knowledge components.

Reflections in actions, “thinking on your feet and has an element of surprise,” (Schon, 1983, p56.). Reflection on action is thinking of an experience of the past.

A table is produced (table 1, p33; appendix 1, p67 of this report) for each meeting showing segments of reflections in action and reflections on action. Themes of discussions are identified for each meeting. Pie charts are produced showing a comparison of reflections in action and reflections on action for all three meetings. Pie charts showing the knowledge components that teachers draw from in their conversation are produced across the three meetings.

3.7 Ethical Considerations

An ethics clearance application was approved with risk level low by the Human Ethics Committee (non-medical) on 19 June 2020. The ethics clearance certificate, protocol number is H20/06/37.

The research participants have given written consent to participate in the research and the research has been explained to them in the participant information sheet.

The names of participant have not been used in this report. The participants are referred to as Teacher A and Teacher N in all reporting.

All supporting documents pertaining to ethical considerations are included in Appendix 5 of this report.

Chapter 4

Results, presentation & discussion

The model of "pedagogical reasoning is shown in fig 2-2 on page 9 of this report. In this model new comprehension is achieved by the teacher through a process involving teaching in the classroom context (Shulman, 1987). This research shows how similar ends of new comprehension can be achieved through teacher discussions on teaching the chemistry topic, stoichiometry.

In this study, teachers discuss their transformations of subject matter in the teaching of stoichiometry. The foundations of these discussions are teachers sharing their ideas of teaching stoichiometry through a process of reflecting on what they do in the classroom. These reflections on action triggers teachers to evaluate their teaching of stoichiometry through reflecting in action leading to new comprehension. Below is a diagram depicting pedagogical reasoning in the context of teacher discussion.

Figure 4-1Pedagogical reasoning model within PLC emerges from this empirical study

The ideas of reflection in action, reflecting on action and knowing in action originate from (Schon, 1983). Schon argues that these ways of thinking are a common place amongst professionals. Doctors, lawyers, and teacher demonstrate these patterns of thinking. Park and Olivier (2008) use Schon's ideas, particularly, reflection in action and reflection on action in their pentagon model (fig. 2.4, page 11 of this report) to show the workings of pedagogic content knowledge. This forms the core of the model and shows the dynamic nature of PCK with the integration of knowledge components of PCK. In my data analysis, I use this model to map teacher conversation, connecting to the relevant PCK knowledge displayed and identifying whether the parts of the conversation is a reflection on action or a reflection in action.

Three meetings were held. The meetings involved three teachers discussing teaching of the topic stoichiometry. The meetings took place during COVID lockdown and are therefore meetings using the ZOOM platform. The ZOOM meetings are recorded and transcribed verbatim.

Through transcription analysis, themes of discussions emerged. For each meeting the themes of discussions are indicated on table 1, 2 and 3 respectively, see Appendix 1.

Reflection on action is defined as the teacher reflecting on an experience of teaching stoichiometry in the context of the classroom or past events of the meetings itself. Reflection in action is defined as a reflection that is happening in the moment of the conversation based on what is being said by others at that given moment. I identify the kind of reflection by looking at the context of the conversation. When the teacher speaks in the past tense of an experience then that part of the conversation is defined as a reflection on action. Table 1, 2 and 3 show the key phrases identified in the transcript that determine the kind of reflection. Using table 1 as an example, in turn 4 of meeting 1 teacher N uses the phrase "…that's what I realise from my experience…." This makes turn 4, in which teacher N discusses the mole as the central concept and its relation to other concepts in stoichiometry a reflection on action.

On the other hand, an example of a reflection in action can be found when considering the phrase of teacher A in turn 111 "… because as we talk about it now, you ask yourself…I ask myself, maybe I was too fast for the learners as we speak like this" A reflection in action can be seen by the teacher using the word "now" and the phrase "..as we speak like this." It is striking that teacher N himself in the next turn 112 identifies with teacher A's reflection, "You always reflect and say maybe I could have done things differently." This shows that teacher N is a reflective practitioner.

Table 1: Extract from Table of Data Analysis

Segment	Participant	Turn /s	Reflection	Key words or phrase indicating ROA/RIA	Teacher Knowledge (Pentagon Model)	Other Models	Theme of discussion
1	N	4	ROA	…that is what I realise from my experience…	Science Curriculum (vertical curriculum)	Loughran (CoRe)	Central concept of Stoichiometry (mole) and how this concept relates to other concepts in the topic.
2	N	44	ROA	…normally I start…; normally I just tell my learners	Instructional strategy, Students understanding	Magnussen (Didactic)	Central concept of Stoichiometry - Mole
3	A	53	ROA	…usually I start on the definition part….; I usually use…; Then I take it for that year…;then I go through..; then I introduce…	Science curriculum (vertical curriculum, curricula material) Students understanding Knowledge of Assessment		Central concept of stoichiometry - Mole
4	N	55	ROA	…our kids are not the same year after year…	Students understanding (Need) Knowledge of assessment		Central concept of stoichiometry - Mole
5	A	56	ROA	…I've realised that sometimes…	Science curriculum (horizontal)		Maths poses a challenge to understanding on topics in chemistry
6	A	58	ROA	…I had this learner who was struggling…now I ask myself	Science curriculum (horizontal), Learner understanding (learning difficulties, motivation & interest)		Maths poses a challenge to understanding on topic in chemistry

The table above shows how the transcripts are analyzed. There are segments of reflections identified as on action or in action. Refer to appendix 1 for comprehensive tables for the 3 meetings. The percentage of reflection in an action compared to reflection on action per meeting can be determined.

The teacher knowledge in terms of the Park and Olivier (2012) model that the reflection draws upon is also indicated across the row of a segment. A segment of reflection could sometimes have more than one component of teacher knowledge that the teacher draws from.

The segments are grouped into themes of discussions, for example in the above table the first 4 segments (turn 4 – turn 55) was a discussion that focused on the mole as a central concept in stoichiometry.

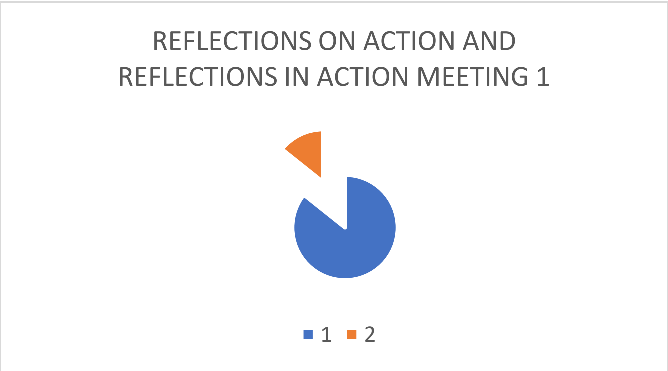
The table of analysis takes the data of the transcripts and converts this data into information that enables the researcher to work with the information to gain a clear picture of the nature and characteristics of the meetings.

In meeting 1, teachers shared their knowledge for teaching stoichiometry by their reflections on action. Meeting 1 shows a predominance of reflection on action leading to moments of reflection in action. In meeting 1, there are five themes that were discussed. These include:

1. The mole as being the central concept in the teaching of stoichiometry and how the mole relates to other concepts (Turn 4 – 55; Segment 1-4)
2. Mathematics poses a challenge to learners in learning stoichiometry (Turn 56 – 58; Segment 5-6)
3. Misconceptions around limiting reagent (Turn 72 -88; Segment 7-11)
4. Chemical reactions at a molecular level (Turn 99 -111; Segment 12 -15)
5. Concentration (Turn 125 -189; Segment 15 -22)

The unit of analyses is reflection on action and reflection in action. In meeting 1 there are 22 segments of reflections. There are some turns that cannot be identified as reflection on action or reflection in action.

The percentage of reflections on action and reflections in action for meeting 1 is show in the pie chart below



1: 85,7 % Reflections on action (ROA)

2: 14,3 % Reflections in action (RIA)

Figure 4-2 Pie Chart RIA & ROA

The data shows that teachers question their own ways of teaching during these moments of reflection in action.

Schematically, it can be shown as:

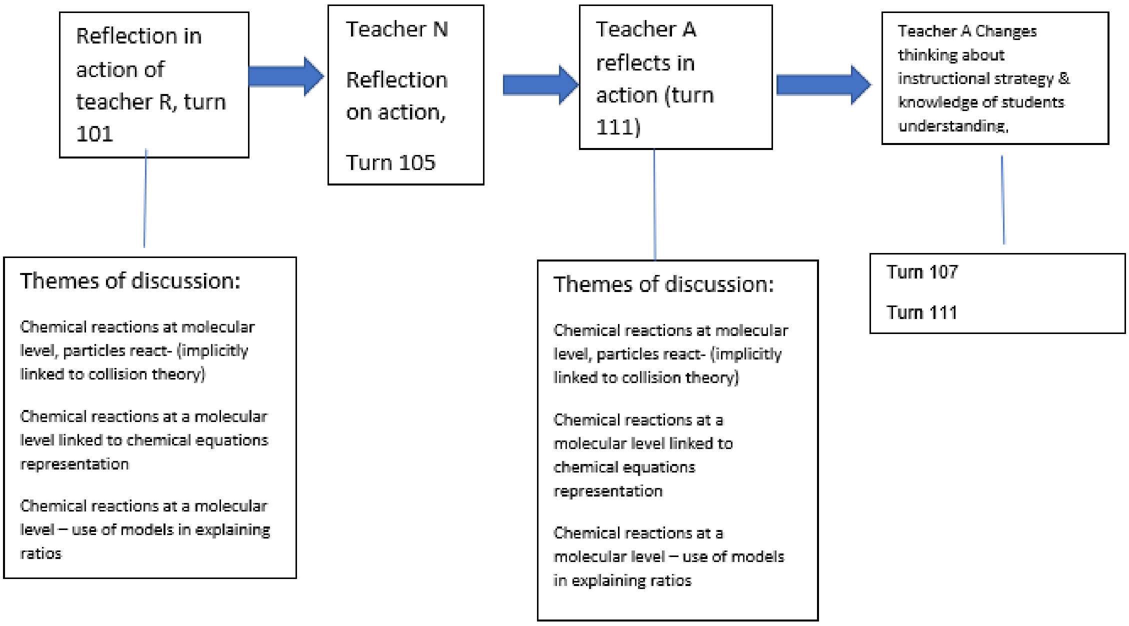


Figure 4-3Pedagogic reasoning meeting 1 (turn 99 – turn 111):

Turn 99 R: In the ratio of the balanced equation, right?

Turn 100 A: Yes

Turn 101 R: So, these particles are reacting. It's not the. It's not like the mass, the mass ratio. Particles, moles are particles.

Turn 102 A: And your question is, how do we go about taking our learners out of the mass to mass. Because our learners will assume it's a mass to mass, therefore you have a bigger mass, you are in excess.

Turn 103 R: What kinds of representations would you use. How would you represent this in the classroom, to show this?

Turn 104 A: I believe its advantageous if you have a class let's say from grade 10, you are now with them in grade 11. It's easy to really remember, did they really grasp the concept, the concept from that 9. How do I first balance my equation, number 1? Number 2, I'm dealing with my masses, now let me turn them into moles. Those number of moles are what I have. Then I go back to the equation. In the equation, those are sharing ratios. If they can remember that I think in numbers, I represent it in numbers, but I separate, this is my equation. Now what I convert from the equation, this is really what I have. This is really what I'm sharing. I would need really a diagram, but a table can do. A table can do.

Turn 105 N: Even also, this to add to what Ayi is saying, even if you get some models, you can use models, you can actually use models, so they can actually see at microscopic level. You can actually represent the molecules using some models. Say ok. If I got, if the ratio of titanium tetrachloride to magnesium is 1:2, if I got one of this, I will need how many of this? They'll *say two. If I got three of this, I'll need how many of that, six. If I got 20 of this, I'll need how many of that, they will give me a number. If I got 100, 200. 1000, 2000 and then this which you have calculated, you need how much of that, then they will multiply by two.*

Turn 106 R: You physically actually show the model, and they can see visually.

Turn 107 A: Which is a good advantage if we were with them in grade 9. Grade 9 syllabus will advise those and its easier. It takes a lesson to do that but sometimes we really do not have much time to do that lets say in grade 11, but for remedial class I advise you to sit down, and you do your models, but it tends to be boring if you got those sharp, sharp, sharp learners.

Turn 108 N: (laughs)

Turn 109 A: Yes, really. I think so.

Turn 110 N: Ya, you are right. Ya.

Turn 111 A: But to agree. You choose a really, really, really good topic that provoke thought. Because as we talk about it now, you ask yourself really have I been doing so right or was I too fast with the learners. Even now, I'm asking myself maybe to those I didn't master it, I'm asking myself, maybe I was too fast for the learners, as we speak like this.

This section of the conversation (Turn 99 – Turn 111) starts off with probing into students' error in using mass ratio is instead of mole ratios in stoichiometry. In turn 104, teacher A relates the procedures that learners are to follow. Procedure are steps to follow. We see these steps by the phrases "….number 1, number 2….," that teacher A uses in turn 104. In turn 105, teacher N suggests the use of models in showing the reaction of particles and the ratios in which particles react. This is a direct effort to challenge learners with misconception leading to the use of mass ratios instead of mole ratios. In turn 107, teacher A initially thinks that the use of models is too simplistic for grade 11 learners and might "bore" them. However, in turn 111, teacher A re-thinks through reflecting in action. The conversation shows that teacher A moves from a focus on procedural knowledge and understanding of the learners to a conceptual understanding where models are used to help learners confront their misconception. Teacher A's perception that the use of models is boring to Grade 11 learners' changes and teacher A now sees the use of models as being useful to learners understanding the use of mole ratios of the balanced chemical equation in solving stoichiometry problems. Turn 111 is an example of metacognition in which teacher A starts thinking about his thinking, questioning his approach. Teacher A's metacognitive thinking is aroused through discussions with his peers.

We see reflection in action in turn 176. This reflection comes about because of teacher A and teacher N's reflection on their instructional strategy in using the analogy of teaspoons of sugar added to tea when teaching the concept concentration. The analogy that both teacher A and N bring to the discussion is, the more teaspoons of sugar added to tea, the sweeter it becomes and the higher the concenteration. In this analogy, the sweetness of tea relates to the amount of sugar added and therefore the concentration of the solution. Teacher R reflects in action to show the limitations of the analogy. Because the same substance is used, changes in mass can be an indication of changes in concentration. Teacher R's reflection in action is important as it provides the need to be explicit about the use of the same substance when using this analogy otherwise the analogy itself can reinforce an existing misconception that same masses of different substances added to the same volume of solvent produces the same concentration.

Turn 176 R: The thing is, with the sugar, with the sugar, you put 1 teaspoon or 2 teaspoons, because the molar mass is the same an increase in mass is going to increase the concentration, right!

Turn 177 A: Same substance

Turn 178 R: Same substance right, the molar mass is the same.

Turn 179 A: Yes

Turn 180 R: Ya

Turn 181 A: And dissolved in a similar substance.

Turn 182 R: Ya, in a similar substance.

Turn 183 A: We can.

Turn 184 R: You can take the masses, ya, ok?

Turn 185 A: As they are.

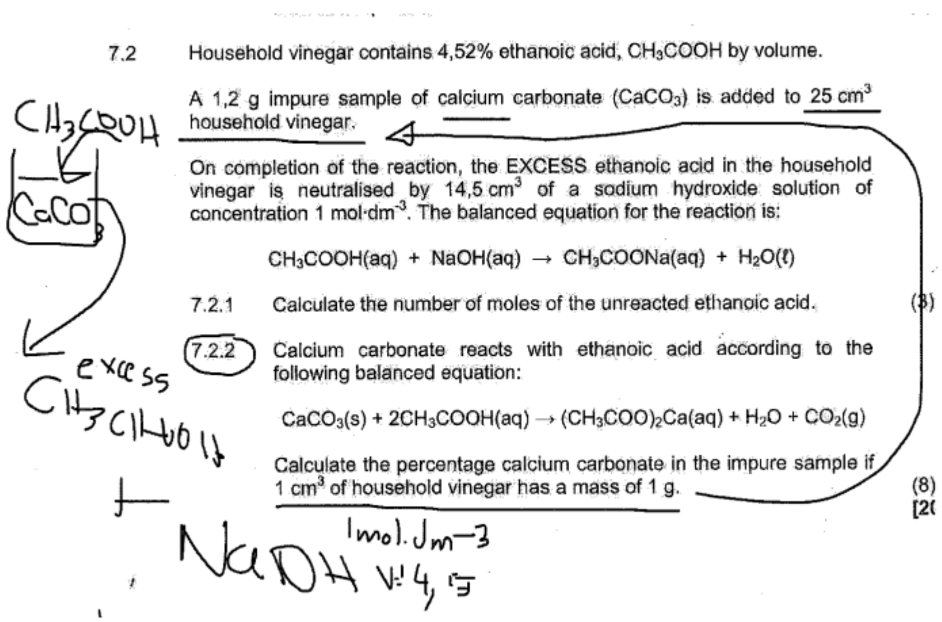
Turn 186 R: Because same molar mass there.

Turn 187 N: Another, sorry

Turn 188 R: Yes Nasi

Turn 189 N: Yes, just to add to that, you can also ask them ok, what's concentration? What are the units of concentration? They will tell you it's mole per dm^3. All right, so who's moles are more per dm^3 for those substances. So, work out your number of moles in these masses. Let's see whose moles is highest. Then it means the substance whose moles is highest should have the highest concentration. So, you can ask them that, so that they can understand and appreciate why the concentrations are not the same even though the masses of the substances dissolved are the same in the same volume of water, or of solvent. So, it can also help them to understand, to say ok concentration is measured in moles of a substance per dm^3. With these 3 substances whose mass is 10 grams each, let's get the moles of each one of them and then we compare which will have the highest concentration based on what, on the moles we should get. I think it can also help to make them understand.

Meeting 2 centred around a discussion of problem 7.2 of the 2020 final chemistry examinations. Below is the extract from the examination.NSC



7.2 Household vinegar contains 4,52% ethanoic acid, CH_3COOH by volume.

A 1,2 g impure sample of calcium carbonate ($CaCO_3$) is added to 25 cm^3 household vinegar.

On completion of the reaction, the EXCESS ethanoic acid in the household vinegar is neutralised by 14,5 cm^3 of a sodium hydroxide solution of concentration 1 $mol \cdot dm^{-3}$. The balanced equation for the reaction is:

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$$

7.2.1 Calculate the number of moles of the unreacted ethanoic acid. (3)

7.2.2 Calcium carbonate reacts with ethanoic acid according to the following balanced equation:

$$CaCO_3(s) + 2CH_3COOH(aq) \rightarrow (CH_3COO)_2Ca(aq) + H_2O + CO_2(g)$$

Calculate the percentage calcium carbonate in the impure sample if 1 cm^3 of household vinegar has a mass of 1 g. (8)

Figure 4-4 Problem 7.2 Grade 12 Paper 2, 2020

The five themes of discussion for meeting 2 include:

1. Concentration: linked to mole ratio & units
2. Excess & limiting reagent
3. Procedural knowledge vs conceptual understanding
4. Problem solving
5. Practical activities

We see the same pattern in meeting 2

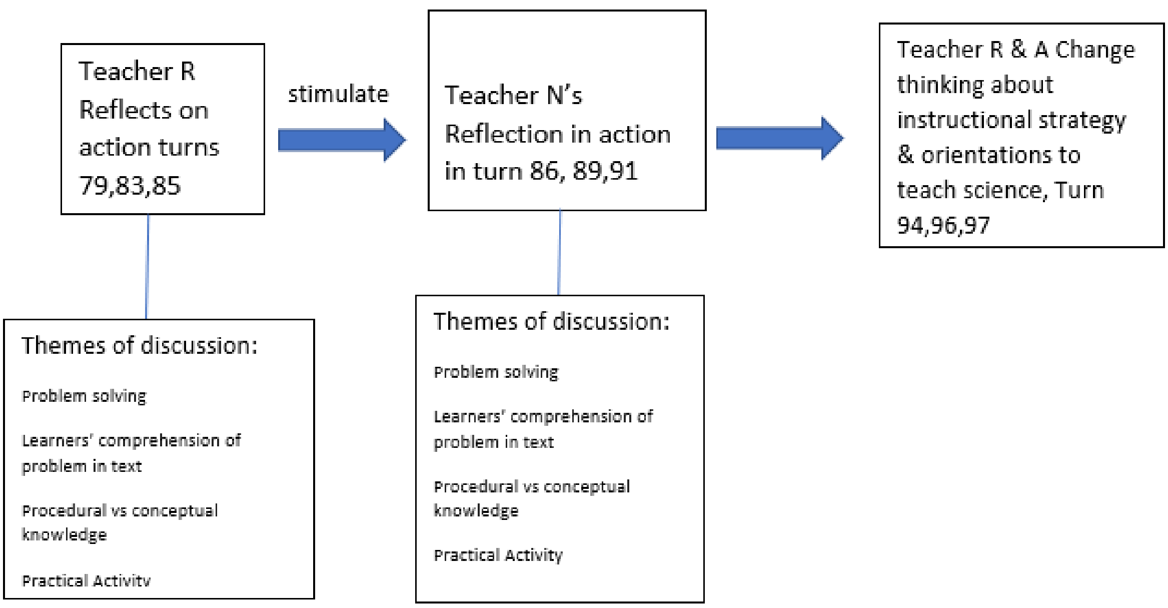


Figure 4-5Pedagogic reasoning meeting 2 (turn 79 – turn 97)

Turn 79 R: ok. One of the points that Ayi has raised is that 7.2.1, ya the learner could get it right but without understanding

Turn 80 N: …what's happening

Turn 81 R: …what's happening right.

Turn 82 N: That's true.

Turn 83 R: That could happen, were they follow a procedure of just using the formulae. So, I mean, in my head I'm thinking about now, I thought about it before too looking at this question. In my head if I'm working it out, in my head I see pictures of two reactions, isn't it.

Turn 84 A: Yes N: Yes (simultaneous response)

Turn 85 R: I see a picture of calcium carbonate and ethanoic acid. Ya the question is saying these things are reacting and then there's an excess there, extra there. That extra there is used to neutralise the base. I don't think the learners are seeing that you know. I mean for you and we are seeing it. We are seeing it. We are seeing it because we are able to see it. The question is, are they able to see it. Are they able to see it. Are they able to see it? (laughs)

Turn 86 N: You are right there because you see we don't expose our learners to a lot of experiments.

Turn 87 A: We don't. We don't.

Turn 88 R: You are saying use experiments as a way.

Turn 89 N: I am saying as we teach our learners' we don't have time to do lots of experiments where they can do titrations like this kind of titration.

Turn 90 A: Yes

Turn 91 N: We normally do the straightforward ones. So, for them to actually visualize it as you are visualizing it, or we are visualizing it is very difficult.

Turn 92 A: Very difficult.

Turn 93 N: They haven't been exposed.

Turn 94 R: Aaha

Turn 95 N: That will be a challenge. They won't picture it the way you are, we are picturing it ourselves.

Turn 96 R: Aaha, Aaha

Turn 97 A: Because to them, because to them it doesn't come across as something really if they haven't seen it because a practical will just draw their interest. Now if you do that practical and if they try to measure things during that practical, then you put into calculations it draws their interest. That class becomes better just gets a better standing than the one that does it in theory. Then it comes back to that point, to that point that I said that sometimes yes if they see that there are numbers coming some are put off, but not all of them. I remember now I was doing organic chemistry. When I got into the section where it was just about IUPAC naming, there is this one kid, this one of my best kids though, asked that are they going to be stoichiometric calculations in this section.

The above extract from the transcription (turn 79-97) shows the conversation of meeting 2 in which teachers recognise through reflections on their experience that learners use mathematical formula and follow procedures without conceptual understanding when answering questions like, question 7.2 of the 2020 NSC Grade 12 Chemistry examination.

In turn 85, teacher R probes into learner understanding of problem 7.2 and verbalises what is happening in the problem

Teacher N's response in turn 86, a reflection in action, provides a reason why learners are not able see. Teacher R and A are shown and pointed in a direction that requires a change in orientation to teach science followed by a change in instructional strategy. Teacher N's remarks that we don't normally do titrations of the kind in the problem becomes an "Aaha" moment, turn 94, turn 96, for teacher R. Both teacher R and A are drawn into a need to change their orientation to teach science moving from a didactic approach to an activity-based approach, (Magnussen et al, 1999). Teacher N's reflection in action here influences the structure of the next meeting. This is important as it leads to meeting 3 being centred around a designed practical activity that relates directly to problem 7.2 of 2020.

All teachers of the discussion group attempted to solve problem 7.2 (Figure 4.4) before this meeting. The extract below shows teacher N explaining the solution to problem 7.2 of the NSC examination, paper 2, year 2020. In turn 130, teacher A, reflects in action and comes to a realisation that he had omitted a crucial step in the calculation that is the subtraction of the unreacted (excess) ethanoic acid from the total ethanoic acid in vinegar.

Below is Teacher A's solution (figure 4-7) to problem 7.2. Teachers A's solution shows that teacher A does not use the titration of ethanoic acid with sodium hydroxide in determining the percentage purity of calcium carbonate. He does not subtract the moles of ethanoic acid in this titration from the total number of moles of ethanoic acid in vinegar. This subtraction is important as it would have given him the amount of moles of ethanoic acid that reacted with calcium carbonate. From this, he would have worked out the mass of calcium carbonate that reacted and hence determined the percentage purity of calcium carbonate.

In turn 130, teacher A reflects in action, realising that he had not used the titration to determine unreacted number of moles of ethanoic acid.

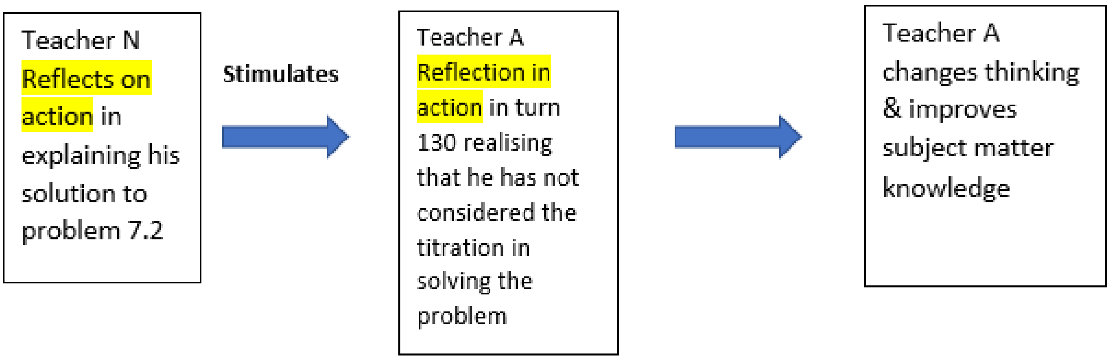


Figure 4-6 Reflective practice improves content knowledge

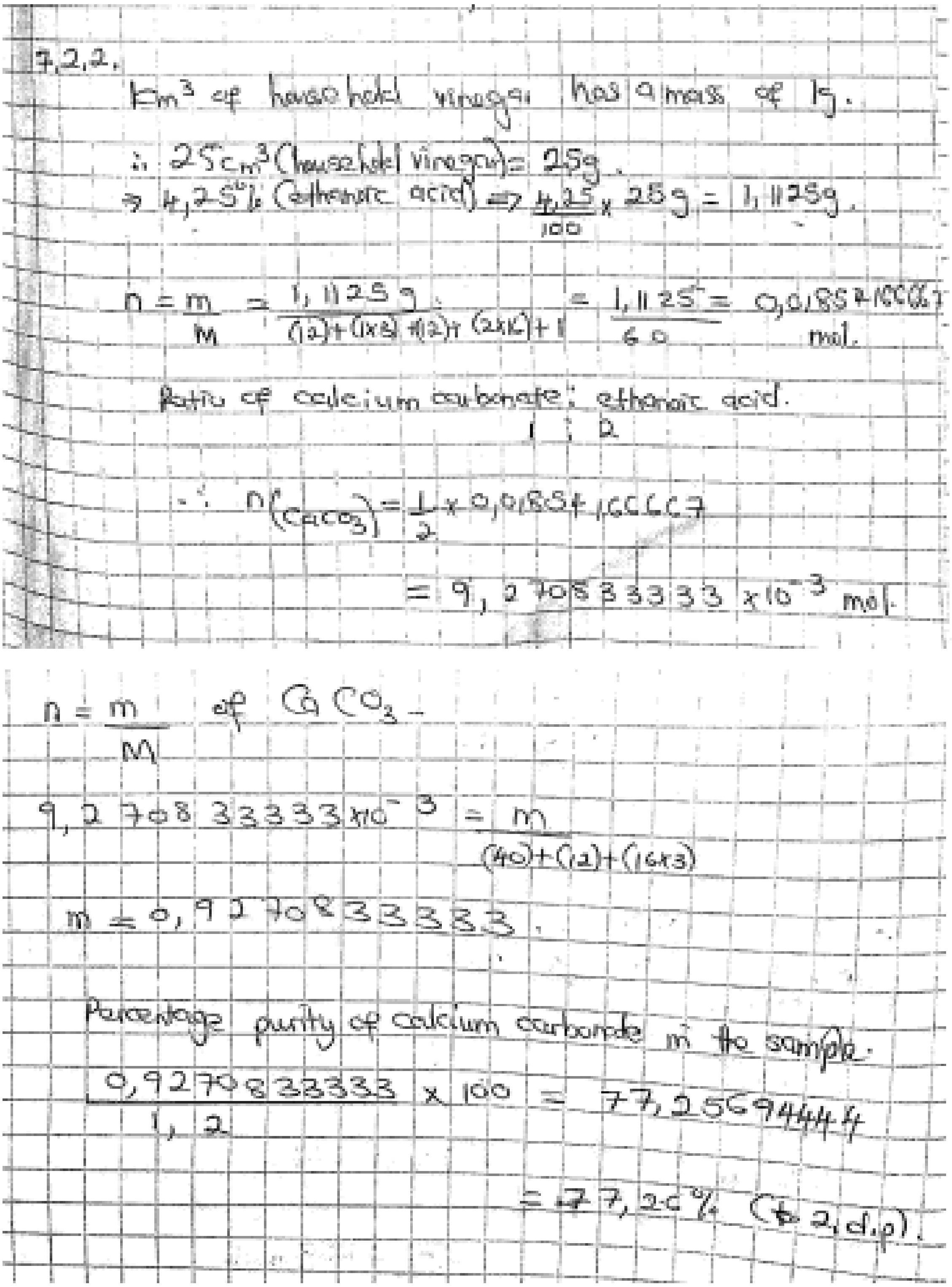


Figure 4--7 Teacher A solution to problem 7.2 shows error in subject matter knowledge

Turn 129 N: Ok let me try this one, because Ayi did the other one. So, from that information in the last statement that one centimetre cubed of household vinegar has a mass of one gram which means you now go back to your volume of your vinegar to which your 1,2 grams of impure calcium carbonate was added and make it what, in grams, it's now 25 grams. You go back again to say 4,52% of that is now going to be your ethanoic acid. You now say 4.45% of 25grams to get the mass of your ethanoic acid which was in the vinegar. Then you get your grams. Once you get your grams, you now divide. The *grams were actually 1,0625 grams, alright. That was the mass of ethanoic acid present in the vinegar. Because in the vinegar there was ethanoic acid and other things which we don't know. So, that mass is 1,0625. Then we now divide it by the molar mass of your ethanoic acid to get how many moles were actually present in the vinegar. So, you divide by 60, you get 0,0177 mol, those are your mole of vinegar which react initially. But now from your 7.2.1 you now know the number of moles which were left of your ethanoic acid. So, the difference between what was left and what you started with your initial will now give us how many moles of ethanoic acid which actually reacted with your calcium carbonate which was present in the impure sample. So you now minus 0,0177 which you got after dividing your mass by your molar mass minus what was left which is your number of moles of sodium hydroxide which you got there which is 0,0145 which is also the same as the number of moles of excess ethanoic acid since the ratio was 1:1. You now minus 0,0177 minus 0,0145, then you get your moles of ethanoic acid which actually reacted with calcium carbonate which was present in the impure sample which you get 0.032 or in standard form is (inaudible)*

Turn 130 A: May I stop you Doc sorry. You know I forgot to subtract the ones that were in excess already. The one that were not used.

Turn 131 N: Ok, you forgot to minus that one.

Turn 132 A: Ya to take out the ones that was in excess already, the ones that were not used. You will check that for me Sir Raven

Turn 133 R: Ya, I see that you did forget to subtract.

Turn 134 A: Ok. You checked that for me.

Turn 135 R: Sometimes we, make these errors, we just busy in the day.

Turn 136 A: Alright thanks Doc, continue. Now we go to the ratios right.

Turn 137 N: Now we go to the ratios to get your calcium carbonate. You now know the number of moles ethanoic acid which was actually used to react with your calcium carbonate is 2:1 which means half of that will give you the number of moles of calcium carbonate present in sample. So, it will be half of 0,032 which is 0,016 or 1,6 x 10^{-3} moles. Those are the moles of your calcium carbonate which were present. And then you now convert those moles into mass by multiplying by the molar mass which is 100. Then you get 0,16 grams. So, it means 1,2 grams of the pure sample contained 0,16 grams of pure calcium carbonate

Turn 138 A: Now go to the formulae

Turn 139 N: Then you now express that as a percentage. You say the mass of the pure calcium carbonate over the mass of the impure sample times 100.

Turn 140 A: The sample itself by 100. Good.

Turn 141 N: 0,16 over 1,2 we get 13,33%. It was a challenging question. Most learners I don't think they were able to do that.

Meeting 3 description

Teacher N, through reflection in action in turn 86 of meeting 2 triggered by teacher R's assertion in turn 85 of meeting 2 spurs on the central feature of meeting 3. Meeting 3 is based on a discussion of a practical activity that mirrors problem 7.2 discussed in meeting 2. Below in the practical activity that forms the basis of meeting 3:

PRACTICAL- finding an unknown mass of a substance

An unknown mass of calcium carbonate reacts completely with ethanoic acid in ~~50 ml~~ 25 vinegar. Vinegar contains 5% ethanoic acid. The density of vinegar is 1,01g/cm^3.

The excess ethanoic acid from the reaction with calcium carbonate is neutralised by _______________ of sodium hydroxide of concentration 0,1mol/dm^3.

Calculate the unknown mass of calcium carbonate.

<u>Teacher guide to test answer</u>

The density of calcium carbonate is 2,711 g/cm^3. Measure 0,3ml of pure calcium carbonate and that will be 0,81 grams. Do not give the learners the value of this mass. Let it be unknown to them.

<u>Note</u>

This practical can overcome the challenge of not having a mass metre at school, if there is a lack of resources. The densities are obtained from the internet.

Figure 4-8 Designed practical activity for meeting 3

Meeting 3 is picking up from meeting 2 in a move away from intellectualizing (solving in the mind only) the problem to practically doing the activity with calculations using the mole ratios of the balanced chemical equation. At the start of meeting 3, one can gauge the problem of limited resources confronted by teacher A and teacher R. Through the conversations, the teachers discuss the challenges of limited teaching resources in terms of apparatus not being readily available to do practical work. Unlike teacher A and teacher R, teacher N has all the available resources to effectively do titration experiments. Teacher N has available a sensitive electronic mass metre that can measure small masses (below 5 grams).

Turn 52 R: We were talking about the context, and you know missing pieces of equipment. I find myself in the same boat. How are things with you in terms of context for experiments? Do you have the resources?

Turn 53 N: I think at the moment I don't have any complaints. For the experiments we supposed to do for SBA (school-based assessment), I have got all the necessary equipment.

Turn 56 R: For stoichiometry, the mass metre do you have, electronic mass metre?

Turn 57 N: The mass metre, actually I bought one on my own. We didn't have one at school. When I went to cash converters, I got a digital mass metre going for R450. I bought that. That's what I'm using at school.

Teacher R, who is coordinating the meeting uses a 10ml syringe to measure volume instead of a burette. He does not have a burette in his classroom (laboratory).

Turn 120 R: Now the challenge is this, I don't have a, I don't have a burette.

Turn 121 N: Burette, yoh, are you sure.

Turn 122 R: (laughs). I don't have a burette.

Turn 123 N: (laughs). Ok.

Turn 124 R: So, the only way out is to use a syringe.

Turn 125 N: Ok

Turn 126 R: I'm going to use a ordinary syringe, 10ml syringe, right.

Turn 127 N: Ok

Turn 128 R: Now, I hope I have enough sodium hydroxide because the sodium hydroxide I found it was 0,1 mol per dm cube. And you remember in the test paper they used 1 mol per dm cubed.

Turn 129 A N: Mmm, Ya that's True (simultaneous response)

Turn 130 R: And they got like 14 comma something cm cubed right utilised. I don't know if I have enough because all I have of that is I have about 40 cm cubed.

Teacher R uses density values obtained from the internet and a measuring cylinder to determine the mass of calcium carbonate as he does not have a chemistry mass scale. Without a mass metre, teacher R is unable to make a standard solution of sodium hydroxide. Teacher R therefore relies on a small bottle of sodium hydroxide of concentration 0,1 $mol.dm^{-3}$ labelled on the bottle as the standard solution. When titrating the sodium hydroxide with the acetic acid, he sucks out the base from the small bottle using a 10 ml syringe. He sucks out 34ml of sodium hydroxide from the bottle, 10ml for three times and 4 ml for the fourth as he titrates the acetic acid. He therefore only has 34ml of sodium hydroxide available for the titration. He does not know this to be the actual volume of sodium hydroxide that he has at the start and assumes that the bottle contains 40ml. He is unsure of whether this volume of sodium hydroxide solution will be enough to neutralise the access ethanoic acid that remains after the reaction of calcium carbonate and ethanoic acid. Vinegar was easily available and teacher R found some phenolphthalein. Phenolphthalein is the chosen indicator that is used to titrate a durable base with a weak acid as phenolphthalein changes colour from clear to pinkish around a pH of 9-10.   Teacher R designs an authentic activity shown below. This activity mirrors problem 7.2 with the difference being the calcium carbonate is pure here therefore the problem of finding percentage purity falls away. Teacher R does the practical activity over a zoom meeting and at the same time a discussion takes place before, during and after the activity.

The approach of using a syringe and density values to do a titration is primitive but the history of science reveals that great ideas of science started with primitive scientific artefacts. In the South African situation, many teachers shy away from doing practical work because of lack of the right resources. This activity shows how an authentic activity can be done by improvising resources, in this case using a 10ml syringe to serve as a burette and density values from the internet to find masses to compensate for not having a sensitive electronic mass metre. On this point, once the change in orientation to teach science from telling to showing and doing becomes strong, challenges of lack of resources can be overcome though creativity. Teacher N sparked the idea in meeting 2 of the importance of doing varied kinds of titrations and not just the straightforward ones so learners can visualize problems of the type of question 7.2 NSC 2020. In meeting 3, teacher R attempts to do a titration that is not straight forward using limited resources. Teacher R was influenced by teacher N and this becomes the basis of meeting 3. Teacher R unfortunately did not end up having enough sodium hydroxide solution to completely neutralize the acid. He used 34ml of base causing the clear acid solution to turn colour to pinkish which held up for about 30 seconds before dissipating to clear indicating a few more ml's needed for complete neutralization. The value obtained for the mass of calcium carbonate was 0,88g using 34ml of base in the calculation. The error in calculation for the mass of calcium carbonate was 8,64%. This is the result of the practical activity (figure 4-8, p43) titled "Finding an unknown mass of a substance."

The themes of discussion for meeting 3 include:

1. Design of authentic practical activity that mirrors problem 7.2
2. Looking for apparatus, scientific artifacts, improvising resources to show
3. Doing authentic activity part 1, reaction 1
4. Doing authentic activity part 2, titration, reaction 2
5. Doing authentic activity part 3, calculation
6. Post practical reflections

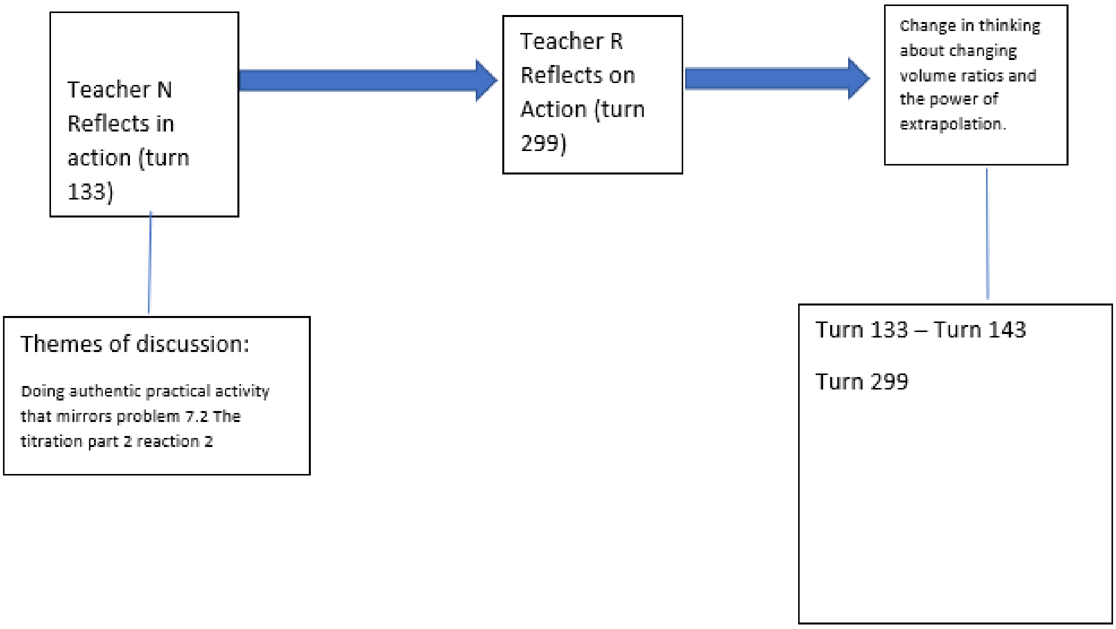


Figure 4-9 Pedagogic reasoning meeting 3

Below is an extract showing teacher N reflecting in action suggesting that teacher R take a smaller volume of the acid solution to titrate with the limited available sodium hydroxide and then use volume ratios to determine how much of the base would have neutralised all the acid solution. Teacher R however fails to register the importance of teacher N's suggestion at that moment, sticking to his plan, teacher R proceeds using all the available base in neutralizing all the acid solution. In doing so, teacher R runs out of base. Here we see pedagogic reasoning occurring differently from figure 4-1, p32 Reflection in action leads to reflection on action which leads to new comprehension as shown in figure 4-10.

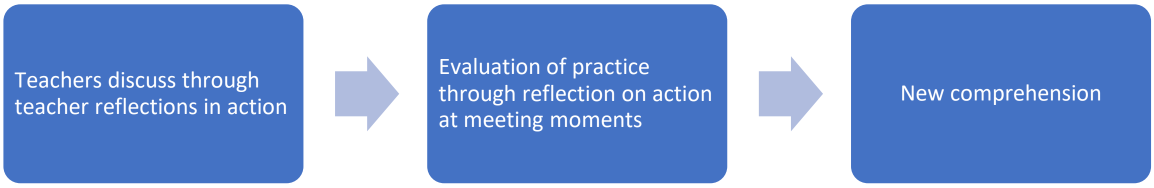


Figure 4-10Pedagogic reasoning meeting 3

Turn 133 N: If you are not sure, you can take 10ml of that, of 40. Hello.

Turn 134 R: Ya, I'm taking 10 ml now. I'm drawing right.

Turn 135 N: What's that, sodium hydroxide.

Turn 136 R: I'm drawing.

Turn 137 N: No, I was going to suggest that if you are not sure that your sodium hydroxide will be enough to neutralize the excess acid in your 40 ml. How many ml's do you have there, in the beaker there?

Turn 138 R: I have 40 ml's

Turn 139 N: In the beaker of your excess acid?

Turn 140 R: No, no, no. Excess acid, how much we have here? Its 25 ml's. There's 25 ml's volume. Remember

Turn 141 N: Ok ya, and you are not sure whether your sodium hydroxide will be enough to neutralize your acid there. You are not sure

Turn 142 R: But let's try

Turn 143 N: I was going to suggest that you take maybe 5ml's of the solution you are not sure of or 10 ml's. You keep the other ml's for in case. You can use it. Ok, I don't know. If you feel you can utilize it go on. Carry on.

Teacher R realises later that the earlier suggestion of teacher N would have prevented the 8,64% error in calculation of mass of calcium carbonate as is evident in the extract below:

Turn 288 R: So probably we need a few ml's more.

Turn 289 N: Ya, ya, probably. That's why I was suggesting you could have taken maybe 10ml's

Turn 290 A: Separately and deal with a smaller volume

Turn 291 N: Yes, and then you can use the ratio. You can say ok 5 mols reacted with 10 ml's then for 25 you can use simple proportion to work out the volume for 25. That was what I was thinking.

Turn 292 R: From here

Turn 293 N: You were going to take 10 out of 25 ml's. Then you neutralize those.

Turn 294 A: Separately, smaller volume to a smaller volume.

Turn 295 R: Ok

Turn 296N: And then we could have worked that and say if I got three moles to 10 what will I have in 25.

Turn 297 R: Oh, ya. I wasn't understanding you.

Turn 298 N: But it's fine.

Turn 299 R: I wasn't listening. I wasn't understanding you. Ya, I should have done that. In retrospect, I should have done that.

Turn 300 N: But its ok. Let's deal with what we have now. So, in this case our answer we getting as Ayi is saying is not as accurate as we didn't reach our end point.

Turn 301 A R: Ya (simultaneously)

Turn 302 N: So that will accommodate the difference between what we got and what we were supposed to get.

In all three meetings, teacher N has been most impactful by bringing about change in the thinking of the other participants. In meeting 1, it was teacher N who suggested the use of models for learners to understand the particulate nature of matter in conceptualizing the use of mole ratio's instead of incorrectly using mass ratios. Teacher N's contribution got teacher A to re-evaluate his instructional strategy.

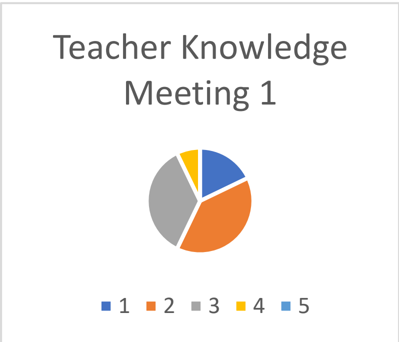
In meeting 2, teacher N identifies not doing titration practical investigations of the type of problem 7.2 2020 as a reason for learners not being able to visualize problem 7.2, 2020. This becomes an "Ahah" moment for teacher R who then designs an authentic practical with limited resources to form the basis of the conversation for meeting 3.

In meeting 3, teacher N suggests that teacher R use smaller amounts of the acid solution to titrate with the limited base available and extrapolate the result using volume ratios.

One notices a correlation between the impact a teacher has on other teachers in the discussion group and the years of experience teaching and qualifications of the teacher. As can be seen from the biographical details below, teacher N is the most qualified and has the most experience in teaching.

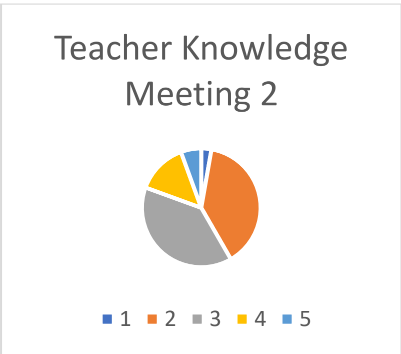
Teachers do form a community of practice as described by Lave and Wenger (1991). Experienced teachers form the core of such a community of practicing teachers and newer teachers start at the periphery and gravitate towards the core. This process of the newcomers becoming the old timers as shown by this study has the potential to be accelerated by the implementation of teacher discussion groups having experienced and more qualified teacher as part of the group.

Figure 4-11. 4-12 & 4-13 below shows the percentage of turns in the meetings 1-3 respectively of the knowledge components of PCK. These figures help us understand the discussion of PCK knowledge components within meetings. For example, in figure 4-11, the teacher discussions articulated the least about teacher knowledge of orientations to teach science and articulated the most about teacher knowledge about student understanding.



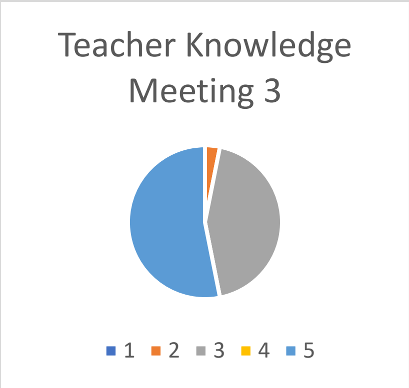
1	18%	Knowledge of Science curriculum
2	39%	Knowledge of students understanding
3	36%	Knowledge of instructional strategy
4	7%	Knowledge of Assessment
5	0%	Knowledge of Orientations to teach science

Figure 4-11Meeting 1 percentage of teacher knowledge discussed



1	3%	Knowledge of Science curriculum
2	39%	Knowledge of students understanding
3	39%	Knowledge of instructional strategy
4	14%	Knowledge of Assessment
5	6%	Knowledge of Orientations to teach science

Figure 4-12Meeting 2 percentage of teacher knowledge discussed



1	0%	Knowledge of Science curriculum
2	3%	Knowledge of students understanding
3	44%	Knowledge of instructional strategy
4	0%	Knowledge of Assessment
5	53%	Knowledge of Orientations to teach science

Figure 4-13Meeting 3 percentage of teacher knowledge discussed

The data in figures' 4-11, 4-12 and 4-13 reveals that teachers articulate most about knowledge of orientations to teach science in meeting three with 53% of the conversation articulating this knowledge component. This is interesting because meeting 3 involved an authentic practical investigation. On the other hand, meeting 1 displayed teachers articulating 0% on orientations to teach science. Meeing 1 was a general discussion . Teachers are more comfortable talking about instructional strategies. 36% of the conversation in meeting 1, 39% of the conversation in meeting 2 and 44% of the conversation in meeting 3 articulated instructional strategies. Teachers seem most comfortable talking about instructional strategies. Instructional strategies knowledge component appears as a relatively constant higher percentage of the conversations in all three meetings.

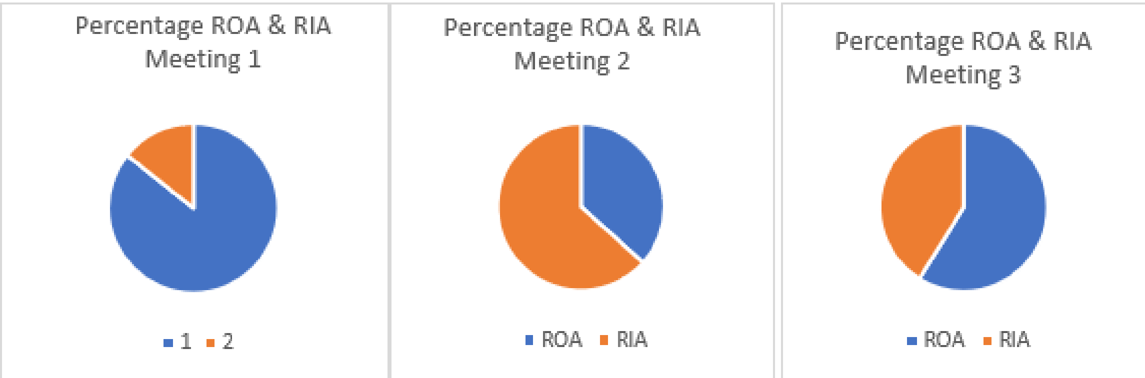


Figure 4-14Percentage reflection in action and on action meetings 1, 2 and 3

The data in figure 4-14 reveals more reflections in action in meeting 2 and 3 compared to meeting 1. Since it is observed that change in thinking occurs within moments of reflection in action then one can infer that there are more opportunities in meeting 2 and 3 for transfer of knowledge between teachers.

The difference between meeting 1 from the other 2 meetings is that meeting 1 was less of an activity focussed meeting. Whereas meeting 1 was more a general discussion, meetings 2 and 3 were focussed discussions on specific activities. Meeting 2, being a discussion on problem 7.2 of the national senior certificate chemistry exam of 2020 and meeting 3 being a discussion of an experiment taking place in the meeting.

One can therefore conclude that teacher discussions that are activity focussed renders more opportunity for reflections in action and therefore more opportunity for change in thinking with knowledge transfer.

Meeting 1 started with a discussion drawing from knowledge of instructional strategy in teaching the central concept in stoichiometry, the mole. As can be seen form the transcripts of meeting 1 both teacher N and teacher A adopt a didactic instructional strategy in teaching the mole.

Turn 14 N: *Usually I say, I give them the definition of a mole of a substance. What do you mean by a mole of a substance?* ***I just tell them*** *that a mole of a substance is the amount of any substance which you are looking at and that amount should contain 6,02 x 10^{23} particles of that substance. So, for example, if I'm looking at magnesium atoms, it means 1 mole of magnesium atoms I'm looking at 6,02 x 10^{23} particles. But of course, the learners sometimes have challenges in appreciating that value because its big. 6,02 x 10^{23} it's a very big number. It's an abstract thing. You can't just put it in. They can't actually see it. They can't see those particles which you are talking about because the number is so huge. But I just emphasis that whenever you say a mole of a substance, you are looking at this number of particles. They normally understand that.*

A didactical approach takes the form of the teacher telling and learners listening to what is being told, much like a lecture in which information is lectured. Teacher N uses the phrase "…. I just tell them…," showing that he uses a didactic approach in dealing with the mole.

Meeting 3 ends with a discussion on an instructional strategy that approaches the concept of mole from activity driven approach in which one mole of the different substances' magnesium oxide, copper oxide, sulphur and water are measured out in volumetric cylinders. Teacher R develops this approach when he starts using densities to measure volumes that give known masses as he designs an authentic activity for meeting 3. Through this process, teacher R develops an activity driven approach that can be used as an instructional strategy when learning of the mole takes place in the classroom context.

Teacher R discovers a new way to introduce the mole concept by reflection in action during preparation of an authentic activity for the subject of meeting 3. I would like to call this a feedback loop. It was teacher N that sparked the thought for teacher R to design the authentic activity simulating problem 7.2 of 2020, and through this process, teacher R suggests an instructional strategy that could add to and improve teacher N's didactic instructional strategy when introducing the mole. This is interesting to see. Teacher N stimulating a thought in teacher R and teacher R closing the loop by stimulating a thought for teacher N.

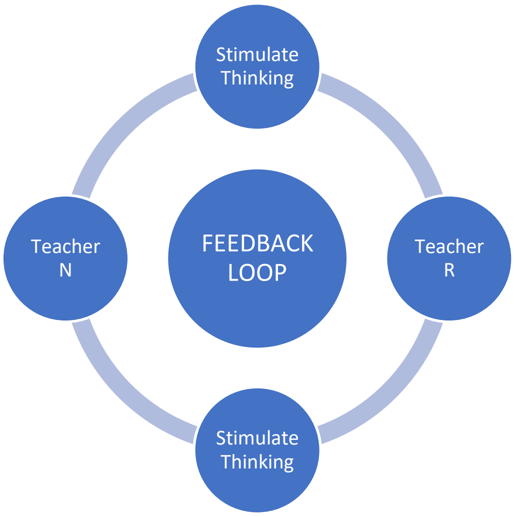


Figure 4-15 Feedback loop

Turn 398 R: I got to think, while I was working with this practical. Then I thought, ok, why don't I take the density values, right and put a mole into a measuring cylinder, right. This is a mole of magnesium oxide. (Shows a mole of magnesium oxide). There's a mole of magnesium oxide. (Uses magnesium powder)

Turn 399 A, N: Ok, alright (simultaneous response)

Turn 400 R: It's about 11 centi meter cubed right.

Turn 401 N: It's a mole of magnesium oxide?

Turn 402 R: Ya

Turn 403 N: Is it solid.

Turn 404 R: Its solid, ya.

Turn 405 N: Ok.

Turn 406 R: You can actually see. I hope you can see. So, there's my mole of magnesium oxide.

Turn 407 N: I see the white powder, something, ya.

Turn 408 A: Its powder.

Turn 409 R: There's a mole of copper oxide. (Places measuring cylinder containing copper oxide next to that containing magnesium oxide)

Turn 410 N: Ok, the black one.

Turn 411 R: And there's a mole of sulphur

Turn 412 N: Ok

Turn 413 R: If I take the densities and I take a measuring cylinder and put water in. So, I'll put 18 centi metre cubed of water

Turn 414 N: Mmm

Turn 415 R: Right, water is 1 gram per centi metre cubed right. If I put 18 centi metre cubed, here's a mole of water. So now learners are able (points to the different measuring cylinders) what is a mole of each substance.

Turn 416 N: Ok

Turn 417 R: And they able to feel it and hold it and its not necessarily equal quantities

Turn 418 N: Ya

Turn 418 R: …in terms of volume or in terms of mass.

Turn 419 A: Yes

Turn 420 R: But they have the same number of particles in them.

Turn 421 N: Ya

Turn 422 R: So those density, values that I found, I can take a number of substances from the lab and put one of each and just show them, you know.

Turn 423 N: Ok, ya. They are not the same.

Turn 424 R: Ya, its one mole.

Turn 425 N: Ok.

Turn 426 R: I find that, I haven't done it, listen, all these ideas I am getting is from you guys in our meetings and when we start talking about these things, I start thinking about it, you know.

Turn 427 A: Alright

Turn 428 R: When you think about one thing, you think about another as well. Because we were working with this practical and thinking how I mass this thing and look at its density, I said why don't I do this as well to introduce the concept of mole. It's something that I will be doing going forward. I haven't done it like this before.

Turn 429 N: Ok.

Turn 430 R: But it's something I'll be doing going forward.

Turn 431 A, N: Ok (simultaneous response)

Teacher discussions in this study is shown to influence teacher orientations to teach science with a move from didactic to academic rigor and activity driven approaches.

Meeting discussions provide a stimulus for teacher reflections which triggers change in thinking about most beneficial pedagogical approaches to the teaching of stoichiometry. This study shows that activity focused topic driven meeting discussion has the potential to diversify teacher orientations to teach science and therefore varying the instructional strategies available in the teacher's toolbox. Teacher reflections operate by teacher reflections on action leading to reflections in action which stimulates self-evaluation of practice leading to change in pedagogical approaches to teaching of the topic.

When comparing teacher N and teacher A on the central concept in stoichiometry and how this concept is introduced, we see richer PCK for teacher N than teacher A. Looking closely at the transcriptions can show teacher N to be the more knowledgeable other. The extract below from meeting 1 shows teacher N demonstration rich PCK, in which he can talk about the big idea, (Loughran, 2005) and link this big idea to other peripheral concepts in stoichiometry.

<u>Turn 4 Teacher N</u>

L1: I think the mole concept is fundamental. They need to understand what is meant by the
L2: mole of a substance. And then once they understand what is meant by mole of a
L3: substance, remember, if you are calculating the mass or volume or whatever in a chemical
L4: reaction, you need to consider the mole, ratio of mole. I think the main concept to be taught
L5: there will be the mole concept. Of course, learners need to know how to balance a chemical
L6: equation. They need to know how to find the number of moles. Of course, there are four
L7: fundamental formulae which learners need to know how to use them. For example, they
L8: need to find the number of mole if they are given mass of a substance. Find the number of
L9: moles when they are given concentration of a solution if they are dealing with solutions.
L10: They should also be able to find the number of moles if they are given the volume of a gas
L11: when it is at STP or RTP, whatever the case may be, and they also need to find the number
L12: of moles when they are given number of particles where they divide by Avogadro's number.
L13: So, these four fundamental formulae, balancing chemical equations, and being able to use
L14: the reacting ratio from the balanced equation to find the number of moles of anything else.
L15: Because normally they are given information which will help them to calculate the number
L16: of moles of one of the reactants or anything of the product. Once they are able to find the
L17: number of moles of either the reactant or product they can use the mole ratio to calculate
L18: the number of moles of anything else where they maybe asked in the question. That's what
L19: I realise from my experience

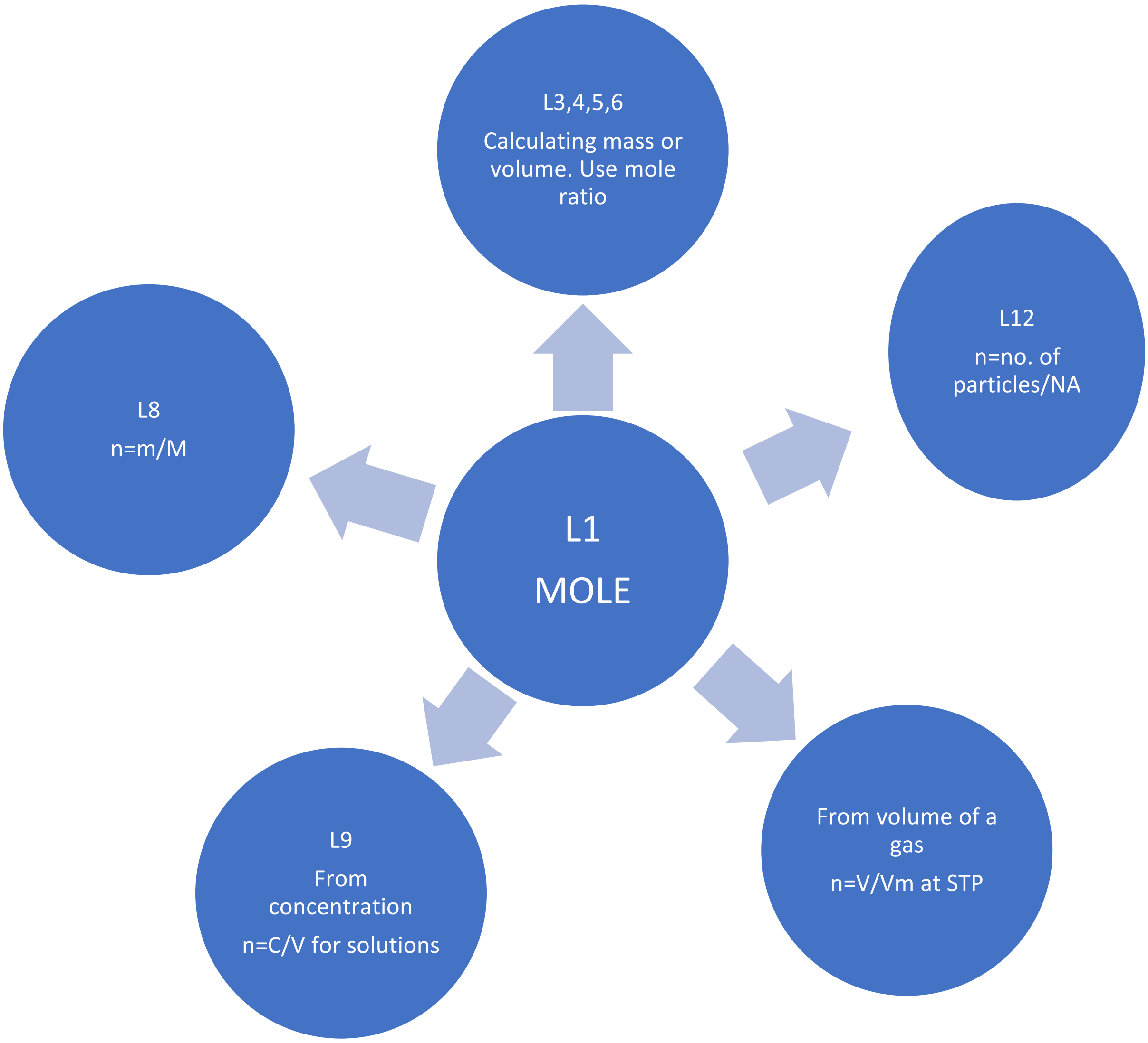


Figure 4-16Teacher N concept map

Teacher N concept map

When compared to teacher A's conversation below, we see that teacher A is textbook-orientated, exam paper driven, and CAPS curriculum orientated. We do not see how concepts are interrelated as in teacher N's part of the conversation. Teacher A is guided by the textbook, past papers, and curriculum document. This is all good as a starting point, however teacher N moves beyond.

Turn 53 A: Ok. Usually the mole concept, really, I think it's the basic aspect of stoichiometry. Without a learner understanding the mole concept, then I don't think the learner can get started. Usually, I start on the definition part. Eh, as doc has said, that sometimes there are different textbooks specially use different definitions. I tend to choose the simpler one for that lesson or *that class at that particular time. The simpler definition that I think will suite them. I usually use different textbooks pertaining to the type of class that I have that year. In some other classes, usually when I get into the class and if it's a good year, I find out that most of them in that class got a certain, after researching, they have got this certain understanding of a mole, usually similar. Then I just take it for that year, if I see that's the correct one. But if it's an average class, that's where I usually impose the one that I think is the simplest one. Then I go through the concept of the formulas of calculating the number of moles because as I said that, and as doc said, the basic part of stoichiometry is how do you calculate the number of moles. Why is it important to know the number of moles if you are dealing with reactions in chemistry. Then I introduce all these different types of formulas when I'm given mass, I'm given volume or its standard temperature and pressure then I take it from there. Then I go try to be complex using the balanced equation calculating the concentration. If it's a good year, usually, let's say I'm in grade 11, I take a really good grade 12 question then I put it to the grade 11's and see how they are faring on these. But in grade 11, usually I also, usually driven by the type of class. I usually if it's a grade 10, I stick to the grade 10 stuff if the class is that average, I don't want to end up confusing them but if I think oh, I will be with this class even next year, I tend to mix what's to be asked in grade 11 and what's to be asked in grade 10 there in grade 10 but if the class is average, I just stop where the CAPS document will advise to be stop but then for a grade 11, I usually go, go further. I usually go further. But now the thing is eh, sometimes uhm after doing this topic a lot, I'm compelled to move out from textbooks. Usually as I teach things, I don't know whether its right or what, I tend to like exam papers. I can teach the mole concept, but I try to say right, let me not use the examples from the textbook. I go exactly through to the past papers where I can find a more complex document especially in grade 11. Then I take it from there. They learn the ratios as they are asked not as I am directed by the textbook. That's what I usually do. But sometimes, yes, I have realised it works well with another class, but with another class sometimes it gets complicated in such a way that I have to go back again. Like I will teach you percentage yield and percentage purity just a little bit then I take a big past paper. Then if I see the response becoming so well, I adopt that system but if the response is so slow, then I go back to the textbook, I take it step by step now. I'll have seen that this class will deserve that other method than this one. Usually, it's not actually, it's the heaviest of the class, that's how I guide them. So, I don't know whether I'm right or wrong then. But that's how I've been doing it. Any suggestions.*

Teacher N is the most qualified (a PhD holder) and experienced (over 20 years). In all three meetings, teacher N has stretched the thinking of teacher A and teacher R. In meeting 1, teacher N provokes thought for teacher A to relook the instructional strategy to incorporate the use of models to confront the misconception around using mole ratios in the balanced chemical equation. In meeting 2, teacher N stimulates teacher A to rethink his solution of problem 7.2 in which teacher A omitted the use of the titration in determining the percentage purity of calcium carbonate. In meeting 2, teacher N provokes thought on change in orientation to teach science towards an activity driven approach involving wider applications of acid base titrations of the type of problem 7.2. In meeting 3, teacher N reflects in action in solving the problem of teacher R having insufficient base, he suggests that teacher R use a smaller volume of base in the titration and then extrapolate the volume ratio to avoid running out of base.

Teacher N provides a rich account in the post activity reflections in meeting 3. In the extract below, teacher N explains a possible source of error in using the density value of calcium carbonate in measuring a volume to determine its mass. Although a novel idea to compensate for not having a sensitive electronic mass meter, this method can be a source of error that teacher R is made aware off.

Turn 304 N: So that deviation between our final answer and our expected answer can be justified by that fact and also, I don't know whether you powder was very fine. There calcium carbonate, were there no gaps between the particles when you put in in the measuring cylinder.

Turn 305 R: Yes, it was…

Turn 306 N: Was it fine powder or was it granules?

Turn 307 A: Was it granules?

Turn 308 N: Yes, it depends.

Turn 309 R: It was fine powder but at certain points it was clumping. It wasn't consistently fine.

Turn 310 N: You see now. So, there could have been gaps in between the particles. So, your 1cm cube, your 1ml may not have been 1ml. Maybe it was 0,8.

Teacher N discusses the appropriate way to do a titration have all necessary apparatus and sufficient chemicals. He identified the problems with the improvised apparatus used to do the activity in meeting 3. In turn 338, teacher N opens up questions that allow learners to think more deeply about the activity.

Turn 330 N: Because, normally in a titration, you do it several times.

Turn 331 R: Ya

Turn 332 N: The first titration you carry out is just a rough one, you don't. It would give you an idea of how much volume you need to neutralize your acid.

Turn 333 A: Yes

Turn 334 N: And then when you are doing the second one you have a rough idea that ok it changed after adding about 25ml's. So, when you are approaching maybe 20, you can adjust your burette so you can add drop by drop. But in your case, you were using a syringe, it was difficult to actually do that, and you should also know that the beaker which you were using is not meant for titration.

Turn 335 R: Yes

Turn 336 N: And, even for measuring volumes, we don't use a beaker to measure accurate volumes. We normally use pipettes and volumetric flasks.

Turn 337 A: Yes

Turn 338 N: Those other apparatus which are precise and accurate in terms of measuring. You can actually discuss those which your learners as Ayi was saying. After conducting your experiment, you can actually have many questions. Why did we use this? Why did we choose to use this? You can actually hear their views and then maybe if there are any misconceptions you can be able to identify them and correct them.

Turn 339 R: And they could understand the value of a conical flask. This is why it's important? (laughs)

Turn 349 N: Why it's important to use a conical flask?

Turn 350 A: And even powdered calcium carbonate.

Turn 351 R: I could understand the importance of the conical flask when my hand was paining. (laughs)

Turn 352 A: You see. Ya.

Turn 353 R: I couldn’t get it to swirl properly.

Chapter 5

Discussion, Conclusions & Recommendations

5.1 Discussion

Three dynamic models of teacher knowledge viz, the refined consensus model of PCK (Borrowski & Cooper, 2019), model of pedagogical reasoning (Shulman,1987) and the pentagon model of PCK (Park and Olivier, 2008) contain teacher reflection as an attribute. These models are shown in figure 2-1, figure 2-2 and figure 2-4 of this report. The Refined Consensus Model implicitly contains reflection, as pedagogic reasoning is at the centre of the model. This research has attempted to take the idea of teacher reflection (Shoen, 1983; Park and Olivier, 2008) and look at its operation within the context of a professional learning community (Vescio et al, 2008) having discussions on the topic stoichiometry.

On analysis of the data, searching for reflections in action and on action (Shoen, 1983; Park and Olivier, 2008) a new model of pedagogical reasoning emerges in the context of a professional learning community meeting discussions (figure 4-1, p.32 of this report). The research concludes that the teachers in this study do reflect in action when interacting within a PLC. Reflections on action triggers reflection in action. It has been shown that the teachers in these moments of reflections in action begin to question their own thinking on their practice. These moments activated the teachers' metacognition when they now start to think about their thinking. This research shows PLC topic focussed meetings creating opportunities for reflection that bring about change in teachers' orientations to teach science which leads to teachers thinking of changing instructional strategies. The move from teaching procedurally to teaching for conceptual understanding through authentic activity and authentic pedagogy (Newmann et al 1993) result from teacher discussions.

The research reveals Vygotsky (1978) notion of the more knowledgeable other stretching the thinking of a teacher with fewer years' experience. Teacher N has been identified as the more knowledgeable other based on having the most experience teaching and the highest qualification, a PhD. Teacher N is shown to be the most impactful in stretching the thinking of teacher A and teacher R. In meeting two, teacher A realises his omission of using the titration in determining the percentage purity of calcium carbonate (problem 7.2 NSC Grade 12 2020) whilst teacher N discusses this question. Teacher A realises the problem he has with regards to his subject matter knowledge that impeded him form understanding this question. This question was most poorly answered in the NSC chemistry paper of 2020.

In meeting two teacher A questions his own thinking, seeing the value of using models to strengthen conceptual understanding of learners to confront the misconception of using mass ratios instead of mole ratios in stoichiometric problem solving. This shift in thinking of teacher A is the result of teacher N's contribution. The analyses of the data shows teacher A moving from procedural knowledge focus to conceptual understanding. Kind (2014) suggests bringing the mathematics and procedures later after strengthening conceptual understanding in stoichiometry by methods suggested by teacher N in the meeting i.e., use of models. Topic focussed PLC meetings therefore has the potential to move the ZPD of novice teachers in terms of PCK and subject matter knowledge.

Teacher R has a "Aaha" moment in meeting two when teacher N raises the issue of teachers not doing titrations of the type of problem 7.2 of 2020. This spurs teacher R to design a titration like problem 7.2. Teacher R does not have all the resources and was able to adapt the practical investigation with limited resources. Teacher N, the more knowledgeable other again triggers teacher R's refection in action and subsequent change in orientation to teach science followed by a change instructional strategy moving to an approach of academic rigor through a scientific investigation (Magnusson et al. 1999).

5.2 Conclusion

Now, to go back to the research question:

What is the PLC knowledge for teaching stoichiometry?

1.5.1 What is the role of teacher reflective practices within a PLC discussion in the way teachers critically evaluate their knowledge for teaching stoichiometry?

1.5.2 How does the more knowledgeable other within the PLC contribute to others in the group moving through the zone of proximal teacher development of teacher knowledge for the teaching of stoichiometry?

This study shows that discussions of teachers in a professional learning community improves teachers PCK for teaching stoichiometry. PLC discussions creates a conducive environment for teacher reflections. Teacher reflection in action is triggered by reflections of on action in which teachers share their experiences of teaching the topic. It is in these moments of reflection in action that teachers become critical of their practice raising a self-awareness and questioning of practice. Below is an extract of the conversation from meeting two which reveals teacher A's self-evaluation resulting from the conversation.

Turn 111 A: But to agree. You choose a really, really, really good topic that provoke thought. Because as we talk about it now, you ask yourself really have I been doing so right or was I too fast with the learners. Even now, I'm asking myself maybe to those I didn't master it, I'm asking myself, maybe I was too fast for the learners, as we speak like this.

It has been shown that the more knowledge other teacher N, is most impactful on the other teachers in moving them across the ZPD for PCK. Teacher N stimulates the thinking of teacher R resulting in teacher R stimulating teacher N's thinking. I have explained this as a feedback loop (figure 4-15, p.51)

This research shows that teachers reflecting on better ways of teaching a topic through PLC discussions allows a platform for teachers to be self-critical and through a process of pedagogical reasoning can change their orientation to teaching science and instructional strategies resulting in PCK gains.

5.3 Recommendations

I would like to end this chapter by now turning to the recommendations and limitations to this study.

Due to the teachers interacting with learners most of the time in the classroom situations, there is more opportunity for teacher reflection on interaction with learners. However, the same cannot be said for interaction of the teacher with other teachers, teaching the same subject simply because teachers don't have the time or make the time to talk to each other on how they go about teaching topics. The formation of professional learning communities as mandated by the Department of Basic Education and Department of Higher Education (2015) creates opportunities for teachers to reflect more on practice through interaction with peers. This study has shown that such an interaction does lead to new ways of thinking.

Furthermore, this study shows that there are more reflections in action than reflection on action when PLC meetings are activity driven. The general discussion of meeting one does not have as many reflections in action as meeting two and three. The analysis of data shows teachers critically thinking about their thinking in these moments of reflection in action. It is therefore recommended that PLC meetings be activity driven and focussed to have the greatest impact on teacher thinking.

Even though PCK was influenced positively by reflection in action and reflection on action, it remains to be seen if the change in orientations to teach and instructional strategies are in fact enacted in the classroom. Further research is necessary to determine whether the fruits of teacher discussions are assimilated by the teachers in their classroom practice. Furthermore, this study is limited as it does not show how change in teacher thinking influences learner performance.

It is recommended that teachers as professional learning groups discuss problems of the type of question 7 as found in the 2020 national senior certificate examinations. These discussions as shown in this study can identify gaps in teacher content knowledge and can potentially improve teacher content knowledge on stoichiometry enabling them to solve these problems with greater conceptual understanding instead of just following mathematical procedures. This will enable teachers to be better able to teach their learners in dealing with problems of this nature. The discussion should be activity drive with academic rigor stimulating higher order thinking amongst teachers, one that encourages multiple orientations to teach science instead of a solely a didactic orientation or teacher centred orientation (Makhechane & Qhobela, 2019).

Furthermore, the results show that through teacher discussion authentic forms of instruction can be created. As discussed earlier in Chapter 2, Newmann & Wehlage (1993) show also that teachers working in teams created space for authentic instruction. Seashore & Helen (1996), concur with this line of thinking in that professional learning communities complement authentic instruction which stimulates higher order thinking leading to authentic achievement. The results show, as found in the literature, that professional learning communities lead to authentic pedagogy through substantive discussions by colleagues. Triangulation is used in qualitative studies to determine reliability and credibility. Other researchers have shown what is evident in this research.

The limitation of this study is that there is uncertainty of whether the teachers will enact the change in orientations to teach science leading to new instructional strategies being implemented in the classroom. There are a host of contextual factors that can hinder this transformation in practice. These factors can be connected to time and resources as alluded to in the meeting discussions.

Teachers do feel as discussed in the meetings that the length of the curriculum does not allow time for enough experiments. However, as shown in this research the time taken to do an activity that is aligned to question 7 of the Grade 12 national senior certificate examination is under 40 minutes and requires extra preparation when there are limited resources. When there are limited resources, teachers can become resourceful. As a case in point provided in this study, the teacher had to think about alternatives in the absence of a burette, he used a syringe. Completion of the curriculum in a teacher centred manner defeats the purpose, and this could be a reason why questions like question 7 is poorly answered.

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APPENDICES

APPENDIX 1: TABLE OF ANALYSIS – MEETINGS 1-3

MEETING 1

Segment	Participant	Turn /s	Reflection	Key words or phrase indicating ROA/RIA	Teacher Knowledge (Pentagon Model)	Other Models	Theme of discussion
1	N	4	ROA	…that is what I realise from my experience…	Science Curriculum (vertical curriculum)	Loughran (CoRe)	Central concept of Stoichiometry (mole) and how this concept relates to other concepts in the topic.
2	N	44	ROA	…normally I start…; normally I just tell my learners	Instructional strategy, Students understanding	Magnussen (Didactic)	Central concept of Stoichiometry - Mole
3	A	53	ROA	…usually I start on the definition part….; I usually use…; Then I take it for that year…; then I go through..; then I introduce…	Science curriculum (vertical curriculum, curricula material) Students understanding Knowledge of Assessment		Central concept of stoichiometry - Mole
4	N	55	ROA	…our kids are not the same year after year…	Students understanding (Need) Knowledge of assessment		Central concept of stoichiometry - Mole
5	A	56	ROA	…I've realised that sometimes…	Science curriculum (horizontal)		Maths poses a challenge to understanding on topics in chemistry
6	A	58	ROA	…I had this learner who was struggling…now I ask myself	Science curriculum (horizontal), Learner understanding (learning difficulties, motivation & interest)		Maths poses a challenge to understanding on topic in chemistry
7	R	72,74,76 78,80,82 84	ROA	Discussion on activity done before the meeting	Student understanding (misconception, learning difficulties)		Misconceptions around limiting reagent
8	N	85	ROA	That's why I was saying	Instructional strategy	Magnussen (Didactic)	Misconceptions around limiting reagent
9	R	86	ROA	A reflection of common mistakes of learners know through classroom practice	Students understanding (misconceptions)		Misconceptions around limiting reagent
10	N	87	ROA	A reflection on practice, steps to follow when determining limiting reagent: "….Those are the stages they need to follow."	Instructional strategies	Magnussen (Didactic) Procedural	Misconception around limiting reagent
11	A	88	ROA	Reflection on practice …maths poses a challenge, from teacher A's experience in the classroom in terms of student understanding of using ratios	Science curriculum (horizontal); Student understanding (learning difficulties)		Misconceptions around limiting reagent Maths in particular ratios posing a challenge to learners understanding of finding limiting reagent
12	R	99-101	RIA	…when I'm thinking about it…	Students understanding (misconceptions)		Chemical reactions at molecular level, particles react- (implicitly linked to collision theory)

13	A	104	ROA	Reflection on procedures follwed in the classroom…use of a table.	Instructional strategy	Magnussen (Didactic) Procedural	Chemical reactions at a molecular level linked to chemical equations representation
14	N	105	Reflection		Instructional strategy (Topic specific-representations) Conceptual		Chemical reactions at a molecular level – use of models in explaining ratios
15	A	111	RIA	Because as we talk about it now you as yourself really….Even now I am asking myself…..realise now how……But now realising really how…Now I ask myself	Students understanding, Instructional strategy (representations) move from procedural to conceptual		Chemical reactions at a molecular level
16	A	125-127	ROA	I remember in one of my class before I give the definition…	Instructional strategy-representation, activities		Concentration
17	N	128-130	ROA	I normally just ask these learners, ok, how many sugars do you add to your tea…	Instructional strategy-representation		Concentration
18	N	132-148	ROA	….they forget, I don't know why?.....Then I say lets start from basics….And what I've noticed…	Instructional strategy-representation		Concentration unit dm3
19	R	163, 165	ROA	Reflection on activity done before meeting	Student understanding-misconception		Concentration misconception
20	A	168, 170, 175	ROA	Reflection on activity done before meeting	Student understanding-misconception		Concentration -misconception
21	R	177, 178, 184, 186	RIA	Comment on teas spoons of sugar added	Instructional strategy, representation		Concentration -misconception
22	N	189	ROA	Reflection on activity done before meeting	Instructional strategy	Magnussen (Didactic)	Concentration - misconception

MEETING 2

Segment	Participant	Turn/s	Reflection	Key words or phrase indicating ROA/RIA	Teacher Knowledge (Pentagon Model)	Other Models	Theme of discussion
1	A	39	ROA	…I will ask myself in stoichiometry as we said the other day…	Science Curriculum (vertical curriculum) Instructional strategy		Mole ratio of balanced chemical equation Concentration
2	A	43, 45, 48	ROA		Instructional strategy		Concentration: units
3	R	51, 54,56,58	RIA	…Now is the learner able to make the link…	students understanding		Excess and limiting reagent- application to use of a titration to determine percentage purity of calcium carbonate.
4	A	59	RIA	Teacher A shows thinking of the question by repeating it.	students understanding		Excess and limiting reagent – application to use of a titration to determine percentage purity of calcium carbonate.
5	R	60	RIA	Teacher R repeats the question to prolong thinking of learners being able to make the link between the two reactions	students understanding		Excess and limiting reagent – application to use of a titration to determine the percentage purity of calcium carbonate.
6	A	61	RIA	Literal answer to the question	students understanding		Excess and limiting reagent – application to use of a titration to determine the percentage purity of calcium carbonate.
7	N	62, 64, 66	ROA	…reflection on practice from experience of learners	Student understanding		Problem solving: Interpretation of long worded examination problems
8	A	68,70	RIA	Teacher A thinks in action as he sees the problem and identifies the coincidence of ratio being 1:1	students understanding		Procedural knowledge vs conceptual understanding
9	R	71	RIA	…comments on teacher A in action	students understanding		Procedural knowledge vs conceptual understanding
10	A	72	RIA	Reflection in action as the problem is being discussed	students understanding		Procedural knowledge vs conceptual understanding
11	R	73, 75	RIA	Reflection in action as problem is being discussed	students understanding		Procedural knowledge vs conceptual understanding
12	A	76	RIA	Reflection in action as problem is being discussed	students understanding		Procedural knowledge vs conceptual understanding
13	R	77	RIA	Reflection in action as problem is being discussed	Instructional strategy		Problem solving, learner comprehension of problems in text
14	N	78	ROA	….key things that learners have to do…	Instructional strategy		Problem solving, learner comprehension of problems in text.
15	R	79,82,85	RIA	Reflection in action as problem is being discussed drawing from teacherA's views	Students understanding		Problem solving, learner comprehension of problems in text
16	N	86,89,91,93 ,95	RIA	Reflection in action drawing from teacher R's views	Instructional Strategy, Orientations		Practical activities
17/18	A	92,97,99	RIA ROA	……the practical just draws their interest…. …..i remember I was doing organic chemistry	Intructional strategy, Orientations, students understanding		Practical activities, Procedural knowledge vs conceptual understanding
19	R	94,96,101	RIA	Aaha moment	Instructional strategy		Practical activities
20	A	102	ROA	….I realise, I think there was a 2017 paper…	Assessment		Problem solving

21	R	103, 105	ROA	…refer to turn 113…	Instructional strategy, representations		Problem solving
22	A	104,106	RIA	…..reflecting in action at teacher R's represention in turn 103	Assessment, Instructional strat		Problem solving
23	R	107, 109	ROA	Refer to turn 113.	Instructional strat		Problem solving
24	A	110,112	RIA	Reflecting in action on teacher R perspective on representations adding some other forms of representations	Student understanding, instructional strat		Problem solving
25	R	113	ROA	"Honestly when I first saw this question….."	Instructional strat		Problem solving
26	A	114	ROA	Even myself, you saw firstly I worked…..	Assessment, Student understanding		Problems solving
27	N	116	RIA	"Yes, I just wanted to comment on your diagram there…."	Instructional strat		Problem solving
28	R	117	RIA	"Yes I was thinking also, the experiment…" refer turns 94, 96 &101	Instructional strat		Practical Activity
29	N	118	Refle ction	??	Assessment		Problem solving
30	A	119	ROA	"…that's what I was also saying…"	Assessment		Problem solving
31	R	124	RIA	"Household vinegar here…(points to the question…)	Assessment		Problem solving

MEETING 3

Segments	Participant	Turn/s	Reflection	Key words or phrase indicating ROA/RIA	Teacher Knowledge (Pentagon Model)	Other Models	Theme of discussion
1	R	7,9,11,13, 15,17,19,21	ROA	….do a lot of reflection from our last meeting	Students understanding, instructional strategy (activity), orientation		Design of Authentic practical activity that mirrors problem 7.2
2	R	23,25,27, 29,40,42,44	ROA	….I started finding things….	Orientation (decision making)		Looking for apparatus/ scientific artifacts/ improvising resources to show
3	A	45	ROA	…..if I were to do a practical…	Orientation (decision making) Instructional Strategy		Looking for apparatus/ scientific artifacts/ improvising resources to show
4	N	53,55,57, 59	ROA	….I have all equipment	Orientation (decision making)		Looking for apparatus/scientific artifacts/improvising resources to show
5	R	65,67,69	ROA	I want to take you through what I've been working on…	Orientation (decision making) Instructional Strategy		Design of Authentic practical activity that mirrors problem 7.2
6	N	70	RIA	…Sorry I have a problem with that…	Orientation (decision making) Instructional strategy		Design of Authentic practical activity that mirrors problem 7.2
7	R	71-94	ROA	…you see what I did was…	Orientations (decision making) Instructional strategy		Design of Authentic practical activity that mirrors problem 7.2
8	A	77,79	RIA	Relating discovery of volume to current idea…RIA	Orientations (beliefs of NOS)		Design of Authentic practical activity that mirrors problem 7.2
9	R	96,98,100, 102,104,10 6,108,110,1 12,114,116, 118,120,12 2,124,126,1 28,130,132	RIA	Does prac, part 1	Orientations (decision making) Instructional Strategy		Doing authentic practical activity that mirrors problem 7.2 part 1 reaction 1
10	N	133,135,13 7, 139,141,14 3	RIA	Makes suggestion by relecting in action	Orientations (decision making) Instructional strategy		Doing authentic practical activity that mirrors problem 7.2 part 1 reaction 1
11	R	144 -190	RIA	Does prac part 2	Orientations (decision making) Instructional strategy		Doing authentic practical activity that mirrors problem 7.2 The titration part 2 reaction 2
12	N	145-165	RIA	Comment on prac in moments	Orientations (decision making) Instructional Strategy		Doing authentic practical activity that mirrors problem 7.2 The titration part 2 reaction 2
13	R	192-248	RIA	Does calculations in the moment	Orientations (decision making) Instructional strategy (Activity)		Doing authentic practical activity part 3 calculation
14	N	250-349	ROA	Reflections on prac	Orientations (decision making) Instructional strategy (Activity)		Post Practical Reflections
15	A	253-350	ROA	Reflections on prac	Orientations (Decision making) Instructional Strategy (Activity)		Post Practical Reflections

16	R	251-351	ROA	Reflections on prac	Orientations (decision making) Instructional strategy (Activity)		Post Practical Reflections
17	R	398-428	ROA	Reflections on mole	Orientations (decision making) Instructional strategy (Activity)		The Mole

APPENDIX 2

Transcriptions meetings 1-3

MEETING 1

R = Researcher

N= Teacher

A = Teacher

Turn 1 R: …and eh, I'm looking at that and having a discussion on how to go about teaching the topic. Of course, each teacher is individual in their approaches and may share some common traits as well.

Turn 2 N: That's true.

Turn 3 R: I need to capture that, to capture how you doing it and to look at how other members in the group do it and to kind of exchange and interchange and see if we can influence each others thinking. That's the idea. So we want to look at what you do in the classroom. I put it on multiple. You can access the screen and you can show us what you do. Stoichiometry, what would you consider to be the central kind of concept?

Turn 4 N: I think the mole concept is fundamental. They need to understand what is meant by the mole of a substance. And then once they understand what is meant by mole of a substance, remember, if you are calculating the mass or volume or whatever in a chemical reaction, you need to consider the mole, ratio of mole. I think the main concept to be taught there will be the mole concept. Of course learners need to know how to balance a chemical equation. They need to know how to find the number of moles. Of course there are four fundamental formulae which learners need to know how to use them. For example, they need to find the number of mole if they are given mass of a substance. Find the number of moles when they are given concentration of a solution if they are dealing with solutions. They should also be able to find the number of moles if they are given the volume of a gas when it is at STP or RTP, whatever the case may be and they also need to find the number of moles when they are given number of particles where they divide by Avogadro's number. So these four fundamental formulae, balancing chemical equations, and being able to use the reacting ratio from the balanced equation to find the number of moles of anything else. Because normally they are given information which will help them to calculate the number of moles of one of the reactants or anything of the product. Once they are able to find the number of moles of either the reactant or product they can use the mole ratio to calculate the number of moles of anything else where they maybe asked in the question. That's what I realise from my experience.

Turn 5 R: How do you in a classroom situation introduce this concept of mole and you welcome to use the… Are you using your phone?

Turn 6 N: Yes, I am using my phone.

Turn 7 R: Or laptop

Turn 8 N: I'm using my phone.

Turn 9 R: It will be difficult for you to use the whiteboard

Turn 10 N: No, I won't be able to.

Turn 11 R: You won't be able to. I understand. Because on your phone you won't be able to. How do you introduce the concept of mole. Maybe you can even talk through the representations that you use, even though you don't have a board to use, but you can talk through how you approach mole with your learners.

Turn 12 N: Mole

Turn 13 R: And what do you take into account of their thinking when they come in. How do you use what they are thinking? What do you do?

Turn 14 N: Usually I say, I give them the definition of a mole of a substance. What do you mean by a mole of a substance? I just tell them that a mole of a substance is the amount of any substance which you are looking at and that amount should contain $6,02 \times 10^{23}$ particles of that substance. So for example, if I'm looking at magnesium atoms, it means 1 mole of magnesium atoms I'm looking at $6,02 \times 10^{23}$ particles. But of course the learners sometimes have challenges in appreciating that value because its big. $6,02 \times 10^{23}$ it's a very big number. Its an abstract thing. You can't just put it in. They can't actually see it. They can't see those particles which you are talking about because the number is so huge. But I just emphasis that whenever you say a mole of a substance , you are looking at this number of particles. They normally understand that.

Turn 15 R: Is there any other analogy that you use?

Turn 16 N: eh. It's very difficult to quantify because of the huge number. It's a very big number.

Turn 17 R: Often enough we know some people, teachers using the analogy of the dozen and 12 is a dozen, and we say that Avogadro's number is like that.

Turn 18 N: Like 12?

Turn 19 R: Like 12 makes a dozen. I mole is Avogadro's number.

Turn 20 N: That number. Ok. Ok Ya.

Turn 21 N: If it was possible to say 1 mole of people, I'm looking at this number of people you see. If it was physical to say I mol of even the chairs you are sitting on, then I'm looking at this number of chairs. So, they tend to appreciate that.

Turn 22 R: Oh ok. Its this number of chairs. It is the same number.

Turn 23 N: Because a mole just referring to whatever particles you are looking at, be it atoms, be it molecules, be it chairs, be it people, it is this number of people.

Turn 24 R: That number. That's what the mole is.

Turn 25 N: And then, if there are two moles, what you do, you multiply that number by two. If there are three moles, you multiply that Avogadro's number by three. They end up understanding what you are trying to put across.

Turn 26 R: A is joining us.

Turn 27 N: Are we the two of us so far.

Turn 28 R: Yes, the two of us so far.

Turn 29 N: So, we need a third person.

Turn 30 R: Yes. He is connecting to audio. Yes, so the mole and eh, A is with us

Turn 31 A: Yes, hello. How are you? Sorry I got tied up but I'm here now.

Turn 32 R: No problem. Nasi was just going through. We started the discussion. Nasi identified the mole as being the central concept in teaching of stoichiometry.

Turn 33 A: Ok.Ok.

Turn 34 R: N went through how he handles the concept of mole with his learners. I think before that he was talking a bit about stoichiometry and the important aspects. The fundamentals of stoichiometry, Nasimu, that's what you were talking about.

Turn 35 N: Yes.

Turn 36 R: N maybe you should rather do it, summarise it quickly for A, instead of me doing it.

Turn 37 N: Hello A.

Turn 38 A: I'm fine Sir. Hello. How are you?

Turn 40 N: Don't call me Sir. I'm Dr now.

Turn 41 A: Oh, you are Doctor by the way. (laughs). Ok, doc.

Turn 42 N: Thanks for coming. Its better to be late than never.

Turn 43 A: Ya, eish. Ya ne. Alright take me through. Take me through.

Turn 44 N: Stoichiometry, normally I start by explaining what is stoichiometry to learners? To say stoichiometry is just the study of the relationship between reactants and products in a chemical reaction. That's the fundamentals of stoichiometry. When you are finding mass, moles, whatever, usually its in relation to reactants and products. So they need to appreciate that. That stoichiometry is just the study of the relationship between reactants and products in a chemical reaction. And then they need to know what is meant by the mole because normally when we do the calculation we are talking about the mole ratio. Ratio of this to that. Ratio of one reactant to another reactant or reactant to a product. So they need to understand what is meant by a mole of a substance. So I was just saying, normally I just tell my learners that a mole of a substance refers to the amount of substance which contain $6{,}02\text{x } 10^{23}$ particles of that substance. I know that in some texts books they define it as the amount of substance which contains as many elementary entities as there are atoms in carbon 12 isotope. But ah, it might just confuse the learners because basically..

Turn 45 A: Sometimes it does

Turn 46 N: … in simple terms just amount of substance which contain $6{,}02\text{x}10^{23}$ particles of that substance. If you are dealing with atoms, then that will be the number of atoms. If you are dealing with molecules, that will be the number of molecules. If you are dealing with ions, that will be the number of ions. And this number does not change and its called Avogadros number.

Turn 47 A: Yes.

Turn 48 N: So the learners know. Then we move on to talk about ways of finding or formulae of finding number of moles. Because normally you find moles when you are given mass. Then you tell them, if you are given mass then you divide mass by the molar mass of whatever. If you are given volume of a gas, if you are dealing with gases, divide the volume by the molar volume and make sure that you units are identical. And if you are finding number of moles when you are given number of particles know that you are going to say number of moles equals number of particles over Avogadros number. If you are given concentration of a solution the number of moles will be given by the product of concentration and volume, and make sure your volume is in dm^3. So those are the four ways of finding number of moles because in most questions you are given information where you will be able to find the number of moles using any one of these formulas. And then you can now always use the ratio, the reacting ratio in your balanced equation. Its also key that learners are able to balance the reaction equation. Because once the reaction equation is not balanced, then you can't get the ratios right. So once they know how to find the number of moles, they can find the number of moles of anything else in the equation by using the reacting ratio from the balanced equation. I think basically, that's where we are now.

Turn 49 A: Ok,ok. that's good. I'm there now. Thank you.

Turn 50 N: If you want to add, you can add.

Turn 51 A: Lets continue.

Turn 52 R: We all do things differently, we cause we are, you know, we teach differently. A, how do you approach this concept of mole to your learners. Think of us being the learners in the classroom. What would you say to us?

Turn 53 A: Ok. Usually the mole concept, really I think it's the basic aspect of stoichiometry. Without a learner understanding the mole concept, then I don't think the learner can get started. Usually I start on the definition part. Eh, as doc has said, that sometimes there are different text books specially use different definitions. I tend to choose the simpler one for that lesson or that class at that particular time. The simpler definition that I think will suite them. I usually use different text books pertaining to the type of class that I have that year. In some other classes, usually when I get into the class and if it's a good year, I find out that most of them in that class got a certain, after researching, they have got this certain understanding of a mole, usually similar. Then I just take it for that year, if I see that's the correct one. But if its an average class, that's where I usually impose the one that I think is the simplest one. Then I go through the concept of the formulas of calculating the number of moles because as I said that, and as doc said, the basic part of stoichiometry is how do you calculate the number of moles. Why is it important to know the number of moles if you are dealing with reactions in chemistry. Then I introduce all these different types of formulas when I'm given mass, I'm given volume or its standard temperature and pressure then I take it from there. Then I go try to be complex using the balanced equation calculating the concentration. If it's a good year, usually, lets say I'm in grade 11, I take a really good grade 12 question then I put it to the grade 11's and see how they are fairing on these. But in grade 11, usually I also, usually driven by the type of class. I usually if it's a grade 10, I stick to the grade 10 stuff if the class is that average, I don't want to end up confusing them but if I think oh, I will be with this class even next year, I tend to mix what's to be asked in grade 11 and what's to be asked in grade 10 there in grade 10 but if the class is average, I just stop where the CAPS document will advise to be stop but then for a grade 11, I usually go, go further. I usually go further. But now the thing is eh, sometimes uhm after doing this topic a lot, I'm compelled to move out from text books. Usually as I teach things, I don't know whether its right or what, I tend to like exam papers. I can teach the mole concept but I try to say right, let me not use the examples from the text book. I go exactly through to the past papers where I can find a more complex document especially in grade 11. Then I take it from there. They learn the ratios as they are asked not as I am directed by the text book. That's what I usually do. But sometimes, yes, I have realised it works well with another class, but with another class sometimes it gets complicated in such a way that I have to go back again. Like I will teach you percentage yield and percentage purity just a little bit then I take a big past paper. Then if I see the response becoming so well, I adopt that system but if the response is so slow, then I go back to the text book, I take it step by step now. I'll have seen that this class will deserve that other method than this one. Usually, its not actually, it's the heavier of the class, that's how I guide them. So I don't know whether I'm right or wrong then. But that's how I've been doing it. Any suggestions.

Turn 54 R: N, any comment.

Turn 55 N: I think it's a good approach which he uses because our kids are not the same year after year. Sometimes you've got a strong class. Sometimes you've got a weak class. Sometimes you've got two classes you are teaching the same grade, the same content. You find that what you used with the first class you meet that day by the time you meet the second class, you can actually adjust your approach to your teaching. Because, you see as a teacher you can prepare the lesson that I'm going to approach the lesson like this and when you find its not working, it didn't work well for the previous class, you can also adjust, maybe modify your approach to try to make learners understand what you are trying to put across to them. And the idea of giving past papers is also good to learners so that they can feel challenged because sometimes what you have in the text books might not be good enough. It needs to be supplemented with past papers and also it prepares them, to one day answer, to what to expect in the exam situation rather than working until the end of the term or the end of the year to do past papers. So when you do it, each topic you look for relevant questions based on what you have taught. Its good, because most of the time they don't have time at the end of the year to go through past papers. Especially this year with COVID, it's a good approach.

Turn 56 A: If I were to ask. I've realised that sometimes I get strugglers when it comes to lets say empirical formulae or just the molar mass, if it was going to be used somewhere and how did I realise that I realised when doing chemical equilibrium with the grade 12. You realise that you give them a past paper, if you give them in the form of a mass sometimes they work out the RICE table without even converting to let say number of moles, even if someone can do it without it. Now the learners struggle when it comes to the application of either molar mass or empirical formulae as any changes with numbers in stoichiometry, there are the strugglers in Maths. Can we say now that its really a difficult task for a learner to pass stoichiometry without being comfortable with maths?

Turn 57 N: I don't think so, because see what we do in stoichiometry is just application of mathematics, its division, multiplication. We are not doing complicated Maths. You know that if I'm finding number of moles, I just divide mass by the molar mass and the molar mass, I just add it, the relative atomic mass of whatever.

Turn 58 A: Yes doc. I want to understand with that. Yes doc. But the thing is in my class, I had this learner who had been struggling with Maths. I think it's a private learner, did not do well in Maths and Physics last year. This learner is not doing well again in maths but now improved so much in other topics like organic chemistry, improved so much but when it comes to anything to deal with stoichiometry or it tends to be longer to her. The girl just gives up from the start knowing now that the methods are going to be long. Even when it comes now to calculating lets say pH, as long as she has to start to calculate the concentration, take on the steps from the balancing of the equation, the girl just stops. Now, I'm trying to ask myself whether our Maths again starts to affect stoichiometry because we know of course it has been affecting forces in Physics a lot. But can we say that it has got a chance to affect stoichiometry as well. Can you really rule it out, say not it doesn't or yes it can?

Turn 59 N: We can't make a conclusion based on one learner. Maybe in her mind stoichiometry once she hears, you see, some of these learners they get influenced by other learners. They say stoichiometry is a very difficult topic. Then they just relax. They don't put any effort. Because, truly which Maths can you say is very, very challenging there in stoichiometry. We are just dividing numbers, multiplying numbers, adding numbers.

Turn 60 A: Nothing more.

Turn 61 N: Even, maths, she just has to practice. Maths is a practical subject. Even science is a practical subject. They are supposed to revise and study. Because without study how can you end up knowing.

Turn 62 A: But doc, sorry to cut you there and sorry to take you out of this topic people. I've realised that there are learners I have been trying to help, let's say in Maths. There are learners you can't really help after practicing and practicing. I've realised that there are really learners that you can say, because you are a teacher, you won't, but if really push comes to shove, you are going to say now, you stop this subject choose another one.

Turn 63 N: (laugh)

Turn 64 A: I've met with, like we progress learners and progress learners and progress learners up until we meet matric.

Turn 65 N: Ok

Turn 66 A: Even after saying, practice and practice but yet still we are doing science. I know you are meeting these situations in Physical Sciences.

Turn 67 N: Ya, but it could be that they choose the wrong subject which they are not able to do. Because science are not for everyone, that why the numbers.

Turn 68 A: That's the sentence that I wanted.

Turn 69 N: I think it's a wrong choice.

Turn 70 R: Ayi and do

Turn 71 A: Sir

Turn 72 R: We could follow the stoichiometric solution with the maths right, the ratios ect. Umm isn't it the conceptual understanding, the understanding of the concepts. The understanding of the concepts and how do we get that through.

Turn 73 A: Is'nt the learners

Turn 74 R: What are the ways that, what are some of the things that you are using to get the concepts through. Umm, it could be a case where the learners could follow the maths and arrive at the solution, may not really, I don't know , possibly could not grasp the concept. I like the way that eh, doc, the way you answered the question. You know, sorry, I didn't put it up. I must find it, where I have it on the system, so I can share it with you. I'm talking about the last question, remember Ayi, the stoichiometry discussion topic specific content knowledge diagnostic test .

Turn 75 A: Yes, I remember that.

Turn 76 R: It's about the magnesium and what is that, the $TiCl_4$

Turn 77 A: Yes

Turn 78 R: You had to find the limiting reagent.

Turn 79 A: Yes.

Turn 80 R: So doc worked it out nicely showing all the steps right, then he concluded there that the magnesium is in excess and TiCl4 is the limiting reagent, right, ok.

Turn 81 A: Yes.

Turn 82 R: Now, the possible, in the learners mind, if you go and look at the learners mind, he may think that, you mention it here to, he may think that TiCl4 because it has the less number of moles, its going to be the limiting reagent, right, ok.

Turn 83 A: Assumption. That would be the assumption.

Turn 84 R: You can see the kind of thinking. If you trying to see how the child is thinking. From a child, its possible that I can think that way. The $TiCl_4$, because it has 18635 moles, less number of moles, oh that's the one going to get finished first or he could think, the other, he could think that you know, the one with less mass will get finished first. It was in that question, it was the magnesium with less mass. It's so happens that magnesium is with less mass and that could be the one that gets finished first and when you work out the mole for TiCl4, that one with less mole could get finished first. So then, how do you deal with this issue.

Silence

That is a way somebody thinks. The one that's less gets finished first. How do you deal with that. And in the working out, doc, you actually went through it nicely, all the steps and you mention that its going to be an issue with the learners. They could think this way. How do we address this?

Turn 85 N: That's true. Ya, I think what's very important there is to ask learners to say ok, these are the masses but can you check the molar mass of your reactants. Check the molar mass of the reactants. You cannot compare masses of reactants with each other because their molar masses are not the same. I think the learners have to know that. The molar masses are not the same and therefore its incorrect for you to compare the masses and deduce your limiting reagent from that because they don't have the same molar masses. You can only compare your number of moles. That's why I was saying that it very important that the learners understand the mole concept. It's not about the mass. It's about the mole concept. Calculate the number of moles then you will be able to deduce which is the limiting reagent.

Which one will get finished first. Because, whatever gets finished first, it means that it is going to limit the product in the chemical reaction.

Turn 86 R: Ok, lets say he works out moles and gets the smaller number 18639. Ok, that's the smaller number, why doesn't that one get finished first. How can we convince the learners to think otherwise.

Turn 87 N: Without using the ratio of how they are reacting (laughs). That's where the ratio comes in. That's where the ratio comes in. You can to moles, check your ratio and then from there you can deduce which one is your limiting reactant. Because just comparing number of moles without referring to the reacting ratio as depicted in the reaction equation is not enough because it doesn't mean that ones the number of moles is small then that's the limiting reagent. You have to consider the way they are reacting. The reacting ratio of your reactants for to determine which one is your. So you have to tell the learners well ok these are the masses, they are given in kg. What we have to do is get the molar mass, then to get the number of mole. Convert your kg into grams. Once you got your grams, get your moles. After getting your moles, look at your reacting ratio. You should be able to tell which one is going to get finished first. Therefore that's your limiting reactant. Those are the stages which they need to follow. The way I see it. I don't know. Ayi, maybe you can chip in.

Turn 88A: Yes, I think you are right there because learners can see numbers and they say ok this one looks like it has a bigger mass therefore it is in excess, the other less mass, therefore it will finish first. But now the question is, there is a ratio and what you have in the reacting container. Once you have worked your ratio using your, lets say your balanced equation. Now learners again should be good in Maths now. How do I share what I have using ratios. Is this one enough. Lets say the ratio is 2:4. As I continuously share it in that ratio lets say 1:2, which one will be finished first. In a grade 10 classroom, yes using that thing like lets take in one by one 1:2, the 1:2 sharing a certain number is easier but now grade 11's will be dealing with now bigger numbers. They really need to understand the which sharing of amount using ratio. If they cannot really grasp therefore they will go back to the concept we are saying, they will look at the bigger mass and then they will assume, then they will assume. Then that's where my question comes is that Maths I'm talking about really coming to cut us down again when it comes to stoichiometry. Because the question now, if you really cannot share using ratios. Now to think that these ratios I have in my equation are just there to share what I have because there is a difference between my ratios and what's really in the container. If really we got learners that cannot do that then whatever we do, our efforts then, we just getting, we can't and I've realised even in that question, if I remember, I don't even have the question. The number was written to the power. I don't know to the power something. The mass right? Like times 10 to the power something.

Turn 89 N: It's given in kg, that is all.

Turn 90 A: And again, we get learners who gets to as you say forget to convert that to grams.

Turn 91 R: When I'm thinking about it, it is particles that react right?

Turn 92 A: Yes

Turn 93 R: It is particles that react. We not looking at masses reacting. Its either at a molecular level.

Turn 94 A: Yes

Turn 95 R: It will be a particle of this and a particle of that.

Turn 96 A: Without the other one

Turn 97 R: Ya

Turn 98 A: But not in the ratio 1:1 right?

Turn 99 R: In the ratio of the balanced equation right?

Turn 100 A: Yes

Turn 101 R: So these particles are reacting. Its not the. Its not like the mass, the mass ratio. Particles, moles are particles.

Turn 102 A: And your question is, how do we go about taking our learners out of the mass to mass. Because our learners will assume it's a mass to mass, therefore you have a bigger mass, you are in excess.

Turn 103 R: What kinds of representations would you use. How would you represent this in the classroom, to show this?

Turn 104 A: I believe its advantageous if you have a class lets say from grade 10, you are now with them in grade 11. Its easy to really remember, did they really grasp the concept, the concept from that 9. How do I first balance my equation, number 1? Number 2, I'm dealing with my masses, now let me turn them into moles. Those number of moles are what I have. Then I go back to the equation. In the equation, those are sharing ratios. If they can remember that, I think in numbers, I represent it in numbers but I separate, this is my equation. Now what I convert from the equation, this is really what I have. This is really what I'm sharing. I would need really a diagram, but a table can do. A table can do.

Turn 105 N: Even also, this to add to what Ayi is saying, even if you get some models, you can actually use models, you can actually use models, so they can actually see at microscopic level. You can actually represent the molecules using some models. Say ok. If I got, if the ratio of titanium tetrachloride to magnesium is 1:2, if I got one of this, I will need how many of this? They'll say two. If I got three of this, I'll need how many of that, six. If I got 20 of this, I'll need how many of that, they will give me a number. If I got 100, 200. 1000, 2000 and then this which you have calculated, you need how much of that, then they will multiply by two.

Turn 106 R: You physically actually show the model and they can see visually.

Turn 107 A: Which is a good advantage if we were with them in grade 9. Grade 9 syllabus will advise those and its easier. It takes a lesson to do that but sometimes we really do not have much time to do that lets say in grade 11, but for remedial class I advise you to sit down and you do your models but it tends to be boring if you got those sharp, sharp, sharp learners.

Turn 108 N: (laughs)

Turn 109 A: Yes, really. I think so.

Turn 110 N: Ya, you are right. Ya.

Turn 111 A: But to agree. You choose a really, really, really good topic that provoke thought. Because as we talk about it now, you ask yourself really have I been doing so right or was I too fast with the learners. Even now, I'm asking myself maybe to those I didn't master it, I'm asking myself, maybe I was too fast for the learners, as we speak like this.

Turn 112 N: (laughs). You always reflect and say maybe I could have done things differently.

Turn 113 A: Serious, yes.

Turn 114 N: We always think about that.

Turn 115 A: Because, realise now how the time we have taken talking only about the mole. We really do not take that much time in class discussing about mole. My lesson will be gone now and I would have spoken about a lot of things just after that mole. But now realising really how important it is. Now I ask myself maybe I've been moving on too fast before they really grasp it.

Turn 116 N: Ya, we always short of time.

Turn 117 A: Ya, its not always. Now, I'm afraid because most of the schools are moving online, online. Mine is moving online. It's a challenging situation.

Turn 118 N: Ya

Turn 119 A: You ask how I am going to be doing it now and assessing, that really did they master it.

Turn 120 N: Ya, its going to be a challenge. It will be worse than the previous groups we taught.

Turn 121 A: It becomes worse. Really, it becomes worse. All right, direct us to where to next now.

Turn 122 R: We spoke about mole. We spoke about mole. We spoke about limiting reagent, right. Concentration.

Turn 123 A: Good.

Turn 124 R: Concentration is also important in stoichiometry. And how do you approach that.

Turn 125 A: It's an interesting one, this one. I remember in one of my classes before I give them the definition, I spoke about how tea can be sweet or less sweet. I said, oh, now that's concentration. The sweeter is more concentrated. More number of moles per given unit volume. That one, I think my learners enjoyed it. But on a serious note, it wasn't as challenging as the other concept. And even the calculation $C = n/V$ and the second one is what, the one with the MV, it's m/MV isn't?

Turn 126 N: Yes

Turn 127 A: Ya. I think that one didn't challenge them so much. Even the definition itself no. I think the way I approached it, it was definition first. Then I gave real life examples, just like tea. Then after that I moved to my calculations. I did not get any challenge. So over the years when it comes to concentration, I just move to it directly like that.

Turn 128 N: Maybe just to add to yours. I think your approach is not very different from mine. I normally just ask these learners, ok, how many sugars do you add to your tea. This one says 2, this one 4. Ok, so ok. Who's, assuming that the volume is going to be the same, who's tea will be sweeter. Aha, the one with 4 teaspoons.

Turn 129 A: Ok.

Turn 130 N: Ok, why is it sweeter? Aaha, because there's too much sugar. What do you mean, there's too much sugar? So it means every sip of tea which she takes or he takes contains more sugar particles per unit volume, which means there are more sugar particles per unit volume of tea. Yes it's going to be less sweet because there are more water particles than sugar particles per unit volume. So that's concentration. So concentration is number of solid particles per unit volume. But our concentration should always be in what, in dm^3. Then the challenge which I normally see is the conversion….

Turn 131 A: Oh wow.

Turn 132 N: …..into m^3 to dm^3. They forget. Sometimes they want to divide. They want to multiply cm^3 by 1000 to change to dm^3.

Turn 133 A: Oh my word.

Turn 134 N: Instead of dividing by 1000, they forget. I don't know why.

Turn 135 A: Oh.

Turn 136 N: Then I say, lets start from basics. Decimetre means what? What's the meaning of decimetre. They don't know. Then I say decade.

Turn 137 A: Ok.

Turn 138 N: What is a decade? It's 10 years. Oh, 10 years, ok. What's a decagon? Ah, it's a shape with 10 sides. So it means decimetre should be what now? Ah, it should be 10 centimetres. Ok, that's correct. Decimetre is 10cm. But here we are saying 1 decimetre cubed. What's the meaning of one decimetre cubed? It means I'm saying 1dm times another decimetre times another decimetre times another decimetre.

Turn 139 A: Decimetre, good.

Turn 140 N: Lets multiply those. I say 1 times 1 times 1, they say 1. Dmxdmxdm. Dmxdm, they say dm squared. Times another decimetre, decimetre cubed.

Turn 141 A: dm^3

Turn 142 N: So $1dm^3$ is equal to, lets substitute dm you said is 10cm. So its 10 x 10 x 10, 1000. cmxcm xcm, cm^3. Ok, so do you agree that $1dm^3 = 1000cm^3$. Ya, yes Sir. Ok, so how do we change dm^3 to cm^3. Ah, then they say we multiply by a 1000. How do we change cm^3 back to dm^3, we divide by 1000.

Turn 143 A: That's a good one.

Turn 144 N: They don't forget. Because conversion also confuses them.

Turn 145 A: A lot.

Turn 146 N: And what I've noticed, they don't know that a centi metre cubed is the same as milli litre. They don't know that.

Turn 147 A: Oh my.

Turn 148 N: They don't know the relation between the two.

Turn 149 A: And dm^3 with the litre.

Turn 150 N: Ya, that's right.

Turn 151 A: And dm^3 with the litre. I understand. I understand.

Turn 152 N: Otherwise. Ya.

Turn 153 A: This also, usually when now stoichiometry affects me in grade 12 when it comes to acids. I remember that I've been when referring back to this concentration stuff in acids, where you get your, where you get your concentrated and your dilute. Your strong and your weak. They get confused there. But if they got a good background when it comes to concentration. Now they can really tell between a dilute, concentrated or a weak and a strong. Even a weak concentrated. A strong, which is also a concentrated one. They don't confuse those.

Turn 154 N: Ok.

Turn 155 A: Ya but, but this one usually it's a direct one except when you come to those conversions. They can even confuse your best learners sometimes.

Turn 156 N: Ya, true.

Turn 157 A: What I get after the exam is , the best learner comes to you and says, sir, when you mark there, please forgive me. I made a mistake in conversion. Ya, the good ones come after the exam and tell you their mistakes because they realise it when they are out, oh, we accept the conversion and stuff. It's a good point to note.

Turn 158 N: Ok, it's a learning curve to them.

Turn 159 A: Even to us. Even to us. There are things that we've been taking for granted. But we cannot anymore.

Turn 160 N: True. True. Because, the kids, they understand differently.

Turn 161 R: The example of sugar is quite nice.

Turn 162 A: Good one.

Turn 163 R: Good one. Now there was a question in the questionnaire where they used different substances, not sugar and sugar. The one you know where they said 10 grams of sodium chloride, sodium bromide and sodium iodide, and we looked at responses from learners. And the responses where, ya the concentration of the three solutions will be the same because you added the same amount of solute in the water. Remember that question.

Turn 164 N: Ya, I remember that. Ya.

Turn 165 R: Concentrations are equal because you are dissolving the same mass of the salts in 100ml of water. Basically lets go back, ya, during a practical lesson you made up, you have to make molar solutions. You are provided with 10 grams of sodium chloride, sodium bromide and sodium iodide. And those were the responses. Remember that one Ayi. We on the second question eh. After teaching learners about concentration you give them an exercise to do for homework. In one question you ask learners the following question. You remember that one. They basically put 10 grams of each of those three different salts into 100ml of volumetric flask, dissolved it. And they said it's the same concentration because they dissolved the same mass.

Turn 166 A: Same mass, oh my word.

Turn 167 R: And then eh, ya.

Turn 168 A: Meaning, they didn't grasp the mole concept. Mmm.

Turn 169 N: Mmm.

Turn 170 A: Because that's the thing we can use to compare those. Moles, not mass.

Turn 171 N: Moles, not mass.

Turn 172 A: Moles, not mass, yes.

Turn 173 N: Very true.

Turn 174 R: So, how do you convince them that.

Turn 175 A: Ya, it takes them back again to where we started. Remember the question was asked is where do we really start when it comes to stoichiometry. You asked three things that are really basic. So, it takes us back to that mole concept. For those learners that have mastered what really is the mole, and how do we calculate the mole and why is it important in stoichiometry. If they really remember that it is there for, it gives us comparison in reactions. We get to get the volume, to get lets say the masses that were used or the produce using the mole alone. Therefore, if for those learners that have grasped that, it will be much , it will be easier for them to really go through that question without any problems. But for those that really did not from the beginning will still come back and compare the masses.

Turn 176 R: The thing is, with the sugar, with the sugar, you put 1 teaspoon or 2 teaspoon, because the molar mass is the same an increase in mass is going to increase the concentration, right!

Turn 177 A: Same substance

Turn 178 R: Same substance right, the molar mass is the same.

Turn 179 A: Yes

Turn 180 R: Ya

Turn 181 A: And dissolved in a similar substance.

Turn 182 R: Ya, in a similar substance.

Turn 183 A: We can.

Turn 184 R: You can take the masses, ya, ok?

Turn 185 A: As they are.

Turn 186 R: Because same molar mass there.

Turn 187 N: Another, sorry

Turn 188 R: Yes Nasi

Turn 189 N: Yes, just to add to that, you can also ask them ok, what's concentration? What are the units of concentration? They will tell you its mole per dm^3. Alright, so who's moles are more per dm^3 for those substances. So work out your number of moles in these masses. Let's see who's moles is highest. Then it means the substance whose moles is highest should have the highest concentration. So you can ask them that, so that they can understand and appreciate why the concentrations are not the same even though the masses of the substances dissolved are the same in the same volume of water, or of solvent. So it can also help them to understand , to say ok concentration is measured in moles of a substance per dm^3. With these 3 substances whose mass is 10 grams each, lets get the moles of each one of them and then we compare which will have the highest concentration based on what, on the moles we should get. I think it can also help to make them understand.

Turn 190 A: Ok, sorry to intervene. How many minutes are we remaining with?

Turn 192 R: The meeting is normally gives 40 minutes.

Turn 193 N: Laughs

Turn 194 A: Yes. What time did we start?

Turn 195 R: Start at 8. I don't know maybe Zoom is being good to us.

Turn 196 A: Ya, it's now 1 hour 2 minutes, if you started at 8.

Turn 197 N: (laughs)

Turn 198 R: (laughs). Thank you. Thank you so much. We'll bring it to a close now.

Turn 199 A: Ok.

Turn 200 R: We need to have a few more meetings. Will that be ok?

Turn 201 A: Yes

Turn 202 N: Ok

Turn 203 A: It's ok. So that we don't waste time with other things, go on and be given us documents we will be just following to guide us through. Us teachers we tend to be taken away by other concepts. You see we've been talking about Maths now.

Turn 204 R: Ya, sometimes, the things you are saying and its being captured, its being captured right! Everything that you say is so important and is so valuable, eh, in this research. So, it's what you, it's your inputs. Eh, I want to think of before the next meeting, think about the kind of. How do I say this? How you transform knowledge right. The kinds of ways that you use to transform the content knowledge into knowledge that's understandable to children, in stoichiometry, right. The kinds of representations that you are using, ok. How you take into account, eh, the learners prior knowledge, right. Eh, your strategy in teaching. Your conceptual teaching strategy.

Turn 205 A: Ok

Turn 206 R: What kinds of strategies are you using? Alright, and how you sequence, you know, your concepts. Eh, so I think, ya, so how you transforming that knowledge, eh, more detail on that.

Turn 207 A: Ok. Do a summary for us so that we don't forget all that.

Turn 208 N: (laughs)

Turn 209 R: I'll send you a whats app or email. The thing is, what makes it so difficult is that umm, we try to get data like what will be happening in a classroom. What will you actually do if you have learners in front of you, you know.

Turn 210 A: Ok, ok.

Turn 211 R: And how would you transform the knowledge, you know, like directly what would you do. What would you tell the learner? What kind of questions they'll ask you and how you would respond to those kinds of questions, you know? What do they find difficult to understand and how do you deal with it? Now, this is something you are doing on a daily basis. You are confronting this everyday. If somebody is asking you something, it's there, you know, and you deal with it in a certain way.

Turn 212 A: Ok.

Turn 213 N: Ok

Turn 214 R: I hope I get some kind of. Am I getting somewhere with that.

Turn 215 A: Ya

Turn 216 N: I think if its possible, one of your, the meetings, if you could have a live one where we can meet maybe in a classroom, and then discuss more and maybe write things on the board. Things like that, if it is going to be possible.

Turn 217 R: Oh ya, ya, ok. I understand what you are saying, like you know you have a, when you can write. But each one of us needs to, isn't it?

Turn 218 A: No, we are saying, I think he is saying we can meet practically .

Turn 219 N: So we can meet in your classroom. Isn't you are teaching learners in your classroom? You no longer using Zoom to teach. We can also do the same.

Turn 220 R: You mean where we have learners there.

Turn 221 N: No, no, no, us as teachers, isn't that we are sharing information on how to teach certain concepts.

Turn 222 R: Yes

Turn 223 A: We don't need learners. We need desks.

Turn 224 N: We need desk, we need a board, we need something to write on and then to demonstrate something.

Turn 225 R: We meet together at one venue?

Turn 226 A: Ya, one venue.

Turn 227 R: Ya, that's such a great idea. It makes the work so much more easier. Ya, ya, I'm actually in for that.

Turn 228 N: We can meet at your school and whatever, and then have a meeting like this, not on Zoom but physically.

Turn 229 R: Can we arrange for that? When?

Turn 230 A: Ya, we can.

Turn 231 N: You tell us when. Remember we are going for marking very soon eh.

Turn 232 R: Ya, ok, so sometime this week.

Turn 233 A: This week, I'm too tight.

Turn 234 R: Tight this week. Ok, let this week go. Sometime next week?

Turn 235 N: Ya, lets find out when we are a little bit free and.

Turn 236 R: Ok, fine

Turn 237 N: Then we can always make a plan.

Turn 238 R: That’s fantastic. That’s awesome really. That’s awesome. That will be great.

Turn 239 N: Ok, ya.

Turn 240 R: Fantastic.

Turn 241 A: Alright, gentlemen, we’ll talk more. Thank you.

Turn 242 R: Thank you guys.

Turn 243 N: Thanks so much Ayi. Good night.

Turn 244 A: Good night to you. Thanks doc. I’m learning a lot from you there.

Turn 245 N: We are learning a lot from each other.

Turn 246 A: Ya, good eh.

Turn 247 N: Thanks.

Turn 248 A: Good night N. Good night.

Turn 249 N: Sharp. Sharp. Ok.

MEETING 2

Discussion of 2020 chemistry question stoichiometry, question 7 titration.

Turn 1 N: How are you Ayi?

Turn 2 A: I'm fine

Turn 3 N: How is the family?

Turn 4 A: Ya, they are fine. How is yours?

Turn 5 N: Ya, they are ok, thank you.

Turn 6 A: Ya, better

Turn 7 N: Ok

Turn 8 R: They very busy on my side. Yoh. I got two small boys. They running all over the place.

Turn 9 N: Ok (laughs). Just lock them outside.

Turn 10 R: (laughs). I did that.

Turn 11 N: Ok. No, its fine.

Turn 12 R: Ok, we get started right. So.

Turn 13 A: Yes

Turn 14 R: I thank you very much gentlemen. So, I looked at the last meeting right. Some points I can draw from there right. A few points. Now, there are different points of views right. One different point of view that comes across is that eh you know, Ayi put across that maths is a challenge in stoichiometry. That was a strong point coming from Ayi. Doc, you were saying that Maths is actually not that much of a problem. That was one different perspective I could pick up. Now the same points of views. The same points of views will be like, you know, both Ayi and Doc consider mole to be the central concept and both consider also past year papers as being good to work with while working with the topic, right. There were different pathways to define the mole. Like, I know Doc, Doc you prefer to stick to Avogadro's number in talking about the mole as other ways can be confusing to learners right and I here Ayi saying that he varies his definitions according to the learners that he teaches. Varies according to the way they are from year to year. So he is open to more than one kind of definition but of course he did mention that if it's a real average class he tends to choose which definition to use. And well some similar pathways in terms of talking about concentration, the same kind of thing that both Ayi and Doc did was to talk about concentration in terms of the analogy of tea being sweet right. So that you know, coming from both sides. Nasimu, when you introduced your discussion you defined stoichiometry and eh you defined stoichiometry as the relationship between reactants and products in a chemical reaction and I see Ayi also spoke about the similar thing. The same thing actually. The way he mentions you know eh, the mole ratio in a balanced chemical reaction, stoichiometry involves that, the mole ratio is a balanced chemical reaction and how this relates to what's happening in a chemical reaction chamber. So these things are coming off right. And one of the things, Nasimu you said that the use of models is ok, is good and Ayi said its ok but you can doing more in the earlier years like in grade 9 because children can tend to get bored with that. So there are, I looked at, and see there are ya there are different, I think the major kind of different point of view is the issue of maths, you know, Ayi felt strongly, ya maths is a problem and Doc didn't feel so much that maths is a problem. So it's something we can work at and look at these different points of views and similarities and see how we can take it from there. Now, today's task is basically to use the questions from last year's paper as a point of departure in terms of an activity to discuss. I think let's start with question 7. We'll start with question 7, have a discussion on it, look at how we going to break this question down especially for the learners, that's the idea. I'm going to put the question on screen, question 7. There's a 7.1 and there's a 7.2. The 7.2 involves a lot of stoichiometry here right and its not a sub question of 7.1. right. It is a sub question kind of, it talks about ethanoic acid but it can be worked out without looking at 7.1. right

Turn 15 N: ya

Turn 16: R: You agree

Turn 17: N That's true. Ya

Turn 18: R We can focus our attention on 7.2 then due to time constraints.

Turn 19: N Ok

Turn 20 R: So Ya eh, how do we go about breaking this down for the learners or breaking it down for each other, to kind of make sense to all of us here. So, who would like to go first?

Turn 21: A Ok, may you repeat your question.

Turn 22 R: My question is, we look at 7.2 right

Turn 23 A: Ok, 7.2

Turn 24 R: Let's have a discussion on this question

Turm 25 A: Ok

Turn 26 R: Amongst ourselves. Look at how we could find meaning in this question

Turn 27 A: Alright

Turn 28 R: What is the meaning in this question? So, would anybody like to go first?

Turn 29 A: Ok, I was trying to check what I wrote. Let me go back to the, to your main question.

Turn 30 R: Its 7.2

Turn 31 A: 7.2

Turn 32 R: Household vinegar contain…

Turn 33 A: Let me go through it. We have got household vinegar right contains 4,52 % of ethanoic acid right which is CH3COOH by volume and a sample eh 1,2 grams of impure sample of calcium carbonate CaCO3 is added to 25 cm3 household vinegar. On completion of the reaction the excess ethanoic acid in the household vinegar is neutraised by 14.5 cm3 of a sodium hydroxide of concentration 1mol.dm3. The balanced equation for the reaction is as follows. So the question says calculate the number of moles of the unreacted ethanoic acid right. You are saying how will someone eh begin it. That was your question. How will you attempt it? What was the question?

Turn 34 R : They ask you for the unreacted ethanoic acid right?

Turn 35 A : And then yourself you say it how would someone attempt it.

Turn 36 R: We going to discuss it ..

Turn 37 N : Approach. What will be your best approach?

Turn 38 R: It its unreacted

Turn 39 A: I think, if I look at the question it asks for unreacted what am I asked is the unreacted ethanoic acid right. That is what I'm asked. So now the thing is, I will ask myself what is the information that I am given right. You can see that the information says at the end there's a 14,5cm^3 of a sodium hydroxide solution of concentration 1mol.dm^{-3} that is the one that neutralises what is in excess. So now the thing is how will I approach this. I will ask myself in stoichiometry as we said the other day that number of moles is a good way. So, if I would know what is the number of moles of that sodium hydroxide that is neutralising what is in excess then I can then use that to calculate what I am really asked. That's how I will approach it.

Turn 40 N: Ya that's correct.

Turn 41 A: That's right, right.

Turn 42 N: That makes sense.

Turn 43 A: So what does this mean, since I'm given both volume and that concentration of sodium hydroxide, now you can see that it makes it easier for me now to calculate the number of moles. But for a learner now the point of emphasis now is to check your SI units right, are they in the values that we need. You can see that we have 14,5 dm cubed, cubic centimetres I mean, so we can't use it like that, can we?

Turn 44 N: No

Turn 45 A: We can't. We have to change it to dm cubed. Since our concentration is already in what, in mol per dm cubed. So that our ratios are makes sense. So we need to just change that 14,5. How do we do that? We divide by one thousand. Is it?

Turn 46 R: Ya. We do

Turn 47 N: Yes

Turn 48 A: So we divide that, it will give us how many 0,0145 dm cubed. So then we go to that formulae C=n/V.

Turn 49 R : Correct. I think we got the picture of that one right. You get the number of moles right.

Turn 50 A: Thank you.

Turn 51 R: The thing is how is the learner doing this thing right. Calculate the number of moles of the unreacted ethanoic acid and Ayi used the word excess, what's in excess, ethanoic acid is in excess right.

Turn 52 A: Yes

Turn 53 N: Yes

Turn 54 R: Excess from another reaction.

Turn 55 A: Yes

Turn 56 R: So the ethanoic acid is in excess from that reaction with calcium carbonate.

Turn 57 N: Yes ; A: Yes (simultaneous response)

Turn 58 R: And that is the excess unreacted ethanoic acid that they are talking about. Now is the learner able to make that link.

pause

Turn 59 A: How will the learner make the link between those two right?

Turn 60 R: Is the learner able to make the link? That, that is the unreacted ethanoic acid they are talking about.

Turn 61 A: Not always. Some wouldn't. Some won't.

Turn 62 N: You see with long questions like this some learners by the time they get to the end of the question they forgotten what the question was talking about in the earlier stages there. Most learners don't want to continue to refer to the question. They supposed to be referring to the question regularly so that they don't miss anything. In some cases some learners don't do that. From what Ayi has just said once they now know the number of moles of sodium hydroxide which reacted or which neutalised the excess ethanoic acid they can now use the ratio of the known which is sodium hydroxide to the unknown which is the excess ethanoic acid, which is 1: 1.

Turn 63 A: Ok Thank you Doc. Thank you.

Turn 64 N: But the challenge is that most learners don't want to continuously refer to the question.

Turn 65 A: Yes

Turn 66 N: Because such long questions they will just give up without even attempting to answer the question.

Turn 67 R: They should look at…

Turn 68 A: and again, again on top of that, you can see that ratio is one is to one right.

Turn 69 N: Yes

Turn 70 A: Coincidently after calculating the number of moles of sodium hydroxide the answer won't change, one will be to one. The same number of moles you got will be the same number of moles of that. That will be a coincident. Some student if it wasn't like that they were going to forget that last step now of using the ratio then multiply by a factor or divide by a factor in that ratio. In this case you can see its one is to one. Coincidently the answer wont change do they might get the three marks pertaining to the memo maybe. Without comparing back now to the ethanoic side acid you have got your number of moles of sodium hydroxide but the learner who could have now forgotten to use the ratio to now have the number of moles of ethanoic acid might still get the same number of moles because of the ratio is the same which is just a coincident in that matter.

Turn 71 R: So you could have, in other words what you saying Ayi is, we could have situations were learners just put numbers in the formulaes without understand meaning behind the question.

Turn 72: A Yes, listen, a learner, a level two learner is taught that you go take the correct formulae put there you will get you one mark right. Lets say the learner did not understand that question but the learner sees that oh I'm calculating the number of moles. I have got volume. I have got concentration. Now I change by volume units, then calculate the number of moles. You can see that without using the ratio, the answer is going to be correct, which is a coincident why, because the ratio is one is to one. So, I'm saying that yes the learners can just use those formulas get to the answer without understanding what they were really doing.

Turn 73 R : Ya, without understanding what they were really doing. Without understanding the concept itself. And perhaps some learners could even refer to the equation in 7.2.2 and work with that one cause they looking at ethanoic acid there

Turn 74 A: You see

Turn 75 R: Unreacted ethanoic acid and identifying it as the excess from the first reaction, that was the key isn't it.

Turn 76 A: Yes, and the other thing if there the value, sometimes you see that there is a value for mass, higher chances you are going to see the formula n=m/M, something that just comes instinctively to them as they continuously calculate number of moles using mass and molar mass. So they can just go into that without understanding it then put it there.

Turn 77 R: Alright, now what are some of the ways, I mean we could, as Doc has even pointed out, listen this is a long paragraph right and there are no diagrams and pictures here. Now how could the learner make meaning of this entire question, because Doc has pointed out as well if you start reading by the time you come to the end you already gave up. So, how can, I mean how can we break this question down. How can a learner, if a learner is looking at this question, what could they do, you know, to help them to make meaning, to change the text with a diagram or what?

Turn 78 N: I think, they just, one way would be to try and highlight some key points as the read the question. They should highlight or just underline or highlight key things in the question like 4,52 % ethanoic acid by volume, underline 1,2 g impure sample added to 25 centi metre cubed of household vinegar, and the excess ethanoic acid there, the 14,5 centimetre cubed of concentration 1 mole per dm cubed sodium hydroxide. Those key words can help them to unpack the whole question as they attempt to answer it. I think those are some of the key things which learner have to do. And then they can now go step by step. Since they were given an equation there for the reaction between excess ethanoic acid and sodium hydroxide they can now do step by step. Three marks there for 7.2.1 would not be a challenging one because thay are given the volume, they are given the concentration, as Ayi has said they can just convert the centi metre cubed to dm cubed and then use the formulae C=n/V to find the number of moles and then use the ratio to get the unreacted ethanoic acid as required by the question. So those three marks I think will not be much of a challenge to most learners to get but I think the challenge will come in the next question there.

Turn 79 R: ok. One of the points that Ayi has raised is that 7.2.1, ya the learner could get it right but without understanding

Turn 80 N: …what's happening

Turn 81 R: …what's happening right.

Turn 82 N: That's true.

Turn 83 R: That could happen, were they follow a procedure of just using the formulae. So, I mean, in my head I'm thinking about now, I thought about it before too looking at this question. In my head if I'm working it out, in my head I see pictures of two reactions, isn't it.

Turn 84 A: Yes N: Yes (simultaneous response)

Turn 85 R: I see a picture of calcium carbonate and ethanoic acid. Ya the question is saying these things are reacting and then there's an excess there, extra there. That extra there is used to neutralise the base. I don't think the learners are seeing that you know. I mean for you and I we are seeing it. We are seeing it. We are seeing it because we are able to see it. The question is, are they able to see it. Are they able to see it. Are they able to see it? (laughs)

Turn 86 N: You are right there because you see we don't expose our learners to a lot of experiments.

Turn 87 A: We don't. We don't.

Turn 88 R: You are saying use experiments as a way.

Turn 89 N: I am saying as we teach our learners' we don't have time to do lots of experiments were they can do titrations like this kind of titration.

Turn 90 A: Yes

Turn 91 N: We normally do the straight forward ones. So for them to actually visualize it as you are visualizing it or we are visualizing it is very difficult.

Turn 92 A: Very difficult.

Turn 93 N: They haven't been exposed.

Turn 94 R: Aaha

Turn 95 N: That will be a challenge. They won't picture it the way you are, we are picturing it ourselves.

Turn 96 R: Aaha, Aaha

Turn 97 A: Because to them, because to them it doesn't come across as something really if they haven't seen it because a practical will just draw their interest. Now if you do that practical and if they try to measure things during that practical, then you put into calculations it draws their interest. That class becomes better just gets a better standing than the one that does it in theory. Then it comes back to that point, to that point that I said that sometimes yes if they see that there are numbers coming some are put off, but not all of them. I remember now I was doing organic chemistry. When I got into the section were it was just about IUPAC naming, there is this one kid, this one of my best kids though, asked that are they going to be stoichiometric calculations in this section.

Turn 98 N: (laughs)

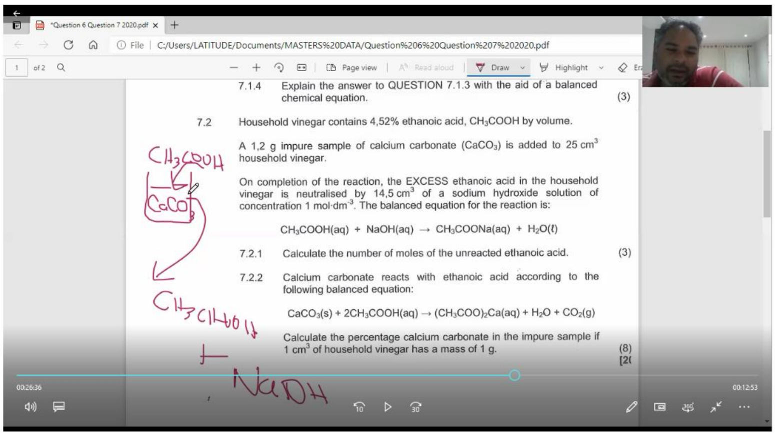
Turn 99 A: I said no, no, no, no. Don't worry about that. Its only structures and naming. The numbers you see will be about names and positions. Then he just became calmer. So sometimes maybe if they see that there are number coming you are right. Doc said that because it is a long thing and they know numbers are there sometimes they are lazy to do that.

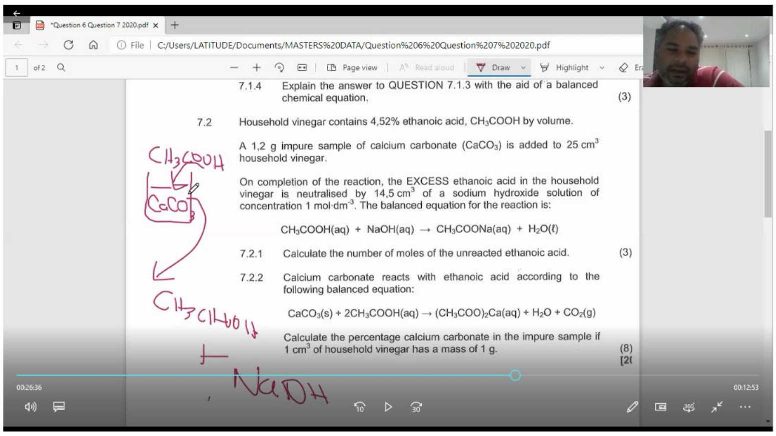
Turn 100 N: Very true

Turn 101 R: Ok. How about a diagram. A picture.

Turn 102 A: Ya, about that. I realise, I think there was a 2017 paper, about titration it has got a glass and utilization titration stuff, even myself after the exam was written when learners wanted to come and ask what we should have done there. According to myself that diagram for me was not putting across a very clear picture. It made the topic a little bit much longer as well. So some yes, some diagrams makes it clear but some adds misery as well again. Yes, they can be used, they are ok, but to a certain extent, not in all situations.

Turn 103: Ayi, what I mean is this. I mean how about a diagram in this particular question. I mean, I'm faced with a question. I'm trying to make meaning of it. Then I can say, there's a story here (draws), there is something here, I'll draw something and I'll say inside here some calcium carbonate, ay, so I'm breaking it up it a kind of way, then let me put some ethanoic acid. You kind of looking at things no more in text but you kind of replicating what you are doing as in the lab. These things are reacting here and they react completely here, but how about there's some extra of this now,





Turn 104 A: Ya, that makes it a little bit

Turn 105 R: this ethanoic acid that's extra from there you gonna now put it with, its like some kind of, I don't know, its like breaking it down a little bit and that is going to react with sodium hydroxide

Turn 106 A: Ya, but for a learner. A learner should be taught right to do that I believe. But we cannot break it in the exam for the learner like that. Because now it's a test, a learner should now be able to do it themselves.

Turn 107 R: No, Ayi, the point is this, not to set the exam question with pictures like this.

Turn 108 A: Ok

Turn 109 R: But what I'm saying for the learner to as you said it's a whole paragraph, you can get lost with it. And if I'm confronted with this paragraph, this is some of the things that I would do. This is some of the representations I would use to kind of break it down for it to make meaning. Will the learner, are learners doing that, you know or they just putting number into formulas. You know, is this going to be of value to them, where they kind of like as you said underline, underline some key words and draw some picture.

Turn 110 A: Ya, it will. But it's a skill you need now to teach them. Is it?

Turn 111 N: Ya, mm

Turn 112 A: In which those are the things teachers do in class, various methods. But sometimes if a learner does not really understand the question even the diagram the learner is doing they might also be wrong still, but they are very useful for a learner just like flow charts, they are useful for a learner but if a learner is just confused about the question they still will be wrong but they are advisable.

Turn 113 R: Honestly ,when I saw this question, when I first saw this question, I myself I got lost with the text and they way I worked this question out is by drawing the picture. It helped me come to an end. I couldn't see it very easily you know. But it helped me, when I put the picture in, it helped me make more meaning to me.

Turn 114 A: Ok. Even myself. You saw that firstly I worked up to 7.2.1 then I said I'll work the other one later. When I looked at it, it took me about 20 minutes to really now say, oh I'm supposed to. Even if you look there 7.22 at the end where its 1g, 1 cubic centi metre to 1 gram, that thing for a learner I think it was part of harsh or cruel at some point. In terms of time not standard. A learner wouldn't take normal time to understand that unless the learner is literate or the learner is very good.

Turn 115 R: Can we go to 7.2.2. Would you like to take us through Doc.

Turn 116 N: Ya, I just wanted to comment on your diagram there. Your diagram makes sense. It can be done by clever kids. Those who understand, they can actually come up with that diagram but I think as Ayi said we need to inculcate this in our learners as we revise so that they can also get used to coming up with such diagrams to help them simplify the question and then it will actually help them to actually answer the question if they do it like that, to break it down, like what you have done. That you got you ethanoic acid, your impure calcium carbonate, even to write the mass of impure underneath your calcium carbonate and then to say now whatever ethanoic acid is left in that reaction is then titrated with the sodium hydroxide of. Under sodium hydroxide you can even put the volume of sodium hydroxide, the concentration because that's what you know. So that they don't confuse themselves by thinking that that volume 14,5 and that concentration is for ethanoic acid. They will know exactly that ok, the 14,5 is for sodium hydroxide. The concentration is also for sodium hydroxide. So by putting those values under sodium hydroxide will also help them to say this information is about this. How can I use this? Why did they give me the concentration of sodium hydroxide? Why did they give me the volume of sodium hydroxide? To work out the number of moles. Once I know the number of moles of sodium hydroxide I can use the reacting ratio with ethanoic acid and get it as 1:1 and therefore I will be able to get the number of moles of excess ethanoic acid which was left in the previous reaction when the vinegar reacted with impure calcium carbonate. So it will actually help them. It's a good thing. We need to just try and do that with our learners if we have time when we are revising. It would be a good idea. But I know that not all teachers will be able to do that.

Turn 117 R : I was thinking also the experiment, doing an experiment when they are actually doing this type of thing. Mixing this. Taking the extra out. Trying to mix with something else. We have like 7 minutes left of this meeting. Could you log back in

Turn 118 N: Can I just quickly make a comment on 7.2.2. That information which was written at the end. The learners will see this information later. They will be puzzled by reading the first question and then the equation. It wont make sense to them.

Turn 119 A: That's what I also said.

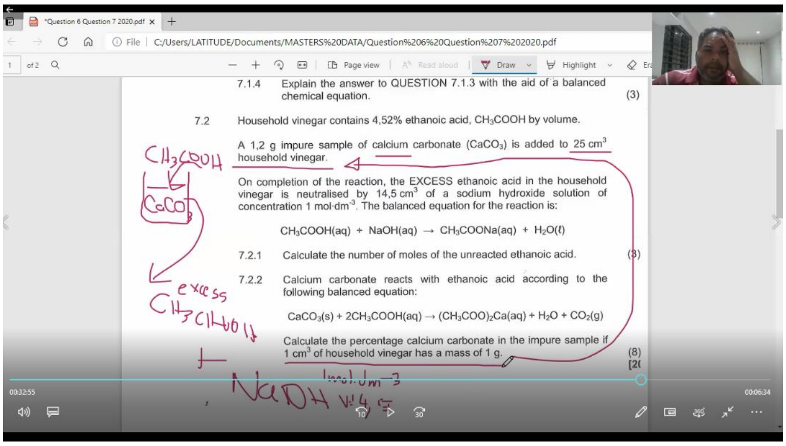
Turn 120 N: That information was supposed to be put together with the question there

Turn 121 A: Or little bit on top. That's why I said I also took 20 minutes to now compare the cubic cent metres and the grams there

Turn 122 N: Critical information in solving this

Turn 123 A: But its at the end

Turn 124 R: Household vinegar here. So you saying this thing could have been somewhere there. (draws arrow to show repositioning of the phrase as shown in the screenshot below)



Turn 125 A: Yes, and I think they were trying to make the question easier to just say you see that 25 cubic centimetres now it would by your 25 grams but now they put the information too below. Now it looks like the information that is not so important.

Turn 126 N: True

Turn 127 A: Thanks

Turn 128 R: Ya, Ayi you can take us through 7.2.2 or Doc. Either one, anyone.

Turn 129 N: Ok let me try this one, because Ayi did the other one. So, from that information in the last statement that one centi metre cubed of household vinegar has a mass of one gram which means you now go back to your volume of your vinegar to which your 1,2 grams of impure calcium carbonate was added and make it what, in grams, its now 25 grams. You go back again to say 4,52% of that is now going to be your ethanoic acid. You now say 4.45% of 25grams to get the mass of your ethanoic acid which was in the vinegar. Then you get your grams. Once you get your grams, you now divide. The grams were actually 1,0625 grams, alright. That was the mass of ethanoic acid present in the vinegar. Because in the vinegar there was ethanoic acid and other things which we don't know. So, that mass is 1,0625. Then we now divide it by the molar mass of your ethanoic acid to get how many moles were actually present in the vinegar. So you divide by 60, you get 0,0177 mol, those are your mole of vinegar which react initially. But now from your 7.2.1 you now know the number of moles which were left of your ethanoic acid. So the difference between what was left and what you started with your initial will now give us how many moles of ethanoic acid which actually reacted with your calcium carbonate which was present in the impure sample. So you now minus 0,0177 which you got after dividing your mass by your molar mass minus what was left which is your number of moles of sodium hydroxide which you got there which is 0,0145 which is also the same as the number of moles of excess ethanoic acid since the ratio was 1:1. You now minus 0,0177 minus 0,0145, then you get your moles of ethanoic acid which actually reacted with calcium carbonate which was present in the impure sample which you get 0.032 or in standard form is (inaudible)

Turn 130 A: May I stop you Doc sorry. You know I forgot to subtract the ones that were in excess already. The one that were not used.

Turn 131 N: Ok, you forgot to minus that one.

Turn 132 A: Ya to take out the ones that was in excess already, the ones that were not used. You will check that for me Sir Raven

Turn 133 R: Ya, I see that you did forget to subtract.

Turn 134 A: Ok. You checked that for me.

Turn 135 R: Sometimes we, make these errors, we just busy in the day..

Turn 136 A: Alright thanks Doc, continue. Now we go to the ratios right.

Turn 137 N: Now we go to the ratios to get your calcium carbonate. You now know the number of moles ethanoic acid which was actually used to react with your calcium carbonate is 2:1 which means half of that will give you the number of moles of calcium carbonate present in sample. So it will be half of 0,032 which is 0,016 or $1,6 \times 10^{-3}$ moles. Those are the moles of your calcium carbonate which were present. And then you now convert those moles into mass by multiplying by the molar mass which is 100. Then you get 0,16 grams. So it means 1,2 grams of the pure sample contained 0,16 grams of pure calcium carbonate

Turn 138 A: Now go to the formulae

Turn 139 N: Then you now express that as a percentage. You say the mass of the pure calcium carbonate over the mass of the impure sample times 100.

Turn 140 A: The sample itself by 100. Good.

Turn 141 N: 0,16 over 1,2 we get 13,33%. It was a challenging question. Most learners I don't think they were able to do that.

Turn 142 A: Sometimes there are those nasty marks. You can see that 13 %, it means it was really, really impure. Imagine if it was a precious stone.

Turn 143 N: Its not viable to mining such and such.

Turn 144R : There was a big range.

Turn 145 N: Too much impurities there.

Turn 146 R: We said 13% but it can go up to 18%. Because of the rounding off issue and because we were working with such small number and remember that Doc when we were marking we looked at a range of values.

Turn 147 N: There's always a range of values

Turn 148 R: In any event, the problem itself, you know, is a very simple problem. It's a very simple problem when we make meaning of it right. If we understand what is happening here, it can be very simple right. As you said if we drew this experiment in the school or if learners can use other kinds of representations it can make it easy for them to break it down.

Turn 149: Ya…

Turn 150: Often, I know..

Zoom ended meeting.

MEETING 3

Discussing practical (finding unknown mass of a substance)

Turn 1 R: Hi Ayi

Turn 2 A: Hey, how are you man.

Turn 3 R: I'm so good man. How are you?

Turn 4 A: I'm fine. I'm fine. What is this room you are in? I'm seeing like apparatus there.

Turn 5 R: You know, I have a story to tell you.

Turn 6 A: Oh

Turn 7 R: I have a nice story. Ayi, so, it was a time for me to do a lot of reflection after our last meeting and there's something, you raised something that's so important in the last meeting. I rather just look at that first. When we were looking at that problem and then Nasimu, Doc said that learners you know, the problem is that learners are not able to see what's going on.

Turn 8 A: Ya

Turn 9 R: They are not exposed and he says we don't have time to do a lot of experiments where they can do titrations of this kind.

Turn 10 A: Ya, we don't.

Turn 11R: We normally do the straight forward ones. So for them to actually visualize it like you are visualizing it or we are visualizing it is very difficult.

Turn 12A: Ya, its very difficult.

Turn 13 R: They haven't been exposed. Then, that was a AaHa moment for me.

Turn 14 A: Ok

Turn 15R: Because I was busy intellectualizing the problem and trying to work it out in my head. But and you threw the final blow when you said, because to them it doesn't come across as something really if they haven't seen it because a practical will just draw their interest.

Turn 16 A: Yes

Turn 17 R: Now if you that practical and if you try to measure things during that practical then you put into calculation, it draws their interest. That class becomes better, just gets a better standing than the one that does it in theory.

Turn 18A: It does.

Turn 19 R: And when you said that, you know, when we had this discussion and when you drew that, that was basically ahha moment for me.

Turn 20 A: Yes

Turn 21 R: The same night at about one in the morning, I had a thought, I said you know what, I got to do this thing practically

Turn 22A: Alright, alright, ok

Turn 23 R: ..practically for learners. So, then I started scrounging around for things.

Turn 24 A: Alright

Turn 25 R: Now the context is, you know, we don't have everything easily available.

Turn 26A: Yes

Turn 27 R: Right, so I started finding things. This is a mass metre right, to measure the mass. I found this piece of equipment last year. It was lying in one of the cupboards in the store room.

Turn 28 A: Alright

Turn 29 R: It's not working.

Turn 39 A: Its not (laughs)

Turn 40 R: It comes on. I brought it home. It does not have the top here

Turn 41 A: Ya, like a beam balance or spring balance. It doesn't have that part.

Turn 42 R: Ya, like the context of it all, in the school that I'm in, I'm there for, its my fifth year now. And when I got into the school, there were things lying all over the place in different areas.

Turn 43 A: Alright. Not used.

Turn 44 R: Ya. I started collected these things and just keeping them and now I'm scrounging around for them. And seeing how best, I can do thing with this kind of question. I don't know about the context on your side. How are things there in terms of context. In terms of what's available to you.

Turn 45 A: To be frank there. You find that if I were to do a practical of let's say momentum. I will have the trolleys but no track. I have got things, but there is always that other piece that's missing. You see, showing that someone at some point donated everything then through its usage things were lost, then after they were lost, the changing of educators and stuff, now no one was really responsible to make the set complete you really need to buy a new set all of it all of it, not saying let me replace the one that's missing and stuff. To be frank there's actually those pieces missing. But what do I do, the question is what do I do with my learners. Usually, let's say its momentum, I now do what is alternative to practical. When I was at University, I did a lot of what is called alternative to practical. What you do is, you download a video that shows all the apparatus so the learners name all the apparatus. Then the learners, they state all the functions of an apparatus. Then I download a video that really demonstrates how things are done. Now after lets say for example I'm still on momentum or even verifying Newtons Laws, then that video will now show the results that I can use. Now when the results are done and there is graphing and analysis now what do I do? What I do is I have a session were my learners comment on what they have seen. Then what do I do? I now set what I call a post practical test. So, now it's the questions about that practical. Its about the apparatus, the usage, the set -up, the variables. Then now, I manipulate the results. I give them my new results. I now say use them whether its to graph, to make a table then now you conclude. That's how at the end I do it because I really physically I don't have all the things. But what I do have, I make them come, touch it and tell me what it is used for. That's the thing.

Turn 46 R: Nasimu. Hello Nasimu. Doc are you there? Doc?

Turn 47 N: Hello.

Turn 48 R: Doc are you engaging in the conversation?

Turn 49 N: Yes, I was hearing what you were saying. I'm sorry I came late. Two minutes late.

Turn 50 R: Not a problem Doc.

Turn 51 N: I've been hearing what you are saying.

Turn 52 R: We were talking about the context and you know missing pieces of equipment. I find myself in the same boat. How are things with you in terms of context for experiments? Do you have the resources?

Turn 53 N: I think at the moment I don't have any complaints. For the experiments we supposed to do for SBA (school based assessment), I have got all the necessary equipment.

Turn 54 A: Ok

Turn 55 N: The trolleys, I do have.

Turn 56 R: For stoichiometry, the mass metre do you have, electronic mass metre?

Turn 57 N: The mass metre, actually I bought one on my own. We didn't have one at school. When I went to cash converters I got a digital mass metre going for R450. I bought that. That's what I'm using at school.

Turn 58 R: So, its something of your own initiative. You had to take initiative to buy that.

Turn 59 N: To buy yes. But it belongs to me, when I leave the school I go with it because its mine.

Turn 60 A: Good idea.

Turn 61 R: I have a great admiration for that. You going the extra, extra mile. And the thing is Doc, these are challenges, these are definite challenges. For example without an electronic mass metre, its very difficult to make a standard solution.

Turn 62 N: Yes, you can't. You can't measure. You are right.

Turn 63 A: But now the thing is when it comes to my part I don't know how I will do it this year. So the thing is last year, last of last year and the other years, what I will do is after chasing those dates so that I submit the task by doing an alternative to practical, I will then set a date with Sci-Bono. Usually I'm in the inner- city school so Sci-Bono is close by. Then I book a date, then they do all that practical at Sci-Bono. But now this year because of COVID and stuff, I really don't know what's going to happen. The learners are going to pass lets say without doing the real experiment which will be something else.

Turn 64 N: Ya, ya, ya.

Turn 65 R: Gentlemen, I want to take you through to what I've been working on since our last meeting. So, I designed a practical. This is what I've come up with. Let me share the screen. So, I said ok, let me do something that's similar to that question that we worked out right.

Turn 66: N, A: Ok (simultaneous response)

Turn 67 R: I said finding an unknown mass of a substance. Now the thing is, I couldn't mass the 1,2 grams because I don't have a working electronic mass meter right. So I said, let it be an unknown mass of calcium carbonate and lets react that completely with the vinegar, the ethanoic acid in vinegar. And the vinegar contains 5% ethanoic acid and the density of vinegar which I got from the internet is 1.01 gram per centi meter cube. Then I said the excess ethanoic acid is neutralised by a certain volume of sodium hydroxide solution of concentration, now I'm going to change this, I couldn't make a standard solution right. But I found a bit of sodium hydroxide in my lab but it had a concentration of 0,1 mol per dm cubed, so that's what I'll change now. And I said ok, calculate the unknown mass of calcium carbonate. So I looked at the internet and I see the density of calcium carbonate is 2,711 grams per cm cubed right.

Turn 68 A, N: Ya (simultaneously)

Turn 69 R: So I said ok, I don't have a mass metre so let me just work out in terms of how many cm cubed that will be right. So 1 ml will contain 2,711 grams right. So I thought if I measure out 1ml, then that's the mass. I won't tell the learners the mass but I'll know the mass.

Turn 70 N: Sorry, I have a problem with that. Calcium carbonate is insoluble in water. How do you make a solution of calcium carbonate when it doesn't dissolve in water? I wanted to ask you that.

Turn 71 R: You see what I did was, when they said its going to occupy that volume in solid.

Turn 72 N: Ok

Turn 73 R: In solid right, I put it as a solid form.

Turn 74 N: One ml is a solid form. Its not a solution.

Turn 75 R: Its not a solution

Turn 76 N: Alright

Turn 77 A: That's how volume was discovered. The eureka moment.

Turn 78 N: (laughs)

Turn 79 A: Like, displacement of water just gives you the volume of a solid.

Turn 80 N: Ya, true.

Turn 81 N: It's an interesting concept. Ok, continue guys.

Turn 81 R: I tried it, but I don't know if its going to be the right thing but we can debate it right. But what I said that 2,117 grams will be too much because we want excess ethanoic acid so I'm changing this one and I'm making 0,81 grams so that will be 0,3 ml. So let me just stop the share and show you what I've done. I took a measuring cylinder right

Turn 82 A: Ok

Turn 83 R : Now this is the calcium carbonate

Turn 84 R: Its 0 comma

Turn 85 A: Three

Turn 86 R: Its 0,3 ml

Turn 87 N: Ok

Turn 88 R: Now I know the mass. I'm guessing the mass here is 0,81 grams right, from the density.

Turn 89 N: Based on the density, ya.

Turn 90 R: Children won't, we don't know. We gonna work out this unknown, its an unknown mass now right and lets see if we get close to that mass.

Turn 91 N: Ok.

Turn 92 R: So, now I took some vinegar. There's the vinegar here right. Now when I look at the vinegar and if you look at the vinegar it actually says 5% strength acidity. It says that, it actually is 5%. So that 4,54 % is actually what it is 5%.

Turn 93 N: Ok

Turn 94 R: And the vinegar says it got some other stuff like sulphites in it as well.

Turn 95 A R: Mmm (simultaneous response)

Turn 96 R: So what I'm going to do, I'm going to take some vinegar, I'm trying this for the first time. I haven't tried this before.

Turn 97 N: Ok.

Turn 98 R: And I'm going to put in 25ml of this vinegar. So over here I'm pouring 25 ml. Right I've got 25ml of vinegar.

Turn 99 N: Ok

Turn 100 R: Now the thing is, I need to put in the calcium carbonate here to get that reaction going right.

Turn 101 N: Ok

Turn 102 R: Let me just turn so you can see better. See better right

Turn 103 A, N: Ya, Yes (simultaneously)

Turn 104 R: Is there too much of light?

Turn 105 N: Ya, looks like light is too much but its fine we can see what you are doing.

Turn 106 R: Now, I'm going to drop it in right. So, I drop it in right and there's the calcium carbonate and it frizzing up right.

Turn 107 A,N : Mmm, yes (simultaneous response)

Turn 108 R: Its frizzing up, the carbon dioxide is showing there. The reaction is taking place right. Now there's it. Now this is the one. Bubbled up quite nicely. There's still some calcium carbonate. I'm swirling it a bit. Try and get all to kind of to react. Ya, I don't see the solid anymore.

Turn 109 N: Ok.

Turn 110 R: Just the gas, some carbon dioxide in there. Now, the challenge is this now. What did we say? We need to now put in sodium hydroxide here isn't it. Titrate it. Am I right?

Turn 111 A N: Ya (simultaneous response)

Turn 112 R: So what I'm going to do, before I titrate it, I need to use some phenolphthalein right.

Turn 113 N: Indicator, yes.

Turn 114 R: Phenolphthalein, because we using the

Turn 115 N: The strong base and the weak acid

Turn 116 R: The strong base and the weak acid. Let me put some phenolphthalein. Now I tested the phenolphthalein, earlier with a base and ya its working, its got this kind of colour right. I'm gonna put some phenolphthalein. How much shall I put? A drop is fine right.

Turn 117 N: Two or three drops

Turn 118 R: Two or three should be fine. Ok, let's put two or three. So, phenolphthalein is in. It's still clear. Phenolphthalein in an acid is clear, right.

Turn 119 N: Ya, it remains colourless, ya.

Turn 120 R: Now the challenge is this, I don't have a, I don't have a burette.

Turn 121 N: Burette, yoh, are you sure.

Turn 122 R: (laughs). I don't have a burette.

Turn 123 N: (laughs). Ok.

Turn 124 R: So the only way out is to use a syringe.

Turn 125 N: Ok

Turn 126 R: I'm going to use a ordinary syringe, 10ml syringe, right.

Turn 127 N: Ok

Turn 128 R: Now, I hope I have enough sodium hydroxide because the sodium hydroxide I found it was 0,1 mol per dm cube. And you remember in the test paper they used 1 mol per dm cubed.

Turn 129 A N: Mmm, Ya that's True (simultaneous response)

Turn 130 R: And they got like 14 comma something cm cubed right utilised. I don't know if I have enough because all I have of that is I have about 40 cm cubed.

Turn 131 N: Ok

Turn 132 R: So let's try. And what I'm interested is to get the volume right, the volume of that.

Turn 133 N: If you are not sure, you can take 10ml of that, of 40. Hello.

Turn 134 R: Ya, I'm taking 10 ml now. I'm drawing right.

Turn 135 N: What's that, sodium hydroxide.

Turn 136 R: I'm drawing.

Turn 137 N: No, I was going to suggest that if you are not sure that your sodium hydroxide will be enough to neutralize the excess acid in your 40 ml. How many ml's do you have there, in the beaker there?

Turn 138 R: I have 40 ml's

Turn 139 N: In the beaker of your excess acid?

Turn 140 R: No, no, no. Excess acid, how much we have here? Its 25 ml's. There's 25 ml's volume. Remember

Turn 141 N: Ok ya, and you are not sure whether your sodium hydroxide will be enough to neutralize your acid there. You are not sure

Turn 142 R: But let's try

Turn 143 N: I was going to suggest that you take maybe 5ml's of the solution you are not sure of or 10 ml's. You keep the other ml's for in case. You can use it. Ok, I don't know. If you feel you can utilize it go on. Carry on.

Turn 144 R: Lets try. I got 10ml's here right. Its 10mls. What are we looking for? We looking for the end point isn't it. We looking for that point were there is a colour change.

Turn 145 N: To pink

Turn 146 R: With that one drop.

Turn 147 N: Ya

Turn 148 R: So, I'm gonna go gently. You do see a colour change already actually with the one drop.

Turn 149 N: Did you shake.

Turn 150 R: I'm shaking. But when I drop it its going.

Turn 151 N: You supposed to be shaking each time you are adding.

Turn 152 R: Each time I'm adding, I am shaking.

Turn 153 N: You don't have a conical flask.

Turn 154 R: Ah, a conical flask will be ideal, but I don't have one.

Turn 155 N: Ok

Turn 156 R: Actually, the conical flask will be ideal to swirl right.

Turn 157 N: Ye, so that it doesn't spill out.

Turn 158 R: I'm putting right. I'm putting. You see when it hits the liquid, there is a colour change.

Turn 159N: Ya

Turn 160R: But, its not enough to change the whole thing, right.

Turn 161 N : Ya. Its couldn't disturb… (inaudible)

Turn 162 R: We want it to change the whole thing.

Turn 163 A, N: Yes

Turn 164 R: So, I shouldn't worry about the slight colour change when the drop hits. I'm going. Nothings happening right. As I say, part of the equipment, like the burette is missing. So, you know, lets see. Right, all ten is in right. Let me draw the next 10. Ok. Now you can see more of the colour change.

Turn 165 N: Which means we are closer now.

Turn 166 R: And my hand is paining. (laughs). Because, I don't have a conical flask. I'm going slow right. Its still clear but as it hits the drop you see more purple diffuses right. Not purple, that pinkish diffuses through the whole thing. So, I'm close, I think. Are you able to see? Too much of light.

Turn 167A: Ya, light is a little bit too much.

Turn 166R: I'm just going to dim the lights in the room.

Turn 167A: Ya, now I can see the liquid.

Turn 168 R: Thank you for that Ayi.

Turn 169 A: Ok

Turn 170 R: You can see that. I don't know if you able to see the pinkish.

Turn 171 A: I can only see the drops. I don't see the pinkish. Ya a little bit.

Turn 172 R: The idea is to see the whole thing. (pause) I'm getting close. I have to draw my next right. So I'm on 20 now. So there's my next 10. The pink is there but its disappearing right. Right, now the pink is coming but disappearing right. The idea is for the whole to turn pink, isn't it?

Turn 173 A : Yes (laughs)

Turn 174 R: So, I may have a problem in that I may not have enough. But lets just see, I'm drawing the last bit right. I have, the last bit is actually, so I put 10, I put 20, now I got 24, 4 here, no 4,2 no 4 point What is this? 2,4,6,8. So just about 24 now. (pause). That conical flask would have worked right but I think I'm almost there. Clear still. Clear still. We have 10 minutes left. If it logs out, please log back in. Ok guys.

Turn 175A: Hello. Ok, I'm here.

Turn 176 R: This is what I'm getting at 24. There is that suspended, see that pinkishness there.

Turn 177 A: Yes, ya.

Turn 178 R: At 24 right. At 24, there's that pinkishness. Its staying but its not uniform completely

Turn 179 A: Right

Turn 180 R: You can see it there right.

Turn 181 A: Ya, I can see it.

Turn 182 R: Its suspended there.

Turn 183 A: It looks purple to me though.

Turn 184 R: It's a kind of purple. You right, it is purple. Its like suspended. The whole solution is not getting the consistent colour.

Turn 185 A: Ya, I can see that.

Turn 186 R: I would have expected the whole solution to have a consistent colour.

Turn 187 A: A change of colour.

Turn 188 R: But we are seeing that it is there at 24. So, I can say maybe that complete neutralization took place at 24. If I assume.

Turn 189 A: Ya, we can assume that.

Turn 190 R: Because the pink is not going away. Its there. It may just have worked. And If I use that volume 24, then I could work out the, the Ayi, I could work out the number of moles right.

Turn 191 A: Ya, you can.

Turn 192 R: So 24, I have to divide by a thousand.

Turn 193 A: Ya, to dm cubed. Yes.

Turn 194 R: 24 time 10^{-3} times 0,1 right.

Turn 195 A: Ya

Turn 196 R: Lets go. 24 exp where's the function here. Ayi please log back on if it cuts right. I'm just trying to get that exp button here. 24 times 10^{-3}

Turn 197 A: Ok

Turn 198 R: Multiplied by 0,1. I get 0,0024. 0,0024 right

Turn 199 A: Moles

Turn 200 R: And we said that's equivalent to the moles of acetic acid that was unreacted.

Turn 201 A: Yes

Turn 202 R: Right. So, that means if I go back to the vinegar, and remember we finding the total moles there right, in the vinegar. The vinegar is 5% right

Turn 201 A: of that volume

Turn 202 R: And that volume we said 25 isnt it.

Turn 203 A: 25 what by the way.

Turn 204 R: 25 ml's

Turn 206 A: So if we have density and we want mass of that it's times density right.

Turn 207 R: I'm taking 5%. Remember we said

Turn 210 A: Ya, 5% of that

Turn 211 R: Of that 25 right

Turn 212 A: Ya. That's what's ethanoic right.

Turn 213 R: Go back to the density. Because we said it's 1.01 grams per cm cubed. So its 25 times 1,05 sorry 1,01

Turn 214 N: Sorry guys. My data was finished.

Turn 215 A: Welcome back

Turn 216 N: Ok

Turn 217 R: The mass of vinegar is 25.25 grams. I used the density. That's the mass of vinegar using the value of the density of 1.01. Now I'm going to find 5% of that because the bottle said 5%. 5 divided by 100 times 25,25 and I'm getting 1,2625. It's 1.2625 grams right. Now I must divide that by 90, right.

Turn 218 N: Its 60

Turn 219 A: Molar mass is what?

Turn 220 R: 90

Turn 220 N: 60

Turn 221 A: Of ethanoic. Its ethanoic.

Turn 222 R: Oh, thank you, its 60.

Turn 223 N: Thank you Nasimu, it's 60

Turn 224 R: Its 60 right. Sorry, its 60. So I must divide that value by 60 right.

Turn 225 A, N: Yes (simultaneous response)

Turn 226 R: So its, 1,2625 divided by 60 and I'm getting 0,021 right. 0,021 ok. That's the total moles right.

Turn 227 A: Ok

Turn 228 R: I'll do the subtraction right.

Turn 229 A: Ya

Turn 230 R: So, 0,021 I must minus the, minus the 0,0024, ok the amount we titrated right.

Turn 231 A, R: Yes

Turn 232 R: I'm getting after subtraction 0,021 minus 0,0024 and I'm getting 0,0186, 0.0186 moles. So that's the moles that reacted with calcium carbonate right.

Turn 233 A, N: Ya (simultaneous response)

Turn 234 R: So, now we go back to the calcium carbonate equation. I must half it.

Turn 235 N: Yes

Turn 236 R: To get the number of moles of calcium carbonate.

Turn 237 A,N: Ya (simultaneous response)

Turn 238 R: So, I divide by 2 and I'm getting 0.00932, right.

Turn 239 N: Ok

Turn 240 R: moles of calcium carbonate. Now I multiply that by 100 isn't it?

Turn 241 N: Ya

Turn 242 R: To get the mass.

Turn 243 N: Yes

Turn 244 R: Remember the mass we working towards we said is 0,81 right.

Turn 245 N: Ya

Turn 246 R: That's what we worked out with the density. Lets see, my fingers are crossed, times 100 equals, you know what I get

Turn 247 N: 0.9

Turn 248 R: 0,93. I get 0,932 grams. Close. Close to 0,81.

Turn 249 A: Ya

Turn 250 N: Maybe the problem with the density maybe. Maybe its not 2,711 grams.

Turn 251 R: That's the internet value, but it could also be that the 1cm cubed wasn't read off properly. Not accurate as accurate can be.

Turn 252 N: There are many sources of error there. The way we were titrating is not the correct way. Of using a syringe.

Turn 253 A : (laughs). Buts it's the close, it's the close we could get without the burette.

Turn 254 N: That's true. It's a good result. Based on what, on how you were doing it. It's not a bad result. (laughs)

Turn 255 R: (Holds up beaker of titration showing suspended colour) When I was titrating right. When you put the drop, ya … (meeting ended. Participants has to log back in)

Turn 256 A: …of the indicator. But under normal circumstances we need to really see it turning pinkish.

(R holds the titration beaker up… the pink has disappeared)

Turn 257 R: So maybe it's a case of me not having complete neutralization.

Turn 258 A: Ya for this case. What about, where's Doc?

Turn 259 R: Doc, he is on his way.

Turn 260 A: Ok, lets reserve this question for him again and get what he says.

Turn 261 R: And I'm thinking maybe if I had more, a little, a little more of that 0,1 mole per dm cubed sodium hydroxide, it would have..

Turn 262 A: Ya, you will get complete neutralization

Turn 263 R: Complete neutralization, so that could also be a possible reason for the slight. We ran out of acid.

Turn 264 R: Now its clear.

Turn 265 A : Ya you see, so if its no longer there we haven't reached the point where we say it has been completely neutralised.

Turn 266 R : The volume should have been..

Turn 277 A: So that's why again there is a discrepancy between that theoretical answer and our practical answer.

Turn 278 R :Yes, yes, yes. Doc. Can you comment. Doc, sorry Doc.

Turn 279 N: I was disconnected again.

Turn 280 R: The question I posed to Ayi, right. When we where titrating, we stopped titrating because the acid got finished right.

Turn 281 N: I told you (laughs).

Turn 282 R: When it got finished, there was a blob. When I was titrating you could see the purple and the purple dissipates right. But when the acid just finished, there was a blob, it stayed for a long while.

Turn 283 N : Then trap it again.

Turn 284 R: Then now after a few minutes, now it's gone.

Turn 285 N: Ya, ya, you were almost there.

Turn 286 R: We haven't reached complete neutralisation right.

Turn 287 N: That's true yes.

Turn 288 R: So probably we need a few ml's more.

Turn 289 N: Ya, ya, probably. That's why I was suggesting you could have taken maybe 10ml's

Turn 290 A: Separately and deal with a smaller volume

Turn 291 N: Yes, and then you can use the ratio. You can say ok 5 mols reacted with 10 ml's then for 25 you can use simple proportion to work out the volume for 25. That was what I was thinking.

Turn 292 R : From here

Turn 293 N: You were going to take 10 out of 25 ml's. Then you neutralize those.

Turn 294 A: Separately, smaller volume to a smaller volume.

Turn 295 R: Ok

Turn 296N: And then we could have worked that and say if I got three moles to 10 what will I have in 25.

Turn 297 R: Oh, ya. I wasn't understanding you.

Turn 298 N: But its fine.

Turn 299 R: I wasn't listening. I wasn't understanding you. Ya, I should have done that. In retrospect, I should have done that.

Turn 300 N: But its ok. Lets deal with what we have now. So in this case our answer we getting as Ayi is saying is not as accurate as we didn't reach our end point.

Turn 301 A R: Ya (simultaneously)

Turn 302 N: So that will accommodate the difference between what we got and what we were supposed to get.

Turn 303 A: Yes

Turn 304 N: So that deviation between our final answer and our expected answer can be justified by that fact and also I don't know whether you powder was very fine. There calcium carbonate, were there no gaps between the particles when you put in in the measuring cylinder.

Turn 305 R: Yes, it was…

Turn 306 N: Was it fine powder or was it granules?

Turn 307 A: Was it granules?

Turn 308 N: Yes it depends..

Turn 309 R: It was fine powder but at certain points it was clumping. It wasn't consistently fine.

Turn 310 N: You see now. So there could have been gaps in between the particles. So your 1cm cube, your 1ml may not have been 1ml. Maybe it was 0,8.

Turn 311 R: Yes

Turn 312 N: So there are many sources of error there

Turn 313 R: Yes

Turn 314 N: In the way we conducted the experiment.

Turn 315 A: But now after the experiment, if learners get a comment session like that, it what aids them to understand now

Turn 316 N: That's very true. Ya, you are right.

Turn 317 A: What aids them to understand.

Turn 318 N: Ya, Ya, Ya, Ya

Turn 319 A: Because the time when I had really good, when I was a practicing teacher, you will be given all these so you would really do them, practically. So its after that comment session that you really now get to see what you were doing.

Turn 320 N: Ya true

Turn 321 A : inaudible

Turn 322 N: Go on, go on

Turn 321 A: Because some learners yes they can see observe, but after if they are asked to comment first lets say by what were the apparatus used and then what were their function. Which one do you think was the most important? Which one did we use to measure volume? Why will we…sometimes we will even draw an X under that beaker and now say to just see that blurriness saying now really the colour has changed here. I do not have, I cannot see that X. Now when you come to ask now why did we draw the X under that beaker? Why did we use this type of indicator instead of that one? Can we see we got all these types? Why are we choosing this one? That's now when they get to grasp the concept. But without that usually the better ones are the ones that usually master it without doing a practical but for the whole class for a whole number to understand the practical gives them that edge.

Turn 322 N: That's true.

Turn 323 R: One of the points that you are making is kind of resonating with me is that there's a whole lot of discussion that can take place after this practical. Even though we didn't have the burette, even though it didn't work as we expected but its an activity for discussion. As you say, the comment session, there is so much of things we can talk about.

Turn 324 A: In the comments. Ya.

Turn 325 R: And then that could aid with making meaning. So..

Turn 326 A: Especially you see that the investigation, usually got a hypothesis. I hypothesis before I start. Now when it comes to those conclusions now, I conclude with my results. Its like I'm coming back to that hypothesis that I have guessed, this is what really is going to happen. And the things about practicals as it makes you sharp it makes them sharp. By mere looking you can tell if a learner is not really, if you say 10ml's you can tell those slight discrepancies on measurement, by mere looking at you can tell no my child this is a little more than 10ml's try again. This is a little less than 10ml's. Now even if you can ask now what is going to be the effect at the end if you were to add 1ml more. Can you see its going to distort your conclusion? Because of the result. Ya, that's what the practical gives you. It gives the teacher and also gives the learner that thing.

Turn 327 R: Nasimu you were saying.

Turn 328 N: Hello, I was just agreeing with what you were saying Ayi, ya. I was agreeing with what you were saying.

Turn 329 R: You having more than one run. Try it again. Do it again and do it again.

Turn 330 N: Because, normally in a titration, you do it several times.

Turn 331 R: Ya

Turn 332 N: The first titration you carry out is just a rough one, you don't. It would give you an idea of how much volume you need to neutralize your acid.

Turn 333 A: Yes

Turn 334 N: And then when you are doing the second one you have a rough idea that ok it changed after adding about 25ml's. So when you are approaching maybe 20, you can adjust your burette so you can add drop by drop. But in your case, you were using a syringe, it was difficult to actually do that and you should also know that the beaker which you were using is not meant for titration.

Turn 335 R: Yes

Turn 336 N: And, even for measuring volumes, we don't use a beaker to measure accurate volumes. We normally use pipettes and volumetric flasks.

Turn 337 A: Yes

Turn 338 N: Those other apparatus which are precise and accurate in terms of measuring. You can actually discuss those which your learners as Ayi was saying. After conducting your experiment, you can actually have many questions. Why did we use this? Why did we choose to use this? You can actually hear their views and then maybe if there are any misconceptions you can be able to identify them and correct them.

Turn 339 R: And they could understand the value of a conical flask. This is why it's important? (laughs)

Turn 349 N: Why its important to use a conical flask?

Turn 350 A: And even powdered calcium carbonate.

Turn 351 R: I could understand the importance of the conical flask when my hand was paining. (laughs)

Turn 352 A: You see. Ya.

Turn 353 R: I couldn't get it to swirl properly.

Turn 354 A: And don't forget to take the dumb one to go clean the apparatus right. But you clean with him. Make him useful. Ya, you take the dumb one, you go and clean. He can participate. (laughs)

Turn 355 N: (laughs)

Turn 355 R: It is so important to me now, to realise this, that ya, the experiment is core. And, you know even if it goes wrong, we don't have all the apparatus but we making a plan…

Turn 356 A: Yes

Turn 357 R: .. and just get it done because what happens is, now if a child in the class has done that experiment and is confronted with the examination question, like this as Ayi as said it is something that really means something.

Turn 358 A: There is a man that I know is too good when it comes to practical, he was a friend of mine but now he is been running a school. He is called, Mr. Bee. You can try google him and try to follow what he does on face book and other platforms. He has got, I think he has got a platform. He calls it crazy Physics.

Turn 359 N: Bee, ya I know him.

Turn 360 A: Ya, you know Bee. (laughs) Bee, ya that man was my mentor at some point. I learnt a lot from him. His energy is just too much.

Turn 361 N: (laughs)

Turn 362 R: Its just too much. I used to allow him to jut have a session with my learners. He knows how to pick up learners, then you just take over. He would just walk with a cup in the class or anything. Lets say its momentum, he'll even bring two toy cars and then smash them and then he starts the lesson.

Turn 363 N: Ok (laughs). He was very creative.

Turn 364 A: Ya, very, very creative. You know him right.

Turn 365 N: I know him. We were marking together. Even, I'm sure Raven know him also. We were marking together last year.

Turn 366 A: Very creative man. I learnt a lot from him.

Turn 367 N: He is now selling books, isn't it.

Turn 368 A: If you just google creative physics. That's what he does. He writes books now. His just all over science. He has got private learners, private schools. That's what he does.

Turn 369 N: Ya, I know the guy.

Turn 370 R: I think the value, when we talk like this, not in our own schools, when we talk to each other, I think you know, we can help each other.

Turn 371 A: Like a lot.

Turn 372 R: In terms of resources. I know Ayi has got a mass metre, maybe if I want to mass something, I can go to Ayi.

Turn 373 A: Myself, myself.

Turn 374 R: Or even a burette

Turn 375 A: I don't have a mass metre. Yes, the other things I have. I will check tomorrow. I will check what I have or not now because my school is now online so I've been disposing a lot of things. So its Iny Academy, its now Iny Academy online school. That's what caused it to go online. Isn't it Moston College, you know Moston College.

Turn 376 N: Ya, ya, ya.

Turn 377 A: So Moston College, it is my employer, so we have got a high school there which is Iny Academy. So Iny Academy is gone online because Moston is also online, isn't.

Turn 378 N: Ok

Turn 379 A: So, whatever, those guys are really adamant. You can't really advise them. We now. It's a disaster, but since they are Jack in naught they are pulling everything. They have all the money.

Turn 380 R: Ayi, if you look at online, you can't really interact with this kinds of experiments. Online.

Turn 381 A: Ya, now that's the thing. That's the thing. Those people will just tell you the online is here at orange grove, will tell you that I build Moston from my backyard, so I'm building Iny the same way. So, any professional advise they don't take. Government has given them a lot of money, millions. Banks have given them a lot of money and clients. Then in two months time, they say ah we are starting this school. They have now got all the funding. They are just pushing it. Now, we are confused how we are doing SBA's (school based assessment). You see, I am not responding when they say moderating this and that. Why? Now they just changed. Now we are Sakai, we are no longer GDE. Now we are Sakai. (laughs). Just like that.

Turn 382 N: Just like that. Ok.

Turn 383 A: So its something man. Now I'm an online teacher. I log online, then I teach.

Turn 384 N: Its sad.

Turn 385 A: I've got few that comes. But the ones that comes we have changed the name of school Moston ABC. Just grade 12 only but online we have got grade 10 to 12 on the other side, but all Sakai.

Turn 386 N: Ok

Turn 387 A: The other grades we have transferred to other schools to say if you don't register online go to another school. Given transfer letters, go.

Turn 388 N: Yoh. Who is the owner, is it a local person? Who is the owner of that?

Turn 389 A: Its Ary, no the guys they are Jews.

Turn 390 N: Oh, they are Jews. Ok.

Turn 391 A: They have connections with Israel, so they have their holidays in Israel. So I'm not sure whether they are locals or from Israel.

Turn 392 R: Just one more, before we diverge.

Turn 393 A: Sorry man.

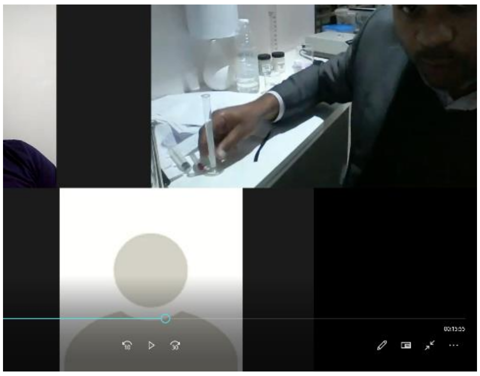
Turn 394 R: Back to the topic right.

Turn 395 A: Yes. Back to the topic.

Turn 396 R: Back to the topic at hand. What I did as well, you know we were talking about how to introduce mole right.

Turn 397 A: Ya.

Turn 398 R: I got to think, while I was working with this practical. Then I thought, ok, why don't I take the density values, right and put a mole into a measuring cylinder, right. This is a mole of magnesium oxide. (shows a mole of magnesium oxide). There's a mole of magnesium oxide.



Turn 399 A, N : Ok, alright (simultaneous response)

Turn 400 R: Its about 11 centi meter cubed right.

Turn 401 N: It's a mole of magnesium oxide?

Turn 402 R: Ya

Turn 403 N: Is it solid.

Turn 404 R: Its solid, ya.

Turn 405 N: Ok.

Turn 406 R: You can actually see. I hope you can see. So there's my mole of magnesium oxide.

Turn 407 N: I see the white powder, something, ya.

Turn 408 A: Its powder.

Turn 409 R: There's a mole of copper oxide. (places measuring cylinder containing copper oxide next to that containing magnesium oxide)

Turn 410 N: Ok, the black one.

Turn 411 R: And there's a mole of sulphur.

Turn 412 N: Ok

Turn 413 R: If I take the densities and I take a measuring cylinder and put water in. So I'll put 18 centi metre cubed of water

Turn 414 N: Mmm

Turn 415 R: Right, water is 1 gram per centi metre cubed right. If I put 18 centi metre cubed, here's a mole of water. So now learners are able (points to the different measuring cylinders) what is a mole of each substance.

Turn 416 N: Ok

Turn 417 R: And they able to feel it and hold it and its not necessarily equal quantities

Turn 418 N: Ya

Turn 418 R: …in terms of volume or in terms of mass.

Turn 419 A: Yes

Turn 420 R: But they have the same number of particles in them.

Turn 421 N: Ya

Turn 422 R: So those density, values that I found, I can take a number of substances from the lab and put one of each and just show them, you know.

Turn 423 N: Ok, ya. They are not the same.

Turn 424 R: Ya, its one mole.

Turn 425 N: Ok.

Turn 426 R: I find that, I haven't done it, listen, all these ideas I am getting is from you guys in our meetings and when we start talking about these things I start thinking about it, you know.

Turn 427 A: Alright

Turn 428 R: When you think about one thing, you think about another as well. Because, we were working with this practical and thinking how do I mass this thing and look at its density, I said why don't I do this as well to introduce the concept of mole. Its something that I will be doing going forward. I haven't done it like this before.

Turn 429 N: Ok.

Turn 430 R: But its something I'll be doing going forward.

Turn 431 A, N: Ok (simultaneous response)

Turn 432 R: Ya, thanks guys. We had very productive meetings. Thank you all for, you gave me lot of insight, you have contributed to my own development, you know in terms of thinking and to me its only when I talk to my colleagues, I start thinking about things in new ways

Turn 433 N: Ok

Turn 434 R: Not if I talk, if I talk to learners its different, ok

Turn 435 N: Ya it is.

Turn 436 R: But when you talk to your colleagues, you start to you know, probing and probing more.

Turn 437 N: Mmm

Turn 438 R: And..

Turn 439: A: Ya, but know the thing is it means that to maintain that, you should be putting something about 85% on your preparation and then 15% on your teaching. And yes, preparation, I think takes it all. Then lets hope as you proceed with your education you will be part of those who are curriculum developers. Because, I've realised that, our learning our teaching guide, our ATP schedules, (annual teaching plans), they are too theoretical. If we take the timeframe, the time factor, they really do not match. You want to do all this stuff and stuff but at the end of the day there's no time for it. But I believe, if people who are knowledgeable are curriculum developers, we will know. Some of the topics, for example we wouldn't need in physics then we take that time and use it for other important topics and so that we prepare well and we can dish all this stuff.

Turn 440 N: Ya..(inaudible)

Turn 441 A: Ya. There is one lecturer who when I was doing my project at University, he told me that you know what science doesn't need to be so boring. What you writing here is too boring. That's why I had to realise that (laughs). That why I had to realise that preparation now should take it. 85% preparation. Now when I go to class all my things are there, I just dish.

Turn 442 N: Ok

Turn 443 A: Thank you Mr Raven and Nasimu, thanks.

Turn 444 N: Ya, I agree with you Ayi there, that for science to be interesting the practical aspect must be there. You must do some experiments not just theorizing all the time. Because theory, theory, theory. Talking about abstract things which are difficult to actually visualize in the learners mind doesn't absorb them, they end up hating the subject. But if you are doing experiments then they are able to see what's happening, see the results, it becomes interesting.

Turn 445 A: And that creativity part.

Turn 446 N: But our curriculum does not give us time for that.

Turn 447 A: It doesn't, it doesn't

Turn 448 R: That's a question you raising, the curriculum is not giving enough time for that.

Turn 449 A: Ya, its not. It's theoretical rather than practical. That's what it is.

Turn 450 N: Mmm

Turn 451 R: The thing is, you know, us talking together as teachers does help.

Turn 452 N: Ya

Turn 453 R: I'm just looking at, we had about three meetings

Turn 454 A, N : Ya (respond simultaneously)

Turn 455 R: When teachers get together and share their ideas, it does help, especially when we are having challenges, I mean there are so many challenges. You may not have one piece of equipment, you may not have a ticker timer or you may not have the ramp or you may not have you know the burette, but there's new ideas, somebody can give you an idea, lets do it, why don't you try this, why don't you try that, you know, I never thought about this way.

Turn 456 A, N: Ya (simultaneous response)

Turn 457 N: That's true.

Turn 458 A: That's why politicians have teachers. If we want to we can take the country by using our kids.

Turn 459 N: (laughs)

Turn 460 A: They are ours, if we wanted to. That's why politicians wouldn't like us. They want us to be on a leach. The laws for an educator sometimes they are just too much. They just want you to be quiet there.

Turn 461 N: (laughs)

Turn 462 R: I mean, just to wrap up, we had four meetings right.

Turn 463 A, N: Ya (simultaneous response)

Turn 462 R : The first meeting was basically an introductory meeting and Irene was part of us at that meeting. And you know, Irene couldn't attend the second and she couldn't follow, we couldn't get the momentum going there. So, she you know, it happened that way so its just the three of us continued and what is your impressions of our meeting and how did you feel about it? Ayi and then

Turn 463 N: Ok

Turn 464 A: Myself is, besides that I'm learning a lot, we just want to reach the goal that yourself you want this project done, and you want to learn as much from it and you want to gather as much information as possible. As long as you are telling us that you are getting what you need in our discussions that's all I think we, I want to hear. It means a lot to be of help, to feel that you are part of something. I will be referring to this after some time in my life. I don't know when but I know I will come and be taking some info from this. Life has got its own way of doing these things.

Turn 465 N: Mmm

Turn 466 A : Ya

Turn 477 R: Doc, your impressions.

Turn 478 N: Ya, it has been very informative. We learn a lot from each other through these discussions. And sometimes, you change your approach of looking at things from what you were talking about from our discussion. You get new ideas which will actually help you in your teaching.

And, as Ayi has said, you are actually getting the right information for your project from these discussions the better, that's the idea. We are trying to be a part of your data source. (laughs)

Turn 479 A: That's why we are still here.

Turn 480 R: On a personal level, I wish to thank both of you for taking the time, effort and energy to be part of this project. It is a research project that I'm engaged with. Thank you for that. But more so, besides being a researcher in this project, I am also a teacher.

Turn 481 A, N: Yes (simultaneously)

Turn 482 R: The question is, how do the discussions influence our thinking, you know each others thinking.

Turn 483 A,N : Yes.

Turn 484 R: I can't be looking from the outside.

Turn 485 A,N : Ya

Turn 486 R: Because, I'm an insider. It's also influencing me a lot. And I have been influenced a lot by it.

Turn 487 A,N : Yes, Ok (simultaneous response)

Turn 488 R: From what you have been saying throughout the meetings, you know, it just triggers new ideas, new ways of looking at things and gives me more motivation as well going forward.

Turn 489 N: Ok.

Turn 490 R: But there are challenges. I must admit, there are a lot of challenges. Its not a easy task to teach. But from the discussions that we have, you know it gives one strength. And, I think going forward you know, not necessarily for the research project but we should be engaging, even when this project is done, we should continue our engagement.

Turn 491 A: Ya, we should.

Turn 492 N: Mmm

Turn 493 R: and discuss any aspect, any topic, you know that we can share our ideas.

Turn 494 A, N: Ya (simultaneous response)

Turn 495 R: We have formed this kind of bond and relationship and I think going forward we should maintain it.

Turn 496 N: Next time we meet, you do a titration, come and borrow the burette and the conical flask from me.

Turn 497 A: (laughs)

Turn 498 N: Don't use beakers and syringes (laughs)

Turn 499 A: Or, he hires you to come and do it for his learners. You'll be a hired guy. You tell the learners that you are will be having a guest educator here, they get excited, when you come wear a white coat. I like putting on a white coat when things become serious. Leave your number there, you can tell any one wants assistance, you can contact that educator. Then the kids get that interest there. (laughs)

Turn 500 N: It’s a marketing strategy.

Turn 501 A: Ya, seriously, seriously.

Turn 502 R: No, seriously, Ayi is raising an important point. This level of collegiality that we should be reaching that you know what if Doc is confident with a certain topic and Ayi with a topic, can we not share. Doc why don’t you come have a talk with my kids, Ayi can come and have a talk with your kids.

Turn 503 N: No problem.

Turn 504 A: That’s what I was doing with Mr. Bee. I will call him and say Mr Bee, equilibrium is starting here, if you are around just pop by 15 minutes, it’ll be fine. When he comes, he is on fire then goes. Weekends, sometimes says I’m available, I’ll pass by. He passes by, talks to my kids, teaches them something, moderates my papers, signs them, gone. That’s what he used to do.

Turn 505 N: Ya, we have to do that.

Turn 506 A: Ya, we have to.

Turn 507 R: Ya, we have to work at that kind of level were you know we have this kind of collegiality and we have this kind of trust amongst each other you know. That we could share our ideas freely.

Turn 508 N: Yes.

Turn 509 R: You know, we can grow immensely.

Turn 510 A: Ya, we can.

Turn 511 R: There are things I can learn from you that’s you know, that you have this kind of knowledge, but I can only learn if I’m interacting. You know.

Turn 512 N: Ya. True.

Turn 513 A: Ya

Turn 514 R: If I’m interacting.

Turn 515 A: And it gives value on what you are doing. Usually when you are alone there and you are in this department and other teachers are serious doing their stuff sometimes teaching becomes a bore, becomes a bore. Seriously.

Turn 516 R: Its, like we are all like minded. We share a common interest, right, which is teaching science.

Turn 517 A: Ya, it gives value.

Turn 518 R: In the school situation, like with me, you only interact with the learners right. The learners just look for the right answers and they look for the right marks.

Turn 519 A, N: Ok. Yes (respond simultaneously)

Turn 520 R: You want to change that kind of thinking. Then when we talk as a group like this we adding value to what

Turn 521 A: To what you are doing.

Turn 522 N: Ya, true.

Turn 523 A: And that confirmation is very important. Sometimes I work out some stuff and then I say oh my God, usually, I am a trained Physics person then I ‘ve been given Maths, then I do Chemistry now. So now, I look around and see who is really going to confirm what I’ve done in Chemistry. I look around and find none.

Turn 524 N: No one. You are alone. (laughs)

Turn 525 A: Ya, you see. Or you look around and you find I’m the only senior here. Then its something else. But to have some people whom you can say now, I’m forwarding this paper to you, check it up, moderate for me. Let me give my kids a correct document.

Turn 526 N: That’s true

Turn 527 A: Ya, that’s priceless. That’s priceless.

Turn 528 R: The thing is, that’s part of the admin, the moderation, exam setting and all that is going on. What interests me but is the actual teaching, what’s happening in the class, what you doing in the class, lets share our ideas, Doc if you doing this experiment, Raven come and have a look at what I am doing. Come check what I am doing.

Turn 529 A: Yes.

Turn 530 R: Ayi, say’s I got something, Doc can you come and have a look at this. Come and visit me. Lets see what I am doing. You know.

Turn 531 A, N : Ya, Ok (simultaneously respond)

Turn 532 R: Guys, I’ve got an idea. Come and visit me. Lets spend some time. Lets see how we can troubleshoot this problem. Its like working as a team. But yet we not from the same school.

Turn 533 A: You are right

Turn 534 R: We don’t have the same departments but we working as a team of professionals.

Turn 535 N: Ya, true. They call it what, community of practice.

Turn 536 R: Yes

Turn 537 A: Ok, ok, Mr Raven. Close us up. We have talked enough.

Turn 538 N: Ya, too much.

Turn 539 A: Its too much (laughs). Just update us.

Turn 540 N: Thanks Ayi. Take care.

Turn 541 A: Good night gents.

Turn 542 R: Good night Doc.

Turn 543 N: Thank you Raven. Good night.

Appendix 3

ETHICAL CONSIDERATIONS

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Rangasamy

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H20/06/37**
PROJECT TITLE	Exploring professional support group teachers' knowledge for teaching stoichiometry
INVESTIGATOR(S)	Mr R Rangasamy
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	19 June 2020
DECISION OF THE COMMITTEE	Approved Risk level: Low
EXPIRY DATE	29 July 2023
DATE 30 July 2020	**CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Dr M Mosabala