CHAPTER 1

INTRODUCTION

1. 1. Introduction

This self-study sought to investigate and develop my content knowledge and pedagogical content knowledge for the teaching of meiosis. Content knowledge is an important prerequisite for the development of Pedagogical Content Knowledge (PCK). According to Hasweh (1987), teachers with common content knowledge may carry their misconceptions over to learners, while knowledgeable teachers use their prior knowledge and exclude the superfluous concepts from the lesson. Common content knowledge was described by Ball et al. (2008) as knowledge which is not specific to teaching; - non teachers are likely to have that knowledge and use it. According to Bishop & Denley (2007), teachers with good content knowledge alone serve no purpose if they cannot deliver effectively. The acquisition of content knowledge and pedagogy required to teach a particular topic results in what Shulman (1986, p9) described as "the most powerful analogies, illustrations, examples, explanations and demonstrations ..." However the ability to transform content knowledge requires more than knowledge of the topic and syntax of the discipline; it requires knowledge of learners and learning, of curriculum and context, of aims and objectives, of pedagogy (Grossman, Wilson & Shulman, 1989) in Segall (2004) . According to Gess Newsome & Carlson (2013) PCK can be defined in knowledge and in practice. PCK knowing is attributed to reflection on action whilst PCK practice is associated to reflection in action (Nilsson 2008b) in Nilsson (2008). The former PCK knowing is concerned with reasoning and planning underlying the teaching of a particular topic whist PCK practice deals with the actual teaching. This self-study was concerned with PCK knowing which is attributed to reflection on action because there was no actual teaching which was done. Observations regarding development of PCK in this study were gathered around situations which did not involve actual teaching. Rather the information was obtained from reflection on action, i.e. on how the knowledge can be applied to teaching a particular topic.

To investigate and develop my content knowledge and pedagogy for teaching meiosis, I used concept maps and Content Representations (CoRes). Concept maps can contribute to one's success in learning new concepts and foster a long term change in thinking argues Asan (2007). Concept maps are therefore able to bring into sharp focus aspects like concept attainment, misunderstandings and difficulties. In concept maps, propositions help to show

how two concepts are linked. Where a proposition is valid in a concept map, it is considered to be the basic unit of knowledge (Novak & Gown, 1984). The validity of a proposition is therefore used as a measure of development of content knowledge.

CoRes according to Nilsson & Loughran (2011) are able to capture both the teachers' content knowledge and pedagogy. The teachers' content knowledge can be captured in the CoRes' big ideas and the prompts. By being able to elicit the teachers' content knowledge it means the CoRes can measure the content knowledge the teacher has. As with pedagogy, CoRes through the prompts will give insights into what the teacher thinks and why certain methods, or example or forms of assessment are chosen. The reasons and choices can provide insights into teachers' pedagogy.

1.2 Context of the study

For my Honours degree, I did a research project in which I looked at learners' understanding of meiosis after I had taught them the topic. The participants were from three different schools. The results of the research project revealed that the majority of the learners from my school were unable to identify and explain some concepts in meiosis such as homologous chromosomes and crossing over. I had expected the learners to know the basic knowledge that meiosis occurs in two phase; meiosis 1 and meiosis 2. Most of the learners from my school who participated in the study failed to define meiosis and to explain the importance of crossing over for example. The failure of the learners to understand this topic made me to reflect on my own content knowledge and teaching of it. One of the reasons in the failure to understand meiosis could have been my teaching approach or my content knowledge. I began to ask myself questions such as: how adequate is my own understanding and my pedagogy of teaching meiosis? Could I be facing the challenge identified by Shulman (1996a) in Shulman (1996) concerning beginning teachers which he said is the failure to transform content knowledge into a form of knowledge that is appropriate for students and specific to the task of teaching? These questions were the motivation for this research. By engaging in self-study it was possible that I could identify ways of improving my content knowledge and my teaching which in turn will impact positively on the results of the grade 12 learners in my school. The study can also hopefully contribute to the knowledge base of teaching in line with Opie (2006) who indicated that one of the reasons for doing educational research is to come up with outcomes that can be shared and used by others and in that way teachers may improve their practice.

1.3 Research problem

When I reflected on the findings from my Honours research project, I began to wonder about my own teaching and my subject matter knowledge. The lack of understanding that was shown by the learners could be due to the way I teach. In this study I sought to investigate and develop PCK for teaching meiosis by using CoRes and concept maps. I postulated that the use of concept maps will help me to develop my content knowledge and understanding of meiosis and CoRes might also improve my content knowledge and my general pedagogy of teaching meiosis as the CoRes give me the opportunity to interact with prompts which focus on the what and the why of teaching a topic.

1.4 Aim of the study and Research Questions

As explained earlier, the findings from my Honours research which I did in 2011 on learners' understandings of meiosis left me wondering about my content knowledge and the effectiveness of my teaching with regards to the topic of meiosis. I became motivated to look at ways of developing my content knowledge and ways of teaching the topic meiosis. The aim of this study therefore, was to investigate and develop my content knowledge and pedagogy for teaching meiosis. The study was guided by the following research questions:

1. How does the use of concept maps improve my content knowledge of meiosis?

2. In what ways does the use of content representations (CoRes) as planning tools improve my Pedagogical Content Knowledge (PCK) for teaching meiosis?

1.5 Self-study

This study was a self-study. In this section I describe what a self-study is and why I chose to do a self-study.

Self-study has been defined by Samaras (2002) in Samaras (2006) as a component of reflection in which teachers systematically and critically examines their actions and the context of those actions as a way of developing a more consciously-driven mode of professional activity. Self-study seeks to improve one's teaching as well as improve students' learning. Self-study helps to develop teacher efficacy, which refers to teacher's belief system and confidence in his or her ability to promote students' learning. According to Samaras & Freese (2006) self-study is a powerful vehicle that can also help to renew one's passion for

teaching. It has direct impact on one's classroom. The aims of self-study include some of the following: to better understand oneself, one's teaching and students' learning; to develop practical knowledge for personal, professional, and classroom improvements; to investigate one's own questions situated in one's particular context; to improve teaching and to conduct research with colleagues (Samaras & Freese, 2006). I therefore chose to do a self-study so that I could better understand my teaching of meiosis and then use that understanding to improve my teaching.

Loughran (2005, 2004) states that the goal of self-study is to articulate knowledge discovered by teachers about their practice so that their work moves beyond the individual and to investigate questions of practice that are individually important and also of broader interest to the teacher education community. Self-study encourages teachers to examine their role and responsibility to their students. Beck, Freese & Kosnik (2004) describe self-study as an inquiry-oriented approach that is personal, reflective, collaborative, and constructivist as it includes some elements of ongoing inquiry, respects personal experience and emphasises the role of knowledge construction. Self-study involves a strong personal reference in that it involves study of the self and study by the self. According to Nilsson & Loughran (2012), self-study helps specialized knowledge about a particular topic to emerge as the teacher actively develops, assesses and articulates the questions, problems, tensions and dilemmas within a specific topic. A self-study allows that which may not have been seen, realized or understood in the practice setting to become more visible to the teacher and others. Another central aspect of self-study is the focus on one's own actions as the teacher and the effects of those actions on learners. According to Samaras & Freese (2006), self-study has five characteristics which are; (1) it is situated inquiry, (2) it is a process, (3) it is knowledge, (4) it is multiple and (5) it is paradoxical. It is paradoxical because the term self-study suggests that the individual is the focus of the study. What it does not reveal is that the work of self-study is a collective task as well (Elijah, 2004). Each of these characteristics is briefly discussed below.

(a) Situated inquiry - this means that self-study starts with teachers' inquiry driven by questions from one's particular context(s). The study is contextually bound. It is grounded in the living issues of practice and incorporates the researcher in their settings. My study was to understand my teaching and then develop my content knowledge. Robert, Bullough & Pinnegar (2001) argued that self-study is a self initiated inquiry of practice which draws from the authority of the practitioner's experience. It enables the teacher to ask himself questions

where the answers are not easy to give because in self-study, the researchers inquire the epistemological underpinnings of their assumptions about knowledge and reality.

(b) It is a process - Samaras & Freese (2006) posits that self-study is a process that gives the teacher permission to change his teaching philosophy without incurring guilt over past experiences and beliefs. They further argued that self-study changes the culture of blame and guilty and takes it to the frame of investigating and reframing practice over time. Self-study is a sustained process where the inquiry is longitudinal in nature resulting in the teacher developing understanding without asserting a particular claim or final knowing (Pinnegar, 1998). Self-study helps teachers to build knowledge over time and can change as knew knowledge is gained thereby enriching the scope and breadth of one's practice.

(c) It is knowledge - this statement refers to the fact that self-study provides an opportunity to develop one's knowledge of teaching as it provides immediate evidence. According to Kosnick, Beck, Freese & Samaras (2006), self-study extends the knowledge base of teaching in three unique, yet highly integrated domains; (first) the personal, (second) the professional, and (third) the classroom, school or institution. The ability of the self-study to develop one's knowledge is one of the reasons I have chosen self-study methodology in this study. In doing a self-study, the teacher engages in all the three areas (mentioned in Samaras *et al*. 2006) in such a way that all the three areas benefit. Self-study embraces the idea of Dewey (1996a) in Samaras (2006) who said that no thought, no idea, can possibly be conveyed as an idea from one person to another... Only by wrestling with the conditions of the problem at first hand, seeking and fighting his or her own way out, does a person think. In self-study, the teacher thus questions his practice and arrives at a new understanding of one's teaching. New knowledge is therefore created as the teacher reframes practice through questioning of the assumptions of his or her practice.

(d) Self-study is multiple - Teachers can practice self-study using different theories, various research methods and with numerous purposes, argues Samaras & Freese (2006). It examines the teachers' everyday practice and brings the underpinnings of one's work to the forefront. Since self-study examines the practical principals of the classroom, it brings attention to the need that practice brings meaning to theory. This is supported by Bullough & Pinnegar (2001) who said that only when a theory can be seen to have efficacy in a practical arena will that theory have life. Self-study research does not include a particular theoretical stance. Multiple theoretical points of view can be used in a single study. In self-study scholars use diverse

qualitative methods derived from different methodologies (Samaras *et al*. 2006) which can include; drama, narratives and visual representations among others. Self-study is also multi-purposed with common aim to have valuable outcomes for the teacher and learners. Each and every self-study therefore is particular and unique for each researcher. This has brought about the rich multiple perspectives on what is knowledge and how one seeks to understand one's own practice through self-study.

(e) Self-study is paradoxical - it is paradoxical in the sense that it focuses on both the self and aligning one's self to the belief of practice and the belief to practice is collective (Samaras *et al.*, 2006). Though the focus is on self, self-study is not complete without collaboration. It is self directed but requires trusted critical friends for clarification, validation and to offer alternatives. Bullough & Pinnegar (2001) argue that self-study scholars must have a deep commitment to checking data and interpretations with colleagues to broaden possibilities and challenge perspectives. This will increase credibility and validity of study because common empirical evidence like in conventional research might not be available. In self-study the self is the instrument and the self-study teacher is both the person doing the seeing and person being seen. It is therefore personal and interpersonal. It is the study of the personal within the professional. It binds the particular teacher to the collective argues Ham & Kane (2004) in Samaras (2006). Self-study can also be private and public. Often the dilemmas which initiated the study could be private but when written down and published they become public as is argued by Mitchell (2006) in Samaras (2006).

In this self-study I am going to use CoRes and concept maps to explore and develop my content knowledge, my understanding and teaching of meiosis.

1.6 Theoretical framework

The construct of Pedagogical Content Knowledge (PCK) is used to guide this self-study. As proposed by Shulman (1986) PCK draws to the attention the value of the special amalgam of content knowledge and the knowledge of pedagogy that a teacher needs. In this self-study special attention is given to content knowledge which is one of the components of Shulman (1986) domains of PCK. The PCK of a teacher can be seen through use of CoRes which were used as a planning tool in this self-study.

1.7 Outline of the research report

Chapter one gives an overview of the study. It includes the context of the study, the problem and aim of the study as well as the research questions and description of self-study.

Chapter two reviews the literature that is relevant to the study. A review of literature on PCK, concept maps and CoRes was done.

Chapter three outlines the research design and methodology. It describes the participants, the teaching of meiosis, data collection, data analysis and reflective journal as processes used in the study.

Chapter four presents the findings from the construction of concept maps and CoRes used in the study.

Chapter five presents the reflections on the use of concept maps and CoRes in investigating and developing my content knowledge and pedagogy for teaching meiosis as well as implications and some recommendations.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

In this chapter I gave a description of the theoretical framework used and motivated why it was useful in my study. I have also looked at what literature says about using CoRes and concept maps in the development of content knowledge, teaching and learning. I then described what literature says about the teaching and learning of meiosis and finally looked at pedagogical content knowledge (PCK) as the theoretical framework used in the study. The research questions guiding the study were:

1. How does the use of concept maps improve my content knowledge of meiosis?

2. In what ways does the use of Content Representations (CoRes) as planning tools improve my Pedagogical Content Knowledge (PCK) for teaching meiosis?

2.2. CoRes

Though PCK is a complex construct and capturing it in practice has proved to be exceedingly difficult according to Nilsson & Loughran (2011), PCK sits at the cutting edge of research in science teacher education today. As highlighted by Baxter and Lederman (1999), PCK is a highly complex construct that is not easily assessed. By definition, PCK is both an external and an internal construct, as it is constituted by what a teacher knows, what a teacher does, and the reasons for a teacher's actions. The challenge for researchers then is to design studies that examine all the three aspects (Baxter & Lederman, 1999). As teachers do not always possess the language to express their thoughts and beliefs, different techniques need to be used to help teachers recognize and articulate their personal knowledge of practice.

In their extensive studies into capturing and portraying science teachers' PCK, Loughran *et al*., (2004, 2006) developed Content Representations (CoRes) to articulate science teachers' knowledge. Often, PCK is best demonstrated through CoRes. A CoRe is designed to elicit participant teachers' knowledge of teaching a particular science concept/topic and as such is a methodological tool used for capturing PCK that has been successfully applied across diverse contexts by a range of science education researchers (Nilsson & Loughran, 2010; Padilla, Ponce-de-Leon, Rembado, & Garritz, 2008; Rollnick, Bennett, Rhemtula, Dharsey, &

Ndlovu, 2008). Kind (2010, p. 195) noted that "CoRes offer the most useful technique devised to date for eliciting and recording PCK directly from teachers". She further stressed that the method is clearly centred in teachers' skills and knowledge, so a completed CoRe provides a powerful means of recording the work of an experienced teacher, available for sharing and exemplifying good practice. The table below shows the structure of a CoRe adapted from Loughran et al. (2011)

Table 1: CoRe template

Grade level for CoRe/ Topic	Important science ideas/concepts				
	Big Idea 'Á'	Big Idea 'B'	Big Idea 'C '	Big Idea 'D'	Big Idea 'É'
What do you intend students to learn about this idea.					
Why is it important for the learners to know this?					
What else you know about this idea (that you do not intend students to know yet).					
Difficulties/limitations connected with teaching this idea					
Knowledge about students' thinking which influences your teaching this idea.					
Other factors that influence your teaching of this idea.					
Teaching procedures (and particular reasons for using these to engage with this idea).					
Specific ways of ascertaining students' understanding or confusions around this idea.					

Sometimes CoRes do not represent a single teacher's PCK but rather can represent some of the most common and agreed aspects of scientific ideas and representations from a group of science teachers at a particular time. Loughran *et al.* (2012) argue that CoRes are just

concrete examples of PCK for a specific topic. They further argue that CoRes provide an overview of how teachers conceptualize the content of a particular topic.

Nilsson and Loughran (2011) suggest that CoRes attempt to portray holistic overviews of teachers' PCK related to the teaching of a particular science topic to make the tacit nature of PCK explicit to others. According to Loughran *et al*. (2012) CoRes are developed by asking teachers to think about what they consider to be the "big ideas" associated with teaching a given topic for a particular grade level based on their experience of that topic. CoRes contain a set of big ideas about a specific topic at the head of the columns and a set of pedagogical questions for each row. The agreed big ideas then become the horizontal axis of the CoRe. The big ideas are then probed and interrogated in different ways through the prompts that will be listed on the left hand side vertical axis of the CoRe. Prompts help to make explicit specific information about the big ideas that impact the content to be taught. A CoRe is therefore a detailed description for teaching a science topic based on a recognition of the "big ideas" for that topic mapped against pedagogic prompts including: what students have to learn about each big idea; why it is important for the students to know these ideas; students' possible difficulties with learning the concept; and, how these concepts fit in with the knowledge the teacher holds about that content.

The construction of CoRes challenges a teacher's thinking about the teaching of a specific topic by recognizing the big ideas against pedagogical prompts. Kind (2010) stressed that doing a CoRe is a complex process, training and guidance on completing CoRes is necessary in order to help (student) teachers to understand what they are being asked to do. The use of CoRes will help the teacher to develop insights into their science teaching especially in relation to specific science topics through the interrogations of prompts that frame the CoRes. Nilsson & Loughran (2011) argue that as a methodological tool, a CoRe offers a focused way of capturing a participant's PCK. Working with a CoRe can help science teachers conceptualize their professional learning and empower them to actively develop their professional knowledge of practice in specific content.

When working with CoRes, some sections of prompts can have more detail than others. Only the amount of information needed in each box should be included. In some cases the boxes can be left empty. Changes can be made in each box as the CoRe is refined or improved. Loughran *et al.* (2012) points out that a CoRe enables a solid base around which an overview of teachers' PCK for a topic can be articulated, and provides insights into the decisions that

teachers make when teaching a particular topic, including the linkages between the content, students, and teachers' practice.

A CoRe is not on itself PCK despite containing valuable information and possibilities of understanding PCK. A CoRe is a tool which can elicit the teachers' PCK. Though the information is limited in terms of providing insights into teachers' experiences of practice, according to Loughran *et al.* (2012), the ability of a CoRe to elicit a teacher's knowledge of teaching a particular topic or concept has contributed to my using it as methodological tool to capture my content knowledge and pedagogy in this self-study. Therefore, in this project the CoRe was used as a tool to make explicit the how, why and what of the content to be taught and to stimulate self-reflection and self-assessment on what I consider to be important in teaching meiosis and thereby developing my meiosis content knowledge and my pedagogical content knowledge of teaching meiosis.

2.3 Concept maps

When Novak (1991) first put forward the concept of concept maps, his argument was that concept maps are a powerful tool for organizing and representing knowledge. Concept maps are effective in identifying both valid and invalid ideas held by students (Novak & Canas, 2008). Novak was arguing in the context of using concept mapping in the classroom. In this study, I am arguing in the context of using concept mapping in the organisation of one's content knowledge as a teacher. I am of the idea that teachers can organize and represent their content knowledge about a topic through concept mapping. Novak & Canas further argued that concept mapping is powerful for the facilitation of meaningful learning in that it serves as a kind of *template* or *scaffold* to help to organize knowledge and to structure it, even though the structure must be built up piece by piece with small units of interacting concepts. In such learning where learning is build piece by piece, rote learning can be avoided. Creating a concept map can be challenging to people who have spent most of their life learning by rote argues Novak & Canas (2008). They further argued that, 'the only solution to the problem of overcoming misconceptions is to help learners learn meaningfully, and using concept maps can be very helpful' (Novak & Canas, 2008, p9.) According to Loughran *et al.* (2012), the use of concept maps by teachers in the classroom offers ways of seeing into the teachers' PCK by identifying what the teacher considers as the concepts of a particular topic. The use of concept mapping in the classroom offers considerable information to a teacher about students' learning and about the way in which the teacher's teaching has influenced learning. When a teacher uses a concept map, there will always be questions surrounding the

nature of the teacher's PCK because what the teacher identifies as concepts elicits his/her content knowledge of the topic. Loughran *et al*.(2012) argue that concept maps enable the teacher to think about the content knowledge as the teacher asks questions about the concepts and how they are related to the topic.

A concept map also brings out elements of pedagogy when the teacher thinks of how he or she might have instructed the learners to approach the task. So concept maps will encourage the teacher to get to grips with both content knowledge and pedagogical knowledge. Maas & Leauby, in Reynolds (1999), claim that concept maps help learners to organize what they know and think in more complex ways. The same can apply to teachers, that is, concept maps can help teachers to organize what they know about a topic. In my view, with concept maps once you have understood one aspect of a topic by mapping it, you will have enabled yourself not only to built a foundation for other topics but you will have enabled yourself to branch into other aspects of the topic and thus build more complex knowledge. Concept maps can therefore bring into sharp focus aspects like relationship between teaching and learning, concept attainment, misunderstandings and difficulties. Concept maps help in the interaction of knowledge of content and knowledge of pedagogy into the type of relationship indicative in PCK. Interaction of knowledge of content and knowledge of pedagogy can be reflected by the concepts identified and how the concepts are linked to each other to form meaningful understanding. Construction of concept maps by teachers can offer helpful insights into the nature a teachers' content knowledge of a particular topic.

Concept maps represent concepts and their interrelationships that are intended to represent the knowledge structures that humans store in their minds (Jonassen, Beissner, & Yacci, 1993). Learning that is meaningful involves reorganization of existing beliefs or integration of new information with existing information. As the learner improves on his or her concept maps one will be integrating new knowledge in what they already have. The same can be said for teachers. If teachers use concept maps to represent their knowledge of a topic they can also learn from the process.

Asan (2007) argued that concept maps can effectively promote one's learning. In this study therefore, the use of concept maps can promote my own learning. Concept maps contribute to one's success in learning new concepts, foster a long-term change in thinking, and contribute to changing one's learning strategies. Concept maps support both constructivist teaching and learning approaches which support the notion that the learner should construct meaning in his

or her learning. One constructivist Glasersfeld (1991) argues that teaching aims at and focuses on the student's understanding of conceptual operations. Learning must be constructed by each individual. The use of concept maps endeavours to meet this objective. The involvement of the learner in the construction of concept maps is of paramount importance. Keles & Saglam (2012) argues that the learner who constructs the concept maps based on his own life experience will be more involved in the effective as learning occurs while constructing the maps. Concept mapping thus enables one to process information effectively as one struggle with the identification of concepts. There will be dialectical relationship between new and old concepts. The notion was echoed by Ahuja (2013) who said that concept mapping aims at the teaching and learning of concepts at 'understanding level' in a meaningful way. The ability of concept maps to involve the learner (the teacher) to process information effectively in the identification of the concepts and their relationships made me to use them (concept maps) in this study.

Novak (1984) defined concepts as patterns or regularities denoted by names, symbols or signs for example "dog". Concepts help us to describe and explain the way something works. In meiosis concepts are words or terms or phrases which help us to describe meiosis so that it can be understood using such words as haploid, diploid and crossing over.

Concept maps further help in the development of knowledge through their propositions. A proposition is made up of two concepts and a word or phrase in-between them. Some examples of words in-between concepts could include words such as; *causes, requires* or *contributes to.* These words in-between two concepts on the line are referred to as linking words or linking phrases and they specify the relationship between the two concepts. The two concepts with the linking phrases that join them form propositions. Propositions are statements about some object or event in the universe, either naturally occurring or constructed (Novak *et al*. 2012). A proposition is a valid relationship between one concept and another. An example of a proposition is: meiosis — produces → 4 haploid cells. Propositions form an important part of the tool to measure a concept map and knowledge development in the one constructing the concept map. A meaningful proposition is the basic unit of knowledge according to the theory of meaningful learning and Ausubel's assimilation theory (Novak & Gown 1984). The number of correct propositions can be used as a measure of how much knowledge one has developed. A proposition has to be valid with respect to the

two concepts it links. If there is no link between the two concepts then the proposition is invalid.

2.4 Teaching and learning of meiosis

The topic Genetics under which meiosis falls has been reported as being challenging to students and undergraduates who are taking biology as a major (Smith & Knight, 2012). Smith & Knight further posit that pupils and teachers consistently place cell division near the top of the ladders of difficult topics. In a study carried out by Knippels, Waarlo & Boersma (2005), they pointed out that some of the difficulties of teaching genetics include the domain-specific vocabulary and terminology, the cytology (cell structure) processes and the abstract nature of the genetics topic. According to Knippels *et al.* (2005) learners often have a poor understanding of the purpose, process and products of meiosis. The poor understanding is further magnified by the misunderstanding of the underlying behaviour of chromosomes during meiosis. Several science education researchers have noted that when concepts and process occur simultaneously at different levels of organisation, students have difficulties in grasping the subject (Bahar et al. 1999; Hallden, 1990). Of the stages involved in meiosis, Oztap, Ozay & Oztap (2003) suggest that the first part of meiotic division, especially chromosome movements during prophase 1 is the hardest part of meiotic division to explain to learners. The difficulties in teaching meiosis might also lie in the methods used in teaching the topic. Teachers might fail to identify suitable teaching strategies which can result in learners failing to understand the topic better. The terminology used in the topic might also lead to misconceptions because the terminology is too abstract for learners. The terminology is not related to the language learners use daily. A variety of teaching methods may help to reduce these challenges being faced by both teachers and learners. The findings of (Smith & Knight, 2012; Bahar et al. 1999; Hallden, 1990; Oztap, Ozay & Oztap, 2003) motivated me to seek my own understanding, content knowledge and my teaching of meiosis.

2.5 Pedagogical Content Knowledge

The construct of PCK will be used as the theoretical framework to guide this study. Shulman (1986, 1987) introduced this construct to draw attention to the value of the special amalgam of content knowledge and knowledge of general pedagogy that a teacher needs in order to be an effective teacher. Shulman distinguished between content as it is studied and learned in disciplinary settings and the "special amalgam of content and pedagogy" needed for teaching the subject. His ideas have had a major impact on the teacher education research community

which has focused attention on the foundational importance of content knowledge for teaching and on pedagogical content knowledge in particular. The central contribution of the work of Shulman (1987) was to reframe the study of teacher knowledge in ways that included giving direct attention to the role of content in teaching. This marked a radical departure from some research which had focused almost exclusively on general aspects of teaching such as classroom management, time allocation and planning. Shulman (1986, 1987) and his colleagues argued that high quality instruction requires a sophisticated professional knowledge that goes beyond simple rules of classroom pedagogy. In order to facilitate students' understanding, teachers must have well-developed knowledge base for teaching, including knowledge of multiple instructional representations and the connections between them (Moseley & Brenner, 1997). Shulman (1987) argues that in producing an effective lesson a teacher must have at least three types of professional knowledge: content knowledge, pedagogical knowledge and knowledge of students. The combinations of these three types of knowledge then form PCK. Pedagogical content knowledge (PCK) is a form of teacher professional knowledge. Within Shulman's (1986) category of pedagogical content knowledge were included the most useful forms of representation of ideas and the most powerful ways of representing and formulating these to make the subject comprehensible to others. It also included the understanding of what makes the learning of the topic easy or difficult; the conceptions that students of different ages and backgrounds bring with them to the learning of a topic as well as the strategies most likely to be fruitful in reorganising and understanding the topic.

From the science teaching perspective as portrayed by Shulman (1996), teachers need to be in a position to convert their pure science content into science content for teaching. This could be enhanced by the contribution of the concept of pedagogical content knowledge (PCK) where content and pedagogy are blended. Hence the reason I have chosen PCK as a theoretical framework in my study is that I will be investigating how concept maps and CoRes may help to improve my content knowledge and pedagogical content knowledge for teaching meiosis.

2.5.1 Other researcher's perspectives on PCK

The initial definition of pedagogical content knowledge by Shulman (1986) was conceptualized further by others to mean a representation or academic construct of specialist knowledge needed in practice (e.g., Gess-Newsome & Loughran, 1999; Bishop & Denley,

2007; Loughran & Nilsson, 2011) which is developed in classroom practice. PCK has thus transcended subject matter knowledge and generalized pedagogical knowledge. Grossman (1990) has conceptualised PCK as consisting of four components: the discipline subject matter; knowledge of student's conceptions and difficulties; knowledge of the curriculum, and knowledge of instructional strategies. This conceptualisation is in agreement with Shulman. Subject matter has played a central role in the professional life of secondary school teachers (Stodolsky & Grossman, 1995). Stodolsky & Grossman have also pointed out that from the moment high school teachers prepare for teaching, subject matter knowledge takes centre stage and influences how teachers think about curriculum, learning and teaching. Although subject matter knowledge is considered very important by Stodolsky & Grossman (1995), some researches do not view subject knowledge to be a stand alone in the teaching and learning of science. Some researches posit that the teachers' orientations like teachers' beliefs and purposes are significant in the teaching and learning of science. In Magnusson *et al.'s* (1999, p. 97) PCK model, science teaching orientations are defined as 'teacher's knowledge and beliefs about the purpose for teaching science in a particular grade level.' This view is in agreement with Borko and Putnam (1996), who said that teachers' beliefs act as conceptual map that guide instructional decisions and practice. In this view, there is therefore a significant relationship between teacher beliefs and teaching practice. However, De Jong (2001) argues that science teachers are focused on themselves (i.e., their knowledge, experiences, and teaching) when preparing lessons and do not think deeply about student learning or the difficulties students face learning new content. This argument of De Jong (2001) captures well how I often prepare my lessons. My teaching has always focused on delivery of the knowledge to the learners without taking into consideration the learners' prior knowledge or their background or the difficulties they are likely to have. This research therefore seeks to develop and improve my teaching of meiosis through considerations of such aspects like learner prior knowledge and learner difficulties as will be reflected in my CoRes.

The use of concept maps and CoRes in this study therefore sought to find out if their use could improve my content knowledge and pedagogical content knowledge of meiosis so that when I teach meiosis I could represent it well enough.

Geddis and Wood (1997) consider PCK to be a broad category of those kinds of knowledge involved in pedagogical transformations of subject matter. Their PCK model includes learner's prior concepts, subject matter representations, instructional strategies, curriculum

materials, and curricular saliency. According to Geddis and Wood (1997), curricular saliency refers to the teacher's understanding of the place of a topic in the curriculum and the purpose(s) of teaching it. Curricular saliency is considered to influence the teachers' decisions to leave out certain aspects of a topic. Geddis and Wood's ideas of PCK were based on the view that PCK represents all the kinds of knowledge that are amalgams of subject matter and pedagogical knowledge. Nothing is however said about the influence of the teachers' actual content knowledge or subject matter knowledge (SMK) on PCK.

Pedagogical content knowing (PCKg) was introduced by Cochran, De Ruiter, & King (1993) as a constructivist version of PCK. They use the term 'knowing' instead of 'knowledge' in describing their concept of PCK to emphasise the dynamic nature of their PCK. The model by Cochran *et al*. (1993) integrates four components of teacher knowledge, which are knowledge of subject matter, knowledge of students, knowledge of pedagogy and knowledge of environmental contexts. The PCKg model amalgamates all the seven components of teacher knowledge identified by Shulman. Though these views portrayed by different researchers have variations, they all have the same notion that PCK is an importance amalgam in science teaching. Most of the researchers (Shulman, 1987; Magnusson, 1999; Cochran *et al.*, 1993; Rollnick *et al*., 2008) have all in their PCK models argued that subject matter (content knowledge) is key in the teaching of a topic.

Ever since the notion of PCK was put forward by Shulman, its conceptualization has been developed and understood differently by different researchers. Table 2 below summaries some of the PCK scholars and their conceptualization of PCK.

In considerations of these arguments, subject matter knowledge will be the main focus of my study. The notion that subject matter knowledge is important to the teaching of science is in agreement with the aim of my study which seeks to develop content knowledge of teaching meiosis.

My study focused on the development of content knowledge by looking at the concept maps and CoRes that I constructed. The analysis of concept maps and CoRes can offer meaningful insights on the teacher's PCK. These aspects can be a base to scaffold one's knowledge of a topic and the best possible ways between teaching and learning which can be coined under the term pedagogy. By using these two concepts to portray PCK, it offers a window to explore and examine the relationship between teaching, learning and content. PCK will not only take a new and significant meaning, but also opens professional practice in scrutinising

ways that highlight the knowledge and abilities of a teacher when teaching and learning of specific content. Table 2 below shows how other scholars have extended Shulman's PCK based on their studies.

Table:2: Components of pedagogical content knowledge from different conceptualizations extended from Van Driel *et al*. (1998)

Knowledge of:						
Scholars	**Subject matter**	**Representations-ns and strategies**	**Students learning and conceptions**	**General pedagogy**	**Curriculum and media**	**Context**
Shulman (1987)	a	PCK	PCK	a	a	a
Magnusson *et al.* (1999)	a	PCK	PCK	a	PCK	a
Geddis & Wood (1997)	b	PCK	PCK	b	PCK	b
Fernandez-Balboa & Stiehl (1995)	PCK	PCK	PCK	b	b	PCK
Cochran *et al*. (1993)	**PCKg**	b	PCKg	PCKg	b	PCKg
Loughran *et al*., (2001)	b	PCK	PCK	b	PCK	b
Bishop and Denley (2007)	PCK	b	PCK	PCK	PCK	PCK
Rollnick *et al*. (2008)	PCK	PCK	PCK	PCK	b	PCK

Note meaning of different letters used in table: a, distinct category in the knowledge base for teaching; b, not discussed explicitly; PCK, pedagogical content knowledge; PCKg, pedagogical content knowing.

It therefore can be argued that in order to recognize and value the development of PCK, a teacher needs to have a rich conceptual understanding of the content of the particular subject. This rich conceptual understanding coupled with expertise in developing, using and adapting teaching procedures, strategies and approaches for use for a particular topic is purposefully

linked to create the amalgam of knowledge of content and pedagogy that Shulman (1986, 1987) described as PCK. The development of PCK can then be considered to be useful in enhancing competence in teaching and in creating new ways of discussing issues inherent in the intricacies and application of content knowledge in practice. Rollnick *et al.* (2008, p 8) stated that in as many ways, finding, capturing and elucidating PCK may well represent what some might describe as the holy grail of teacher development.

Kind (2009) identifies three common factors that appear to contribute to the growth of PCK in early career teachers. The first factor identified is the possession of good subject matter knowledge; the second is classroom experience. Experience brings about significant changes in the development of PCK in teachers according to Kind (2009). The third aspect identified is the possession of emotional attributes like personal self-confidence and the provision of supportive working atmosphere in which collaboration is encouraged.

In this study I adopted Rollnick *et al.'s* (2008) model for PCK to look at how elements of my PCK were transformed during my study (figure 1).

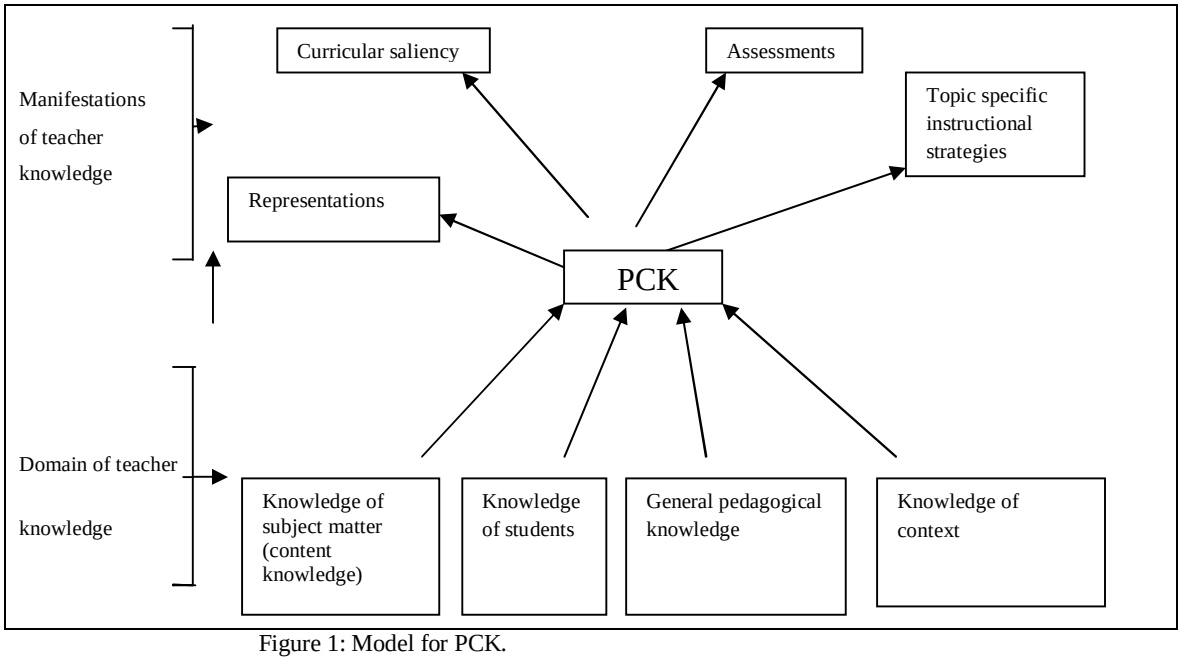


Figure 1: Model for PCK.

The diagram shows that PCK develops from the domains of teacher knowledge and moves to the manifestations of teacher knowledge. The domains referred to as teacher knowledge consist of four fundamental domains of knowledge for teaching which are knowledge of subject matter; knowledge of students; general pedagogical knowledge and knowledge of context. When these four fundamental domains of teacher knowledge are integrated, observable products are produced in the classroom, referred to as manifestations.

Manifestations may include any visible products like subject matter representations, topic-specific instructional strategies, curricular saliency and assessment of teaching that may be observed during teaching in the classroom.

I have chosen this model because in this study I seek to improve my content knowledge, and I hope to achieve this by working on some of the domains of teacher knowledge and manifestations of teacher knowledge as in Rollnick *et al*.'s (2008) model. This study will focus mainly on the knowledge of subject matter since I am seeking to improve my content knowledge. Where the other teacher domain knowledge besides content knowledge are explained, they are only to support the main content knowledge domain which I seek to develop.

2.5.2 Domains of teacher knowledge

1. **Knowledge of subject matter** (Content knowledge) –This forms the content knowledge (CK) which the teacher has. Content knowledge (CK) is knowledge about the actual subject matter that is to be learned or taught. Content knowledge is the most important prerequisite for PCK. In order to integrate the other components of PCK, the teacher must have good content knowledge (CK). According to Koehler (2011); Abbott (2014) & Shulman (1986) content knowledge is knowledge about the actual subject matter that is to be learned and taught. The content knowledge includes the central facts, concepts, key ideas, propositions, structures of the concepts, relationships, appropriate representations that make the content comprehensible, theories, principles that are taught and learned, procedures within a given field; knowledge of explanatory frameworks that organize and connect ideas; and knowledge of the rules of evidence and proof. Ball, Thames & Phelps (2008) argued that a teacher requires a specialized form of pure subject matter knowledge – 'pure' because it is not mixed with knowledge of students or any other form of teacher knowledge. They argue that the specialized knowledge can be seen in the examples and terms used by the teacher. Ball *et al.* (2008) identified four domains of teacher knowledge as knowledge demanded by the work the teachers do. These domains are: (a) Common content knowledge (CCK); it is knowledge and skill used in settings other than teaching. CCK is knowledge not unique to teaching. It is not scientific knowledge for teaching. (b) Specialised content knowledge (SCK); this is the scientific knowledge and skill unique to teaching. It is knowledge not typically needed for purposes other than teaching. With SCK teachers have to do a kind of mathematical work (for example) that others do not do. The work involves a kind of unpacking of a (science)

topic that is not needed or even desirable in settings other than teaching; such as how to choose, make, and use scientific representations effectively. (c) Knowledge of content and students (KCS); is knowledge that combines knowing about students and knowing about mathematics for example. KCS makes teachers be able to anticipate what students are likely to think and what they will find confusing. (d) Knowledge of content and teaching (KCT); which combines knowing about teaching and knowing about mathematic such as knowledge of sequencing particular content for instruction. Some of these domains identified by Ball *et al.* (2008) are in agreement with domains identified by Shulman (1986; 1987); he called this kind of knowledge 'specialized'. It is knowledge which is unique to each topic to be learnt. The teachers' orientation to this specialized unique content knowledge influences the ways in which they teach that content.

The way a teacher learns CK depends on his/her beliefs, prior knowledge and misconceptions (Hasweh, 1987). According to Hasweh (1987), teachers with limited content knowledge carry their misconceptions over to learners, while knowledgeable teachers use their prior knowledge and exclude the superfluous concepts from the lesson. For CK to be meaningful, the teacher must learn the content in a pedagogical context rather than learning content in an abstract way (Halim & Meerah, 2002). Learning content in a pedagogical context means learning CK and learning how to transform it to be comprehensible to learners. Learning content in pedagogical context is done by teachers to simplify CK without losing the meaning. Shulman (1986, p9) argues that "to think properly about content knowledge requires going beyond knowledge of facts or concepts of the domain". Cochran, de Ruiter & King (1993) argue that the transformation process is the continuous restructuring of CK for the purpose of teaching. Teachers who do not have a broader view of the content may give learners inappropriate and misleading examples (Halim & Meerah, 2002).

2. **Knowledge of students**- has to do with the appreciation of learners' prior knowledge, how they learn, their interests and aspirations as well as their linguistic abilities (Rollnick *et al.* 2008). The purpose of teaching is to enable learning. The teacher must know the learners' misconceptions of a particular topic so that he or she will be able to interpret the learners' actions and ideas. Halim & Meerah (2002) argue that the key component of PCK is learners' understanding and the teachers' understanding of their misconceptions of a particular topic. It is very important for the teacher to know learners' prior knowledge before the introduction of a new topic. Teachers can come to know the learners' prior knowledge by either giving the learners a pre-exercise or from literature. Learners come from different backgrounds and

they already have some kind of knowledge from their different environments. Even the scientific knowledge they bring to class is different. Learners' prior knowledge can be affected by the context of their environment. According to Cochran *et al.* (1993) context includes attitudes, ages, motivations, developmental levels and prior knowledge.

3. **General pedagogical knowledge**- is having an understanding of what constitutes good teaching, taking into consideration the best teaching approaches in a given context, which are informed by appropriate learning theories (Rollnick *et al.* 2008).

4. **Knowledge of context**- refers to all contextual factors influencing the teaching condition like resources, class size, learners' socio-economic background, curriculum, conditions in the classroom and availability of time for teaching and learning (Rollnick *et al*. 2008).

2.5.3 Manifestations of teacher knowledge

Representations- refers to the forms of representation that can be shown by the use of most powerful analogies, illustration, examples, explanations, simulations and demonstrations (Shulman 1986). In order to produce effective representations that will be linked to the knowledge intended, the blending of subject matter knowledge (SMK) with the other three domains of teacher knowledge is required (Rollnick *et al*., 2008). Hence a deeper knowledge of SMK is essential. Halim & Meerah (2002) argued that knowledge of representations refers to the type of knowledge that can be used to help learners understand specific scientific concepts. The teacher thus cannot have special strategies for teaching a certain topic if s/he does not have the CK. They further argue that knowledge of representations refers to the type of knowledge that has specific useful strategies to help learners understand specific scientific concepts.

Curricular saliency- is about "providing perspectives on the dilemma of breadth versus depth of coverage" (Geddis & Wood 1997, p. 612). It refers to how deep the teacher decides to go when teaching a specific topic and also what not to teach. Curricular saliency is in most cases influenced by the curriculum in terms of its guidelines and also by what is most likely to be in the learners' final examinations or what may be useful to the learners. The other aspect that plays an important role in curricular saliency is the experience that a teacher has in teaching that particular subject (Geddis, Onslow, Beynon & Oesch, 1993). Hence it will be easy for him or her to understand what comes before and after in the topic in hand (Rollnick *et al*., 2008). Shulman (1986) states that teachers must know what the curriculum entails. They

must know what is required of them to deal with a specific topic. This means that they should know the curriculum requirements. From the content they have learnt they still have to strategically select certain concepts or to omit others so as not to confuse learners. This is what is referred to as curriculum saliency (Geddis & Wood, 1997). Teachers with good PCK sometimes arrange concepts differently from the curriculum documents to avoid confusing learners. Teachers are able to look at the whole curriculum or certain topics and decide on concepts to begin with that will lead to better understanding of learners. PCK helps teachers to reduce any misunderstandings that can arise during the lesson.

Topic-specific instructional strategies- refers to different approaches that teachers use like whole class teaching, problem-first strategy, group work, question and answer strategy. However, according to Geddis *et al.*, (1993) the strategy used should be able to help the teachers in focusing more on the development of conceptual knowledge i.e. content knowledge or the ideas of the topic which should be known rather than on the development of procedural knowledge which is mere knowing how something is done.

Assessment- may be in the form of formative or summative tasks. Formative assessment may include the type of questions asked during the teaching period and also the type of questions asked in the exercise to consolidate what was learnt during the teaching.

I have considered Rollnick *et al.'s* (2008) models to be useful in my study because it integrates some components from Cochran *et al.* (1993) and Geddis and Wood (1997) models which had elaborated well on PCK. The Cochran *et al.* (1993) model indeed claims that the integration of domains in teacher knowledge produce PCKg. However, it examines only the underlying knowledge without showing how this knowledge is combined to produce what happens in the classroom (Rollnick *et al.*, 2008). On the other hand, Geddis and Wood (1997 p. 162) describe PCK as "a broad category of those kinds of knowledge involved in pedagogical transformations of subject matter". This includes amongst others subject matter representations, instructional materials, curricular saliency, which are observable products called manifestations in the Rollnick *et al.* (2008) model.

2.6 Topic Specific PCK

Although the theoretical framework used in this study is PCK as put forward by (Shulman, 1986; 1987), I further considered some literature on PCK for a specific topic because my focus will be on a specific topic.

In this study I am investigating my own knowledge of a specific topic – meiosis which can be regarded as Topic Specific PCK (TSPCK). According to Mavhunga & Rollnick (2011), Topic Specific PCK is regarded as the understanding that provides the needed knowledge for Subject Matter Knowledge (SMK) transformation in a particular topic. The concept of Topic Specific PCK is premised on the understanding that transformation of SMK is one of the key elements in the establishment of PCK. For teachers with high quality PCK, each topic is transformed as the teacher reasons about its teaching (Shulman, 1987). When a specific topic is thought through, certain topic specific components of PCK are considered. These components are (i) Learners' Prior Knowledge, (ii) Curriculum Saliency (deciding what is important for teaching and sequencing), (iii) What makes the topic easy or difficult to understand, (iv) Representations, including powerful examples and analogies and (v) Conceptual Teaching Strategies. All these components are similar to those established by Geddis & Wood (1997). For each individual topic engaged through these topic specific components, the resulting knowledge will be different and specific to that topic according to Mavhunga & Rollnick (2011).

According to Mavhunga (2011) when targeting transformation of a specific topic, the resultant PCK should be with respect to the specific topic. TSPCK can thus refer to the type of PCK as PCK within a topic, different from the generic type of PCK at a discipline level. There is agreement in the literature about the topic specific nature of PCK as a theoretical construct (e.g. Loughran, Berry, & Mulhall, 2006). Within this background, it can be argued that the topic specific nature of PCK suggests the need for a PCK construct that is defined more sharply to reflect the specificity of the topic rather than reference to a subject or discipline. Geddis (1993) pointed out that teachers need to develop the awareness that teaching requires the transformation of their SMK or content knowledge, generally. Also, once this awareness is in place, the articulation of the kinds of knowledge needed to achieve such transformation becomes important. According to Geddis (1997, p. 676) knowledge of a 'multitude of particular things' about SMK that are relevant to its teachability is required. The 'particular things' that are identified in Geddis (1993) & Geddis & Wood (1997) is what

Mavhunga (2011) says is specific to each topic. These components can be called content specific components because of their orientation to SMK, requiring specific considerations to be made about SMK. When a particular element of SMK is thought about and reasoned through these content specific components, understanding for teaching is generated that is specific to that topic. That is, the initial element of SMK is transformed to a version that is suitable for use in teaching learners. This transformed version now has representation and analogies which makes the core concepts of the topic to be well understood by learners.

In the model of TSPCK used by Mavhunga (2011), one recognizes subject matter knowledge as a component of PCK. The model identified four knowledge domains as contributing to PCK, which are knowledge of context, knowledge of students, subject matter knowledge or content knowledge and pedagogical knowledge. The model shows that the knowledge which results in transformation of subject matter knowledge is directly linked to the subject matter domain and so leads to PCK. Such knowledge is topic specific. Figure 2 shows the amalgamation of two models of PCK resulting in Topic Specific PCK adapted from Mavhunga (2011).

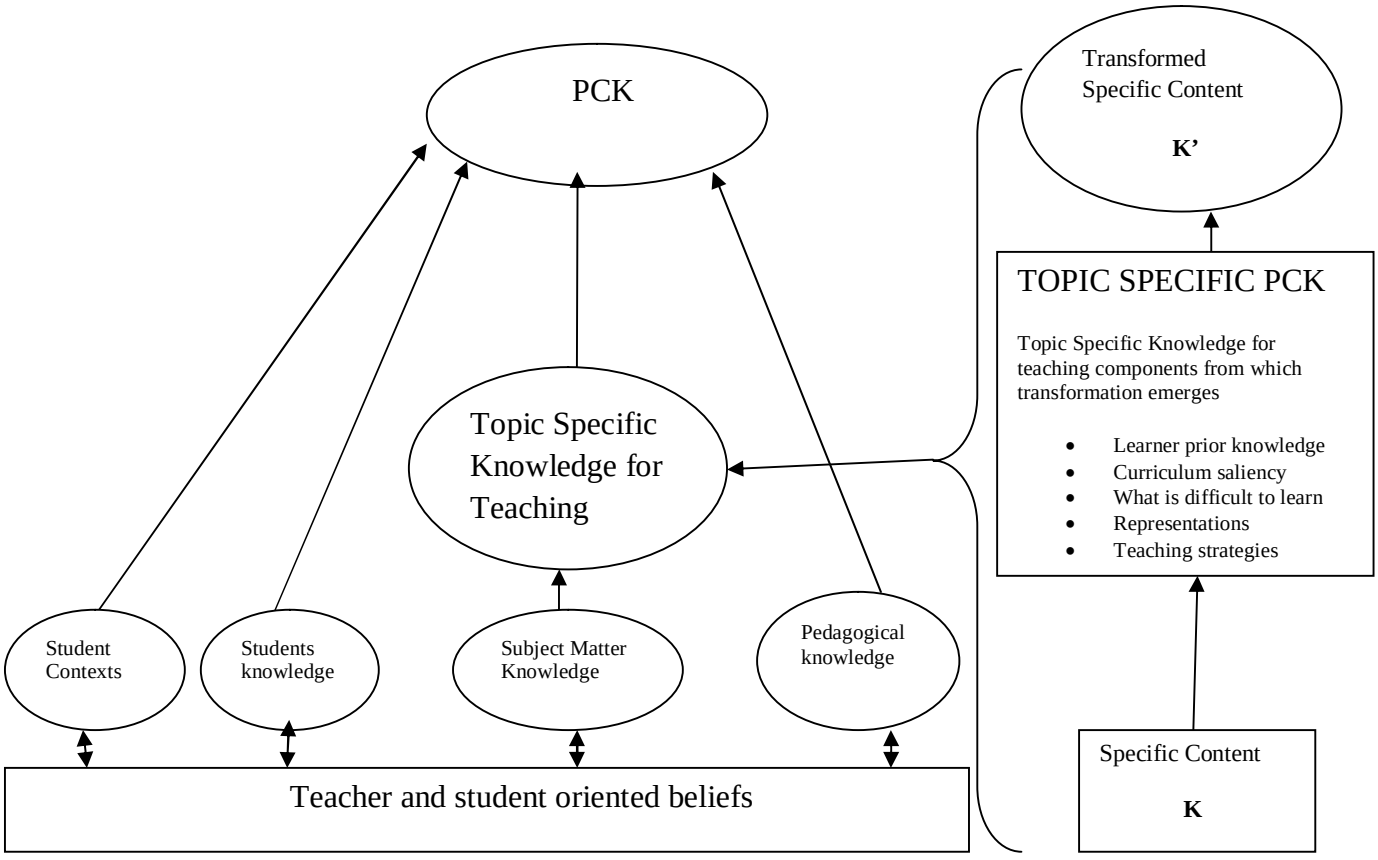


Figure 2: Amalgamation of two models of PCK

The first model is from Rollnick *et al.* (2008) and the second model is from Mavhunga (2011).

The four components in the first model (student contexts, student knowledge, subject matter knowledge and pedagogical knowledge) give rise to the general PCK. The other model shows that each specific topic requires its own teaching strategies, its own representations, has its own content that is difficult to learn, requires curriculum saliency and learners have prior knowledge about it. These five components are specific to each topic. These five components contribute to TSPCK which in turn contributes to general PCK according to the amalgamation made above. The resultant is the transformed specific content for that topic. In this case the content has been transformed into content which learners understand. The resultant is the same topic but with a different version which is easy to teach to someone (a transformed version of the original). Mavhunga (2011) argued that the understanding and deliberation of a specific topic through topic specific knowledge for teaching will give rise to the transformation of individually understood content (K) to versions that are understood by learners (**K'**). When such experience is observed, it can be an indication of the presence of PCK for the topic at hand, hence entitled Topic Specific PCK. (See figure 2 above).

This study considers the quality of teaching resulting from such considerations as being influenced by both the knowledge of the content specific components as well as their interaction among each other. Similar to Shulman, however specific to a topic level, the capacity to transform SMK of a topic through such considerations as PCK located within that topic is termed (Topic Specific PCK). This transformation is displayed in Figure 2 (left side) as shown above. The left hand side of the figure displays a model of PCK that acknowledges the influence of four generic teacher knowledge domains, namely knowledge of context, knowledge of students, subject matter knowledge and pedagogical knowledge. The right hand side of the figure displays a model of PCK that acknowledges the influence of five aspects which are different in each topic namely teaching strategies, representations, what is difficult to learn, curriculum saliency and learners prior knowledge. When these five aspects are combined with the content required in that topic, the resultant is transformed knowledge for teaching for that particular topic.

However in this self-study there was no teaching done and therefore the manifestations of teacher knowledge could only be seen in the planning not teaching. Manifestations could be seen in the representations which are highlighted in the planning. Of much interest to this

study was the domain of teacher knowledge within a topic. I therefore decided to use Mavhunga's 2011 model as it includes components of general PCK and TSPCK.

2.7 Conclusion

In this chapter I gave some description of literature on concept maps and CoRes which were be used as data sources in the study. I further described literature on PCK which was used as the theoretical framework in the study. I also gave documented literature to show that PCK can be captured using CoRes. In the next chapter I discussed the research design and methodology that facilitated the process of data collection and analysis.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3. 1 Introduction

This study is a self-study in which I investigated the development of my content knowledge and my Pedagogical Content Knowledge for teaching meiosis. As stated by Nilsson & Loughran (2012) self-study helps pedagogical content knowledge about a particular topic to emerge as the teacher actively develops, assesses and articulates the questions, problems, tensions and dilemmas within a specific topic. In this chapter I provide a discussion on how the research was carried out, including methods of data collection used in the study. The chapter includes the explanation of the type of research method used, instruments that were used as well as ethical issues. Finally, the issue around rigour and validity is also discussed. The study is guided by the following questions:

(a) How does the use of concept maps improve my content knowledge of meiosis?

(b) In what ways does the use of Content Representations (CoRes) as planning tools improve my Pedagogical Content Knowledge (PCK) on meiosis?

3.2 Research design

A self-study is the methodology employed in this study. As described in chapter one, a self-study is a methodology in which the teacher systematically and critically examines his/her actions and context of those actions as a way of developing a professional activity (Samaras, 2002). Self-study seeks to improve one's teaching and improve students' learning.

Data in this study was analysed both qualitatively and quantitatively. Qualitative analysis was chosen as it gave me the opportunity to express my experiences in the study. Qualitative researchers believe that knowledge comes from multiple realities, which can be based on the feelings, fears and the participants' environment among others (McMillan & Schumacher, 2010). Qualitative research is thus subjective, and its basis is on how the researcher understands the world and the ultimate purpose of his/her research (McMillan & Schumacher, 2010). McMillan & Schumacher (2010) further said that qualitative researchers are concerned with understanding the social situation or event from the participant's perspective. Quantitative paradigm was also employed as it gave me the opportunity to use figures to determine increase in knowledge. The quantitative researchers believe that

knowledge comes from the facts, and it is therefore objective (McMillan & Schumacher, 2010). Quantitative analysis involves determining amounts of characteristics on display whilst qualitative involves describing the characteristics of events (McMillan & Schumacher, 2010). Although the approaches qualitative and quantitative are used, there is always an overlap between the two. Opie (2004) argued that there is always an overlap as educational researchers have tended to frequently use both approaches. Even though quantitative use numerical data, describing the numerical data is qualitative.

A combination of both qualitative and quantitative approaches has been suggested by Burton, Brundrett & Jones (2008) as approaches which can significantly strengthen arguments as numerical data will give immediate point of impact to the reader whilst the qualitative evidence give meaning to the numbers thereby enriching the interpretation and analysis.

The reason for choosing a self-study approach is that it is relevant and appropriate for my research questions in this study in that I will be investigating how both the concept maps and CoRes can improve my content knowledge of teaching meiosis. All the research questions in this study seek to find whether my use of both concept maps and CoRes will help to improve my content knowledge and pedagogical content knowledge. The CoRes sought to develop my pedagogical and topic specific knowledge as shown in the model of Mavhunga (2011). Concept maps predominantly sought to improve my content knowledge. The data in this self-study research was collected from the construction of concept maps, content representation (CoRes) and reflective journal.

3.3 Participants

Since this study was a self-study research I was the main participant of the study**.** The other participant was the critical friend. The critical friend was actively involved in the analysis of concept maps and CoRes. A critical friend is someone who provides collaborative reflection during the analysis of data. A critical friend helped me (the researcher) to move from my personal views to other perspectives. A critical friend provides opportunities for support, opportunities for new insights into one's work as well as offering different perspectives. A critical friend offers probing questions, opportunities for clarification and alternative explanations. A critical friend contributes to the validation of the findings because the analysis extended beyond one's personal views, thus addressing potential biases (Samaras & Freese. 2006). Participation of the supervisor was implicit. Initially the supervisor had no role in the research design. However, when I submitted my first concept map, the feedback was a

long session in which the supervisor pointed out what was wrong with my concept map which helped me to develop the subsequent concept maps. It was from this feedback session that I realized that in addition to a critical friend, I also needed a content specialist. Therefore my critical friend and supervisor formed the collaborative team that worked with me throughout the study. As part of the collaborative team, the supervisor was playing the role of the content expert. My supervisor is a lecturer responsible for teaching genetics including meiosis and therefore I saw it fit that she becomes part of the team. I used the name Simon to refer to my critical friend and the name Anna to the content expert which happened to be my supervisor.

3.4 Reflective Journal

Reflection is a critical way of thinking about one's practice that makes sense of the complexities of teaching (Samaras & Freese, 2006). A reflective teacher consciously and creatively participate in own growth and development.

A reflective journal is a diary where the researcher/teacher writes about his/her personal feelings, fears, challenges and successes that occur before, during and after the study. Ideally, it should be written daily so that the researcher does not lose any important data. In a reflective journal the researcher writes about self, contributions from the collaboration team (Simon and Anna in my case), colleagues and learning and behaviour of learners. The researcher writes in detail about what is going on in his mind, around him and what he learns from the experience. Withholding data results in poorer findings which may be mere generalities. According to Samaras and Freese (2006), a self study is about whom the teacher is, and from the journal one can understand who the teacher is by the way it is written and its content. The data in the journal comes from me. In the journal I documented my reflections on the process of my construction of concept maps, CoRes and all the discussions and feedback I had with Simon and Anna. Hoban, Butler & Lesslie (2007) argue that a journal should be a reflection of a researcher's events and thinking. Since I was looking into my own practice, reflecting was the most important aspect in this study. I used a journal mostly for writing what I had gathered in each of the sessions I had with collaborative team. The journal reflections in this study are presented in the chapter of results as reflections from discussions and are written in both narrative form and also shown as quotes.

3.5 Data collection

3.5.1 Data collection instruments

The complexity of teacher's knowledge cannot be captured by a single instrument (Kegan, 1990). Baxter & Lederman (1999) argued that assessment of PCK requires a combination of approaches that can collect information about what teachers know, what they believe, what they do, and the reasons for their actions. In this regard quantitative data was collected from concept maps. Qualitative data was collected from CoRes, concept maps and reflective journal. Three concept maps were constructed and three CoRes were done in the collection of data.

3.5.2 Data collection through concept maps

The aim of constructing concept maps was to assess and develop my content knowledge of meiosis. (Loughran *et al*. 2012) argue that concept maps enable the teacher to think about the content knowledge as the teacher asks questions about the concepts and how they are related to the topic. Concept mapping is grounded in a sound cognitive learning theory, Ausubel's assimilation theory (Ausubel, 1968; Ausubel, Novak & Hanesian, 1978) in Novak (1984). Assimilation theory posits that new knowledge can be learned most effectively by relating to previously existing knowledge. Novak & Gowan (1984) noted that the act of mapping is a creative activity, in which the learner must exert effort to clarify meanings, by identifying important concepts, relationships, and structure within a specified domain of knowledge. The activity fosters reflection on one's knowledge, providing a kind of feedback that helps students monitor their learning...perhaps with assistance of teachers and peers.

Based on my knowledge of meiosis, I constructed my first concept map. I listed the concepts that I thought were important in teaching meiosis. I then used the concepts to construct my first concept map. After I constructed my first concept map I gave it to Simon (critical friend) and Anna (content expert). I had discussed with the collaborative on the methods we were to use to score each of the concept maps. So when I gave them the concept map they were well versed with what to do. We then discussed the concept map together. Using the inputs from the discussion I had with the collaborative team (Simon and Anna), I reflected on them and documented my experiences, feelings and what I learnt from the discussions. I constructed the second concept map, sent it for discussion with team and I then constructed a third concept map which became my last. The discussion with Simon and Anna and the

documentations of my reflections were done on each of the three concept maps done. The discussions from team and my reflections informed the construction of the other two concept maps. In the discussions, we had to identify both correct and incorrect concepts as well as the correct and incorrect propositions. The discussion also was to draw from me the reasons why I had chosen these concepts as main concepts in meiosis.

3.5.3 Data collection through CoRes

After I had learnt about CoRes in first year of my master's course in 2012, I was so captivated with them so much that I decided that I could use CoRes as a tool for planning my lessons. The way the CoRes are structured showed me that when I use a CoRe, I will get an opportunity to think about what I will be teaching. However I had not yet used a CoRe in my teaching until this study. The use of a CoRe in this study was going to be my first attempt at using CoRes.

The literature reports that a CoRe was used to provide an overview of how a group of teachers worked to understand the teaching of the subject matter knowledge of a specific topic (Loughran *et al.*, 2011). Three CoRes were developed in this study. I developed the first CoRe based on my knowledge and experience of teaching the topic meiosis. The CoRe represented the way I had been was teach meiosis. In the construction of the CoRe, I again listed the concepts I had used in my concept map. I wanted these concepts to guide me in the construction of the CoRe. I used the concepts I had produced in my final concept map to help me formulate the big ideas by grouping related concepts. After I had listed the three big ideas, I then started to complete the prompts. I completed each of the prompts in each of the big ideas first before I go to the next prompt i.e. in the first prompt which says: what do you intend students to learn from this idea; I had to complete for each of the three big ideas I had. But as I continued to complete the other prompts I found out that I needed to keep going back to some of the prompts I had completed for ideas and additions. The CoRe could not be completed in one sitting. Often when I thought I had completed the prompt, some of the information I had included seemed not in agreement with what the prompt was seeking and I had to delete.

After I had completed constructing the first CoRe, I then sent it to the team (Simon and Anna); I then met the team to discuss the CoRe. I presented to the team the framework I was going to use. Table 3:1 below shows the framework I presented. The framework was adapted from Mavhunga and Rollnick (2013). The adapted framework was then modified to suite my

study. I wanted the framework to take into account the big ideas which were used in my study, the teaching strategies and the representations which I wanted my research to bring out. In Mavhunga & Rollnick (2011) framework, big ideas and teaching strategies were not used. It is the big ideas and teaching strategies which were fundamental in my study. In the discussion we deliberated on what is meant by curricular saliency as used in the framework. In this study as in Mavhunga and Rollnick (2013), curricular saliency includes the big ideas in the CoRe and the first three prompts of the CoRe. We agreed to the meaning of curricular saliency as adapted. We then discussed each of the other components of the framework and agreed. We had to agree on what to consider constituting prior knowledge and what not should be considered as prior knowledge. We discussed on the aspects considered to be making the topic difficult to learn as well as the teaching strategies which should be considered as appropriate. Table 3 below shows framework used to analyse the CoRes.

Table 3: CoRe components adapted from Mavhunga and Rollnick (2013)

Components forming the analytical framework
A. Curricular saliency
A1. Identification of big ideas - adapted*
A2. What is it I intended learners to know – original
A3. Why is it important to know – original
A4. What I knew about meiosis which I did not want learners to know yet - original
B. Student prior knowledge
B1. What are typical students thinking or misconceptions when teaching this big idea? – original
C. What makes the topic difficult or easy to understand?
C1. Difficulties/limitations concerned with teaching the idea - original
D. **Teaching strategies**
D1. What effective teaching strategies would you use? - adapted*
D2. What questions would you consider important to ask in your teaching strategies? - adapted*
E. **Representations**
E1. What representations would you use in your teaching strategies? - adapted*
E2. What specific ways would you use to assess students understanding? - original

*Key: The word adapted means that the statement was not in the original CoRe of Loughran *et al.* (2012)

After I had given the CoRe to the team, the team then gave me feedback. I reflected and commented on the feedback and then analysed the CoRe using the framework. I used the feedback to construct the second CoRe. After I had constructed the second CoRe, I gave it again to the team which then gave me feedback. I again reflected on the feedback and commented on it. The feedback informed the construction of the third CoRe and again took it through the steps I had done with CoRe 1 and CoRe 2.

3.6 Data analysis

3.6.1 Analysis of concept maps

Analysis was both qualitative and quantitative. A scoring method was used to score concept maps. Scoring a concept map is assigning scores in the form of numbers based on certain scoring strategies. However there is no commonly accepted way of scoring concept maps. The literature however agrees on some approaches that are more or less subjective (Keppens & Hay, 2008). Some of these scoring strategies are: considering the closeness of a concept map with a master map (a concept map from an expert), number of concepts, number of relationships, number of valid propositions, shape of concept maps and graph based measures. The weighted sum of all these approaches could be used as the final score. In this study, three concept maps were compared. The analysis of the three concept maps was based on the number of propositions and the number of concepts in each concept map. For each proposition and for each concept, one mark was assigned. Canas *et al.* (2003) posit that this scoring technique does give a great deal of information on the map creator's knowledge structure. I presented my scoring system to Simon and Anna for discussion. We went through each of the proposed scoring methods one at a time so as to have a common understanding of what constitutes a concept and a proposition. We also discussed and agreed on the mark to be allocated for each score. An agreement was then reached on the scoring method chosen. I then scored my concept map. The concept map was then sent to Simon and he also scored it. I also asked Simon to score to improve validity of the scores. We discussed our scores, compared and agreed. The scoring system was adapted from Novak & Gowin (1984) who argue that the counting of propositions and concepts is one of simple ways of measuring concept maps. This view agrees with Shavelson, Ruiz-Primo & Wiley (2005) who posit that one quantitative method of scoring concept maps is counting the number of propositions.

The scoring also considered correctness of the propositions for content validity. Content validity refers to the correctness of a concept in relation to other concepts. This is in agreement with Kharatmal (2006) who said that concepts and linking words both form the unit of analysis for the content validity. Correctness is the accuracy of all of the links that are written down. In assessing correctness I and the team considered the number of correct links made in relation to the quality of the link statements and the number of concepts or nodes.

3.6.2 How I analysed my first concept map

Figure 3 below shows part of the first concept map and how it was scored. In the figure, boxed words were meant to represent concepts for example: (1) Nuclear division (2) Crossing over and (3) Genetic variation. Examples of valid propositions are two boxed concepts with a word or phrase in between them. These include: Meiosis —is a → nuclear division; and crossing over — provides → genetic variation.

The word meiosis and nuclear division are two concepts. When these two concepts have a word in between them they then form a proposition.

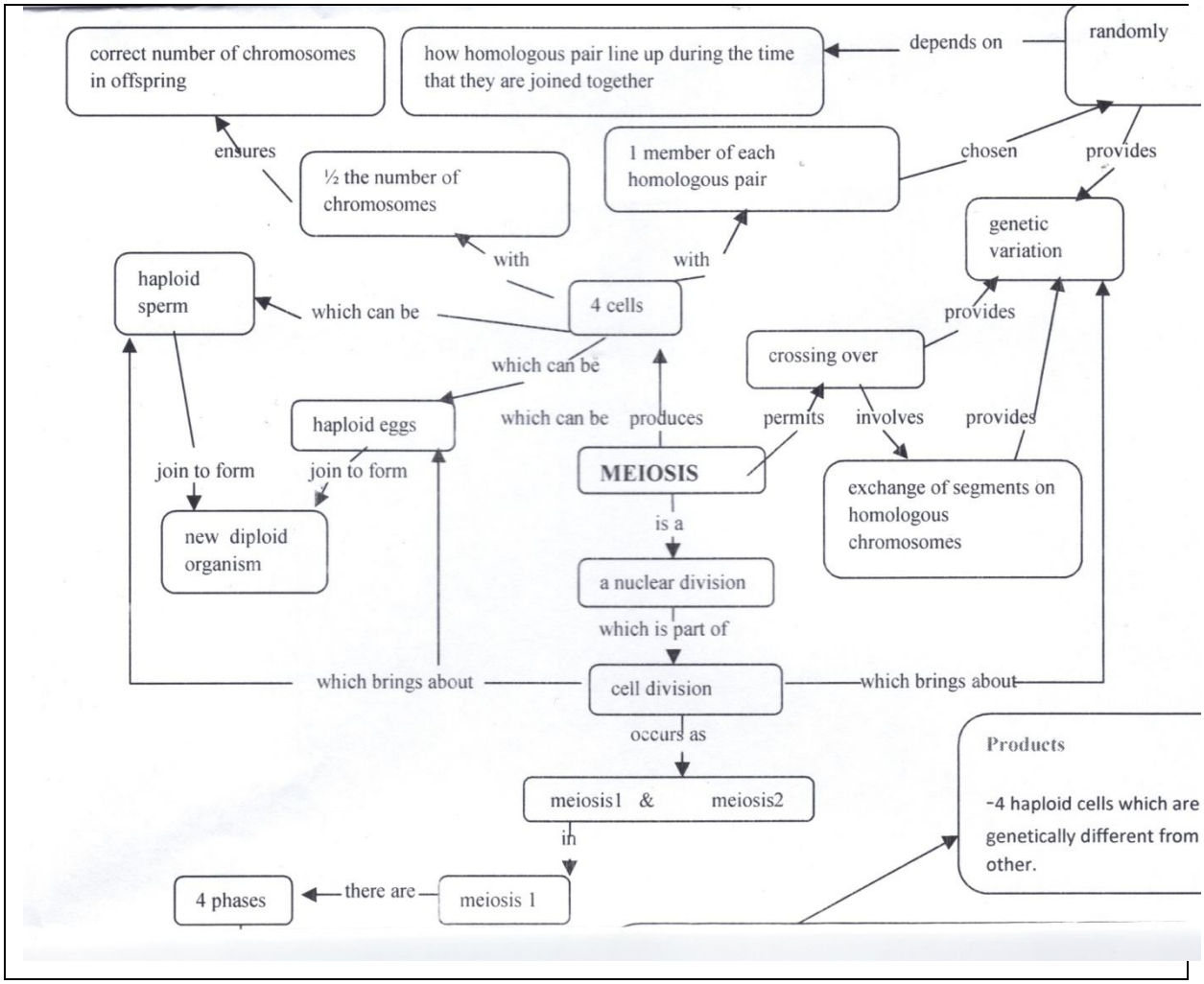


Figure 3: Part of concept map showing concepts and propositions

3.6.3 Data analysis of CoRes

When a specific topic is thought through when a CoRe is used, certain topic specific components of PCK are considered. This study adapted five of the specific components as used in Rollick & Mavhunga (2013). The components are (i) Learners' Prior Knowledge, (ii) Curriculum Saliency (deciding what is important for teaching and sequencing). According to Mavhunga & Rollnick (2013), curricular saliency is reflected in the CoRes' big ideas and the first three prompts of the CoRe which are: what is important to learn about the big idea, why it is important to learn and what else the teacher knew about the big idea I did not want learners to know yet. All these prompts are about content and curricular saliency is also about content. (iii) What makes topic easy or difficult to understand, (iv) Representations including powerful examples and analogies and (v) Conceptual Teaching Strategies. These five components formed the framework through which the CoRes were analysed. These five

components are adapted from Mavhunga and Rollnick (2013) are originally from Loughran *et al.'s* (2006) CoRe.

A total of three CoRes were constructed and analysed using the above framework. As was explained in section 3.6.3 above, after constructing each CoRe I gave it to the team which then gave me feedback. I reflected on the feedback. I then used the feedback to construct each f the next CoRe. The data analysis of the CoRes was done to portray the development of my CK from the construction of one CoRe to the other. The components helped to analyse the manifestations that occurred throughout the study.

3.7 Ethical Issues

Ethical concerns are about the rights of the subjects and the researcher getting the truth McMillan & Schumacher, 1993). The researcher must not violate the participant's right in order to get the truth. In this study since I was the main participant, I did not need consent letters to parents. However I had to get the Ethics Clearance letter from Wits School of Education and another letter to approve the research from Gauteng Province Department of Education.

3.8 Validity

Validity is about the research tool actually measures what it is supposed to measure (Scaife, 2004). It shows the link between result explanations and what really happened in the study.

According to Schumacher and McMillan (2010), validity of qualitative research measures the extent at which the researcher's interpretations have a mutual meaning as those of the participants. Since qualitative research relies on interpretations and using multi-methods to assist with the triangulation. In this study I used a reflective journal, collaboration team for triangulation to ensure credibility. In a self study, according to Bell (1999), validation should be an ongoing process**.**

3.9 Conclusion

In this chapter I highlighted how I would collect and analyse the data collected using concept maps and CoRes. I also showed the purpose of the reflective journal I used to document some of feelings and tensions I experienced during the discussions I had during feedback on both concept maps and CoRes. The next chapter presents the findings and the discussion of the findings of the study.

CHAPTER 4

PRESENTATION OF FINDINGS AND DISCUSSION

4.1 Introduction

This chapter has two sections. In the first section, I present the findings from the construction and analysis of concept maps. In the second section I present the findings from the use of CoRes as planning tools. The study was seeking to answer the following research questions:

(a) How does the use of concept maps improve my content knowledge of meiosis?

(b) How does the use of Content Representations (CoRes) as planning tools improve my Pedagogical Content Knowledge (PCK) for teaching meiosis?

Section A

4.2 Analysis of and presentation of findings from concept maps

As described in chapter 3, three concept maps were constructed. There was no specific number of concept maps which I had initially planned to construct. The construction of concept maps two and three was a result of what came out of the discussions I had with my collaborative team.

As explained in chapter 3, there is no single scoring method which can accurately describe all different forms of information in concept maps (Novak & Gowin 1994). In this study only two methods of assessing a concept map were used, which are; counting the number of concepts and the number of propositions. Counting the number of concepts and the number of propositions were opted for because they offer a simple way of assessing understanding (Schwendimann, 2006). I then agreed with Simon and Anna on the definition of what constitutes a proposition and what a concept is. A concept according to Novak (1984) is a pattern or a symbol which describes and explains the way something works. In meiosis concepts are words or phrases or terms which help to describe meiosis so that it can be understood such as haploid cell or segregation of chromosomes. A proposition is made up of two concepts and a word or a phrase in- between them such as:

Meiosis — in which occurs ⟶ crossing over.

Below I present the concept maps one by one. The presentation of each of the concept map is followed by the presentation of the outcomes of a discussion that I had with the team on the concept maps. The presentation of outcomes of the discussion with the team is then followed by my reflection.

4.2.1. Concept map 1

The first concept map was constructed based on the knowledge I had since I had taught meiosis for more than fifteen years. Figure 4 below shows my first concept map.

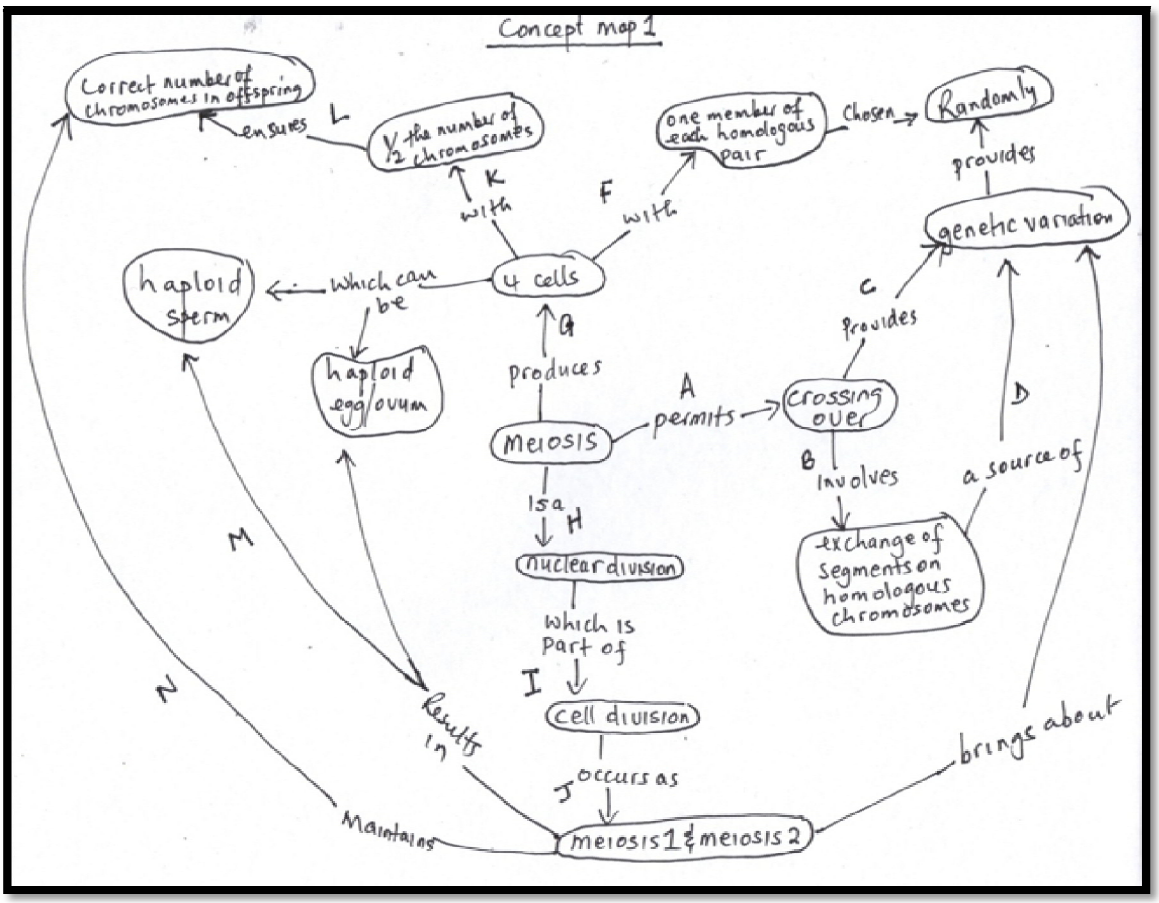


Figure 4: Concept map1

Key: Circled words or phrases indicate concepts and letters indicate propositions. [1]

[1]In concept map 2 and concept map 3 these letters are not shown again. These letters are meant to show the reader what a proposition is.

4.2.2 Discussion of concept map 1 with the team

I showed my concept map to the team. The first comment came from Anna, "*Can we revisit our definition of what a concept is because I am not in agreement with the way you have identified your concepts. Define what a concept is for me?"* I took time thinking of what to say and then I mentioned the word random as an example of a concept. Then she said *"I am not surprised because some of the words in your concept map are not concepts at all."* After further discussions, I then said in response to what Anna said, ***'I now see what you are talking about. What I am assuming to be concepts are the words I use in my teaching.***' I checked my concept map and saw the word random. '***Actually random means something on its own but it is not a concept'.*** Anna was very correct. 'Random' is not a concept at all on its own. I began to see what Anna meant and I then loudly asked myself this question, ***'What would I want learners to know from the word random?'*** As we continued to discuss the concept map, I discovered that most of what I had 'boxed' as key concepts were not concepts at all. See appendix A 1.

My concept map had only seven concepts which could be considered as correct concepts of meiosis which are; meiosis 1, meiosis 2, genetic variation, haploid sperm, haploid egg, nuclear division and crossing over. Even though I had identified seven concepts which could be accepted as concepts, some of the words I had considered to be concept which include; 4 cells and one member of each homologous pair are on their own not concepts at all. Simon: *"Meiosis is about chromosomes and so the concept 'chromosome' cannot be left out. The list can be extended."* Even some of the propositions I had in this concept map are not correct. An example of a proposition whose meaning was not clear is proposition labelled K which is:

4 cells — with → one member of homologous pair.

Such propositions like one shown above do not show a clear understanding of links between concepts or they fail to bring out meaning of the proposition. Simon: *Your concept map has very few concepts and some of the propositions do not create meaningful links. Can you think of why you could not list the concepts on meiosis and why you created the kind of links that you have in your concept map?*

4.2.3 Reflections from the discussion

I used the teams' comments and questions to reflect on my first concept map. As I reflected I wrote: '*Why did I fail to identify concepts? Are these the only concepts I know for all these*

years I have been teaching this topic?' The exclusion of words like chromosomes, haploid sperm or haploid egg show that I had not applied the kind of thinking that would result in the identification of the concepts. In my concept map, I had identified very few correct concepts and made very few correct links. *'What is causing this?'* When I directed this question to Simon, his response was: "One possible cause could be the way you teach. Reflect on how you teach meiosis and see if there is any link to the way you have constructed your concept map" When I reflected on my teaching of meiosis, I realised that the way I had been teaching meiosis could be the reason for struggling to define and identify concepts. My teaching was based on defining what meiosis is, describing the phases involved such as meiosis 1 and the events taking place in each of the phases such as in (Prophase 1, Metaphase 1, Anaphase 1 and Telophase 1) and identifying the products. Though it is correct to describe what will be happening in each of the phases, it does not bring meaningful learning. Anna referred me to the work by Ball *et al* (2008) on content knowledge. From the Ball *et al.* (2008) I came to understand that just giving definition of meiosis and describing the process and products is what Ball *et al*. (2008) called common content knowledge which the teacher possesses and is found in textbooks. Any other person who at some point learnt meiosis can define meiosis and describe the process. Common content knowledge is all I have been teaching to my learners. I was not sitting to think deeply about the concepts I should include as I teach. I think the assumption I had was that there was nothing more than the definition of meiosis, the process and products which learners needed to know. The way the topic on meiosis is presented in the lesson plans given by the Department of basic Education (2014) could also have made me to follow them as strategies of teaching without thinking at all. Many other teachers might also be trapped in the thinking I had. My teaching was based on following the topic as presented in textbooks. It was only through the discussions I had with the team that I began to see that it was not that I did not know the concepts for example the concept chromosomes. I was always using the word chromosomes throughout the teaching of meiosis but what I did not know was that the word chromosomes is a concept that I was supposed to identify and make sure students know and understand what it is and its purpose in meiosis. This is the specialized content knowledge which Ball *et al.* (2008) identified as knowledge needed for the purpose of teaching. Lack of specialized content knowledge is what caused the serious exclusion of key concepts like 2 nuclear divisions, homologous pair; segregation of chromosomes, gametes and diploid cell in my first concept map. My teaching was just summarising meiosis. I was so confident with what I knew about meiosis since I had taught the topic for many years. I thought I knew meiosis so well that I did not require time to

consult other textbooks or think deeply about it. I was not focusing and thinking on what is important about meiosis. My focus was just on defining what meiosis is, the processes involved and the products. '*So this is rote learning kind of teaching I am doing?*' One other factor which caused my failure to identify concepts was that I did not know much of what a concept map is and how to construct one. Poor knowledge of what concepts are and how to construct a concept map is what led Anna to say, *"I am not surprised because some of the words in your concept map are not concepts at all."*

4.2.4 Concept map 2

To construct concept map 2 I needed to incorporate the concepts that were missing in my first concept map. I needed to think deeply about concepts which are important to know. Concept map 2 is shown in Figure 5 below.

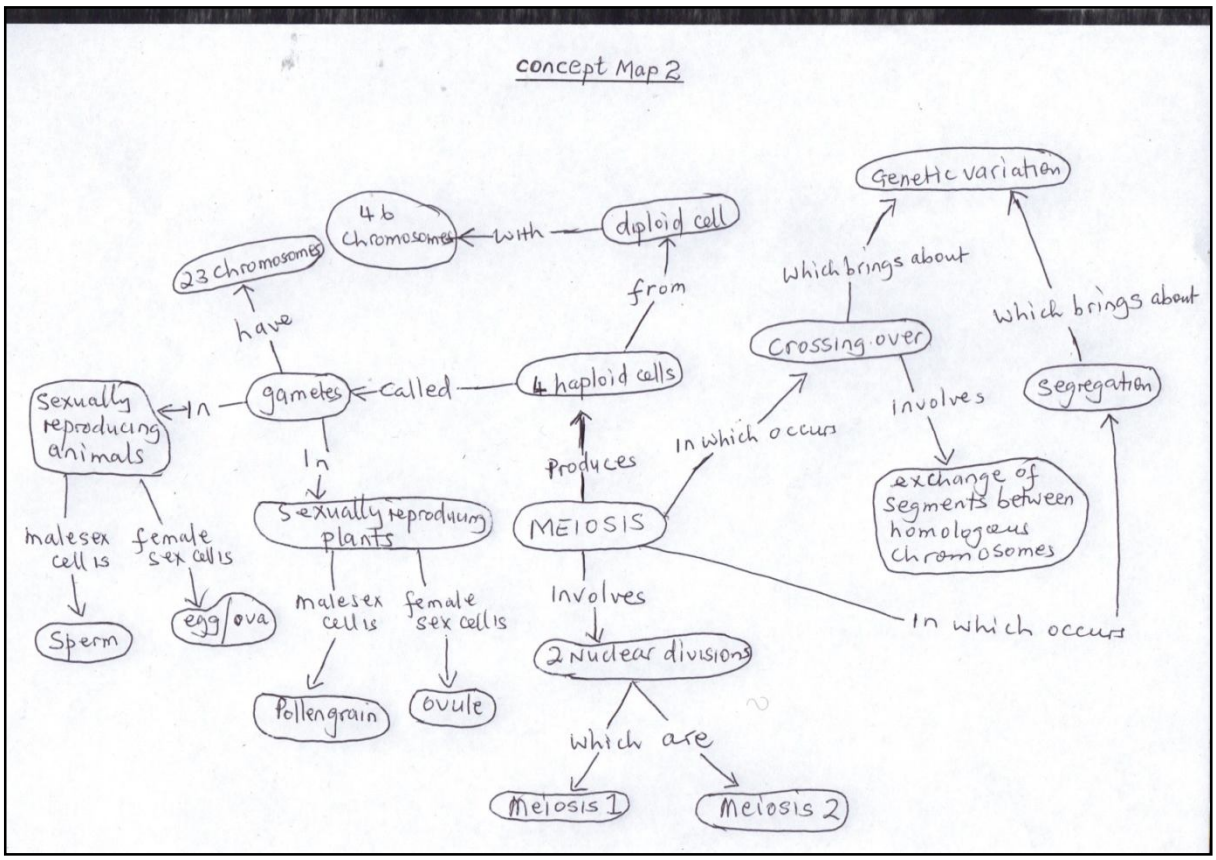


Figure 5: Concept map 2.

I then constructed the second concept map incorporating the new ideas I got from recommendations from the team and my serious thinking of concepts I had to do.

4.2.5 Discussion of concept map 2 with the team

After I had constructed my second concept map, I again presented the concept map to the team. As we discussed the second concept map, it emerged that my concept map had some propositions which the team commended as correct; such as meiosis produces four haploid cells and meiosis involves two nuclear divisions. Anna however identified some elements of misconceptions in my concept map. Some of the comments from Anna were in connections with propositions such as:

Meiosis — produces → (4 haploid cells) — from a → (diploid cell) — with → 46 chromosomes.

Presenting such a proposition as one above gives an impression that meiosis occurs only in humans. Anna said *'If you want to bring out 46 chromosomes then you should specify that it is only in humans. If it is not clarified then some learners will have the misunderstanding that in all organisms where meiosis occurs, they will have forty six chromosomes'*. It is only when someone raises such an observation does one begins to see how important it is to be explicit. Anna*: Meiosis does not occur in humans only*.

As the discussion continued, Anna commented, '*I have an issue here. This is a misconception that you highlight. When we talk of meiosis we don't talk of cells but talk of nuclear division'*. I began to see something I had not considered important for many years and then I said, ***'Oooh! That's why we say meiosis is a nuclear division not cell division'.***

Simon commented about the proposition which says:

Meiosis — in which occurs → crossing over.

The proposition 'meiosis in which occurs crossing over' is correct when standing alone. However when placed where it is in concept map 2 it will appear like crossing over occurs often throughout meiosis yet it occurs only in meiosis 1 and in Prophase 1. This made me then to see the need to reorganise the concepts in my concept map so that related concepts stand on their own. Further misconceptions were highlighted on the propositions such as: *Meiosis — produces → 4 haploid cells.*

This proposition sounds very correct but meiosis literature spells out that meiosis ends with Telophase 2. Telophase 2 ends when two groups of chromosomes reach the two poles of the cell. The proposition gives the impression that cytokinesis is part of meiosis. Cytokinesis is

not part of meiosis. '*These are some of the things I had not considered important'*. I said. From the discussion I realised that I needed to construct another concept map to correct what the team had highlighted. I also needed to regroup some of the concepts in my concept map. See appendix A 2. The whole section which has concepts crossing over, genetic variation, exchange of segments between homologous chromosomes and segregation must appear under meiosis 1. '*So there is need of rearranging concepts to show understanding of how concepts are related. I have not been thinking about grouping related concepts all along'*.

4.2.6 Reflections from the discussion

As I was reflecting, I wrote in my journal: '*So it is very easy in teaching to omit small but important information which can cause misconceptions.* That meiosis ends with cytokinesis is some of the subtle knowledge I have always taken for granted. The importance of being specific only emerge when asked such questions like, does meiosis occur only in humans? It is only when such a question is asked does one begin to see the importance of exposing one's teaching to others in the same discipline. The team helped me to pick up small but important omissions which can result in misconceptions. *Why is it that I do not discuss with the teacher I share the grade with then? I need to point out these ideas to my colleague.* Pointing out such minute detail should not be taken by a colleague to mean that one does not know but it is just to remind each other on subtle important special content knowledge which needs to be made specific when we teach.

4.2.7 Concept map 3

The discussion and reflection from concept map 2 informed the construction of my third concept map which became my last. Figure 6 below shows concept map 3.

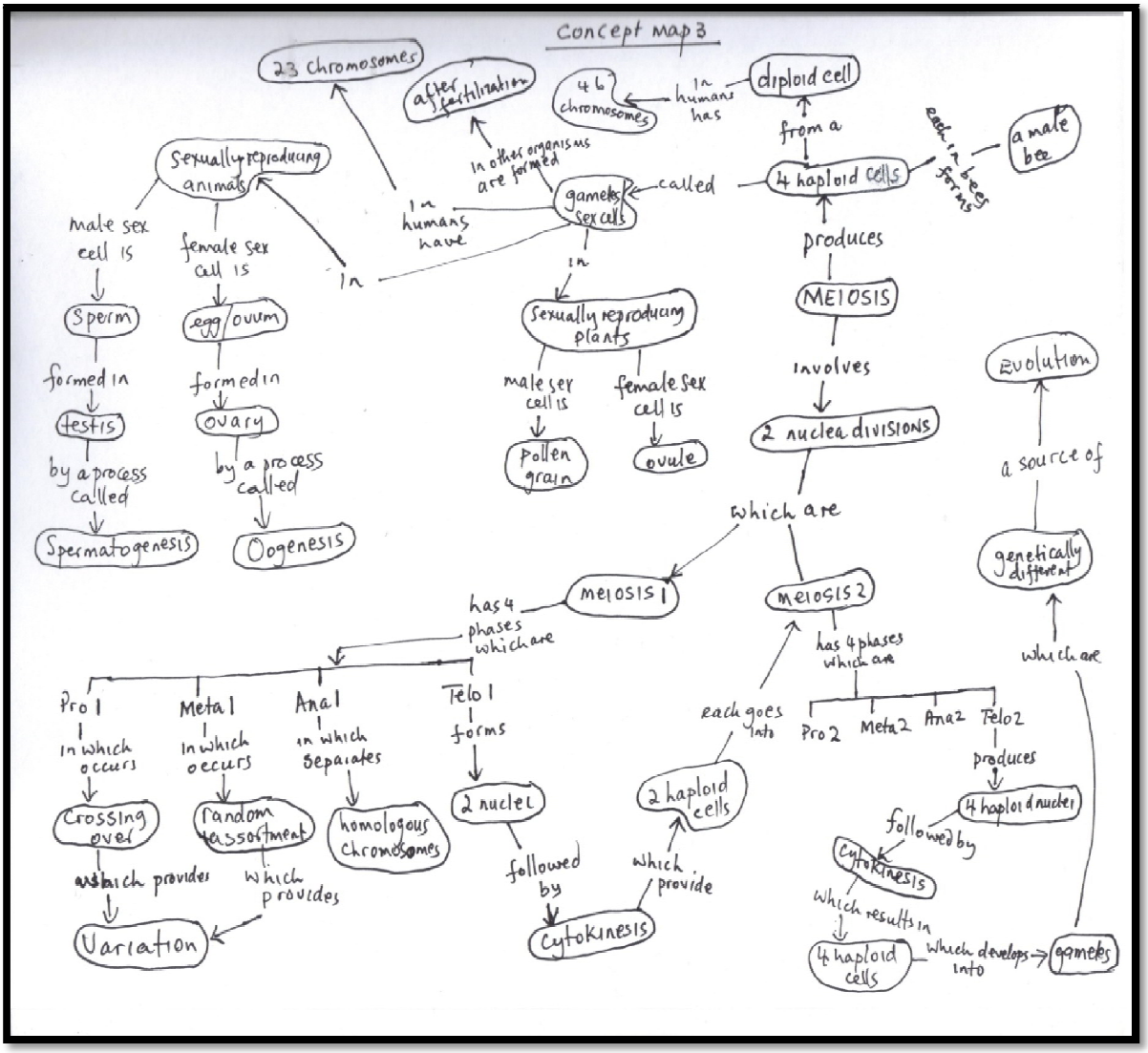


Figure 6: Concept map 3

4.2.8 Discussion of concept map 3 with team

Simon: *'Do you now see that if you understand what concepts are you can continue to add more meaningful related concepts to your concept map?*' Was the first comment I got. We agreed that concept map 3 now shows more concepts than concept map 2. See appendix A 3. We also agreed that the concepts were no longer scattered like in concept map 2 and that the propositions were more descriptive compared to the first two concept maps. *'You have now*

reorganised your concepts that anyone can follow the relationships they have'. However some few additions were proposed by the team. Some of the proposed additions were on the inclusion of the concept cytokinesis; and that I should specify that 46 chromosomes are in humans. The propositions were then incorporated.

4.2.9 Reflections from discussions

The increase in both the number of concepts and propositions is attributed to the inputs and recommendations I received from the team I worked with and from my critical thinking. It was now evident that it is only through thinking that I was able to reorganise concepts and to add more concepts which I had left out in my previous concept maps to improve my content knowledge and understanding of meiosis. The specific content knowledge for teaching a specific topic makes features of particular content visible to and learnable by students (Ball *et al.* 2008). In this study the process of construction of concept maps and discussing them with others who are experts in the field helped me to identify what Ball *et al*. (2008) called specialised content knowledge for example that it is important to make explicit that meiosis ends with Telophase 2 not with cytokinesis.

4.2.10 Final discussion on concept maps

In this self-study concepts and propositions in a concept map formed the basis for measuring my content knowledge.

From concept map 1 through to concept map 3, there are three aspects about my knowledge of meiosis which emerged. The three aspects are: (1) At first I was not aware of the main concepts and the relationships between them. Failure to identify concepts was because it is very difficult to identify the concepts from the textbook I use daily. One needs to think critically and purposefully to identify the concepts. I did not have the kind of content knowledge which a teacher should have for teaching a specific topic. Knowledge of main concepts does not develop automatically through teaching. Knowledge of main concepts develops when one thinks critically and purposefully about the topic to be taught. It is the critical and purposeful thinking and through teaching which results in the development of content knowledge for teaching. (2) Construction of concept maps helped me to identify the main concepts and related concepts on meiosis and to reorganise my content knowledge in meaningful ways. The organisation of concepts is critical for a teacher because that is the knowledge which makes features of particular content become visible and learnable by

students. Teachers who do not have well organised content knowledge may find it difficult to give effective representations in their teaching. (3) Simon made me to think about what it is that I am learning and to see the raw content knowledge I had. The construction of concept maps and discussing them with experts revealed some of the salient misconceptions that I held. Such misconceptions can only be identified if you expose your content knowledge to others in one way or another. Concept mapping is one way of doing that. It however makes you very vulnerable.

The construction of concept maps helped me to identify 'small bits' of information that if emphasized during teaching will promote a better understanding of content. Examples of those bits of information include; chromosomes (what they are and what they do) and that cytokinesis must not be taken as part of meiosis. If emphasised during teaching it will bring a better understanding. Such information is not made explicit in textbooks. Textbooks do not spell out explicitly these bits of knowledge. Knowing such bits of knowledge shows the type of content knowledge for teaching that Ball *et al.* described as specialised content knowledge. While Ball *et al.* (2008) argued that this type of knowledge can only be identified during teaching; I became aware of it through constructing concept maps and discussing them with experts. While in my study I discussed the concept maps with an expert and my supervisor, the same can be achieved by discussing with colleagues in the same subject discipline.

4.3 Quantitative data for the three concept maps

In this self-study, the purpose of constructing the concept maps was to assess the breadth and correctness of my content knowledge. The above discussions (section 4.1) were all about quality and correctness of the concept maps. After I had qualitatively described and discussed the three concept maps with the team, I then had the knowledge of the concepts which were correct. Now I wanted to see the quantity of the content knowledge I had developed. I then quantitatively compared the three concept maps. To begin with, I compared the number of concepts and the number of correct concepts in each of the three concept maps and scored them (see chapter three on how I did it).

Table 4: Concept map scores

Concept map number	Number of concepts	Number of correct concepts
1	14	7
2	19	12
3	27	26

According to Abbott (2014) and Novak (1984) concepts and propositions are measures of one's content knowledge. Table 4 above shows the summary of the three concept maps.

From table 4.1 above, it emerged that there was a large increase in number of correct concepts from concept map 1 through to concept map 3 which is observed.

Though it shows that there are fourteen (14) concepts in concept map 1, some of the concepts in concept map 1 are not valid concepts such as 'random and 4 cells'. Only seven of the concepts in concept map 1 were considered correct. However the number of concepts which were correct showed some significant increase in concept map 2, which has twelve and concept map 3 which has twenty six. The correct concepts in each concept map are shown in Table 5 below.

4.4 Concepts as a measure of content knowledge

As highlighted in chapter two, content knowledge can be measured in terms of concepts, relationships, ideas and propositions. In terms of concepts my first concept map shows that I had recalled only **seven** concepts from my teaching (see table 4). These seven are the concepts I could identify. I was not critically thinking about the concepts at all. As I developed my second concept map the number of concepts increased to **twelve**. My third concept map shows that I had **twenty six** correct concepts (see table 5). The number of concepts developed in each concept map is a measure of content knowledge one has for a particular topic as is argued by Koehler (2011); Abbott (2014); Novak (1984).

Table 5: Some correct concepts in concept maps 1, 2 and 3

Correct concepts in concept map 1	Correct concepts in concept map 2	Correct concepts in concept map 3
1. meiosis	1. meiosis	1. meiosis
2. nuclear division	2. 2 nuclear divisions	2. 2 nuclear divisions
3. crossing over	3. crossing over	3. crossing over
4. genetic variation	4. genetic variation	4. genetic variation
5. haploid	5. 4 haploid cells	5. 4 haploid nuclei
6. exchange of segments on homologous chromosomes	6. exchange of segments on homologous chromosomes	6. exchange of segments on homologous chromosomes
7. cell division	7. segregation	7. segregation
	8. diploid cell	8. diploid cell
	9. gametes	9. gametes
	10. 23 chromosomes	10. 23 chromosomes
	11. meiosis 1	11. meiosis 1
	12. meiosis 2	12. meiosis 2
		13.cytokinesis
		14.homologous chromosomes
		15. random assortment
		16. 46 chromosomes
		17. sexually reproducing Animals
		18. variation
		19. sperm
		20. egg/ovum
		21. testis
		22. ovary
		23. spermatogenesis
		24. Oogenesis
		25. ovule
		26. pollen grain

4.5 Correctness

Although the team had looked at the correctness and quality of my concept maps, I decided to quantify the concept of correctness. My reason for quantifying the correctness of the propositions was to have the visualisation of the improvement in the quality of my content knowledge and the level of accuracy of my knowledge. Table 6 below shows the comparisons of the links forming propositions in each of the three concept maps. Table 6 is adopted from Rollnick et al. (2008)

Table 6: Results showing comparison of links forming propositions adapted from Rollnick et al. (2008)

CORRECTNESS OF PROPOSITIONS						
Concept map number	Number of propositions	Missing or incorrect link	Link with no linking word	Link that represent superficial idea	Link representing an idea that is scientifically acceptable but could be clarified	Link with detailed and sophisticated understanding that is scientifically rich
1	14	4	0	3	3	4
2	19	1	0	0	4	14
3	32	0	0	0	6	26

Example of each type of link:

1. Incorrect link: Genetic variation — provides → randomly

2. Links that represent superficial ideas: 4 cells — which can be → haploid sperm

3. Links with detailed and sophisticated understanding that is scientifically rich:

Meiosis — produces → 4 haploid nuclei — called → gametes — in human have → 23 chromosomes

From table 4.3 it can be seen that concept map 1 has the lowest score in correctness. The reason attributed to the lower score is that it had many incorrect links and represented superficial ideas. The higher score in concept map 3 relative to both concept maps 1 and concept map 2 is because of the more links of higher quality. Table 4 shows that correctness increased when the number of links is greater than the number of nodes in each particular concept map. According to Kinchin and Hay (2000) a concept map that displays a high level

of connectedness shows the ability in understanding the following two properties: The representation of one's mental model and the organization of ideas.

In both concept maps 1 and 2 the concepts are less than the links. This also shows that connectedness of the concept maps increased from concept map 1 to concept map 3. The fact that I had more valid links and cross-links in the third concept map, which led to more connectedness, suggests that I was able to think more deeply about the content.

In all the concept maps, the numbers of propositions were increasing from one concept map to the other. This was caused by the fact that in most of the cases, some concepts had more than one link.

4.6 Relationships as a measure of content knowledge

An understanding between the relationships between concepts is also considered to be an indication of content knowledge acquisition (Abbott, 2014; Koehler, 2011). In this study a proposition represents a link between two concepts and therefore it is a representation of a relationship between two concepts. In my first concept map I only had **four** links (propositions) with detailed and sophisticated understanding that is scientifically rich (see table 4) The links were; crossing over involves exchange of segments on homologous chromosomes, meiosis is a nuclear division, crossing over provides genetic variation and the exchange of segments on homologous chromosomes is a source of genetic variation. These relationships were the only ones I had identified. The number of the relationships or links with detailed and sophisticated understanding that is scientifically rich then increased to **fourteen** in my second concept map (see table 4). Some of the rich links include; meiosis can result in four haploid cells, two nuclear divisions which are meiosis 1 & 2 and four haploid cells called gametes. In my last concept map 3 (table 4) shows that the number of links which show detailed and sophisticated understanding that is scientifically rich had rose to **twenty six**. Some of the understanding which is scientifically correct includes; genetically different cells called gametes, gametes in sexually reproducing animals the female gamete is called egg/ovum in animals and a detailed link of meiosis 1 showing the four phases and what happens in each of the phases. My content knowledge of meiosis shows some development from concept map 1 through to concept map 3.

4.7 Conclusion on concept maps

The use of concept maps in this self-study has helped me to gain some specialised content knowledge from the common content knowledge which I initially had. Development of this specialised content knowledge helped me to understand the topic on meiosis better. It helped me to develop subject matter knowledge which is unique for teaching a specific topic. Initially I had common content knowledge which developed to specialised content knowledge through the constructing concept maps. I am now aware of what I need to make explicit when I teach. The common content knowledge I had, had reduced my teaching to rote teaching which may promotes misconceptions and rote learning.

Section B

In this section I described my analysis of CoRes and presented the findings. The purpose of constructing CoRes was to answer the following research question:

(b) In what ways does the use of Content Representations (CoRes) as planning tools improve my pedagogical content knowledge for teaching meiosis?

4.8 The analysis of CoRes

As described in chapter 3, three CoRes were constructed. The number of CoRes constructed were not pre-determined but directed by the team. The CoRes were analysed qualitatively as explained in chapter 3. The CoRes were analysed using five specific components of PCK. The five components of PCK used were adapted from Mavhunga & Rollnick (2013). The components are: (i) Learners' Prior Knowledge, (ii) Curriculum Saliency which covers the first three prompts of the CoRe which focus on content to be known by learners (what do you intent learners to know, why is it important for students to know this and what else you know about the idea that you do not intent learners to know yet). Curriculum saliency also included identifying the big ideas as in the CoRe (Mavhunga & Rollnick, 2013) (iii) What makes topic easy or difficult to understand, (iv) Representations including powerful examples and analogies and (v) Conceptual Teaching Strategies (teaching strategies). These five components formed the framework used to analyse the CoRes. These five components are closely related to the eight prompts used in Loughran *et al.* (2006). A prompt is a statement which seeks to unpack the science teachers' understanding of what matters in a particular content area and why (Loughran *et al.* 2006). Some of the categories mentioned above accommodated one or more of the prompts as used by Loughran *et al*. (2012). The first three

prompts speak of the content knowledge which needs to be known by learners. Table 7 below presents some guidelines to show the components of PCK used and their explanations as considered during the analysis.

Table 7: Overview of the five components and their explanations

Component	Explanation of component
Curricular saliency	I needed to identify the content in terms of concepts that I would teach and organise it into meaningful ways. I would do it by: (a) identifying the big ideas in meiosis (b) identifying what I intended learners to learn and why
Student prior knowledge	(a) I needed to identify the students' conceptions or prior knowledge about meiosis.
What makes the topic easy or difficult to learn	(a) What I needed to identify are the concepts which I think make the understanding of the topic difficult.
Teaching strategies	(a) I needed to identify suitable teaching procedures I could use for students to better understand the topic (b) what questions I would consider important to ask in the teaching of the big idea.
Knowledge of representations	(a) I needed to identify suitable examples and models which make the abstract concept of meiosis be understood by learners. (b) To identify ways to use to assess students' understanding

After the construction of each CoRe, I met and discussed with the team. Below I present the CoRes one by one. Each CoRe was analysed using the five components mentioned above.

4.8.1 Construction of CoRe 1

Based on the knowledge I had gained in using CoRes in my studies of the CoRes in my Masters courses, I studied how the topic on meiosis was presented in the text book that I use daily with my class to determine 'big ideas'. After I went through the topic as laid down in the text book, I again referred to my concept map on meiosis to see if I could use the concepts I had identified to produce big ideas. Even though I critically studied the concept maps I had produced, identifying the big ideas was not easy. The process was challenging. I could not

group the concepts I had used in the concept map to formulate big ideas. Reorganizing the concepts from the concepts was a mammoth task. I could not decide on which concepts to use to formulate big ideas. Eventually I resorted to following the topic layout in the textbook. The textbook layout is easy to follow as there are only three aspects one needs to look at when teaching meiosis. I decided on three aspects of meiosis I could use as 'big ideas' which are: (1) What is meiosis? (2) Processes involved in meiosis and (3) Products of meiosis. I then started completing the prompts in the CoRe. At first I thought it would be easier to complete each prompt for each of the identified big ideas but as I continued, I discovered that a lot of thought was needed. A lot of knowledge of meiosis was important. I had to read the textbook for information and often the textbook did not have the information I could use to complete the prompts. To complete the prompts of each of the big idea, I had to keep on moving forward and coming back again with more information on different aspects of the prompts. This required me to read lots of textbooks and articles on meiosis. It is only from different reading material on meiosis where I could get some information I could use to complete prompts. In some of the prompts I could not get information to write so I left them blank. After I had completed the prompts for each big idea, I then met the team to discuss the CoRe. See comments written on CoRe 1 under appendix B 1 – CoRe 1.

Table 8: CoRe 1

Grade 12 Life Science (Meiosis)	**Important science ideas/concepts**		
	What is meiosis?	Processes involved during meiosis.	Products of meiosis
What do you intend <u>students</u> to learn from this idea.	-That meiosis is a nuclear division that in humans occurs only in male testes and female ovary tissues. (It also occurs in plants), and is characteristic of sexual reproduction. -In meiosis the nucleus divides twice unlike in mitosis -That meiosis involves the division of a single parent diploid cell to produce four daughter haploid cells. -That meiosis is a reduction in the amount of genetic material – that is one half the original genetic material of the original cell. -That meiosis is different from mitosis. -That meiosis is the great process that shuffles the cell's genes around.	-Learners to know that meiosis involves two phases meiosis 1 and meiosis 2, which makes it different from mitosis. -That the phases of meiosis are not stagnant as might be portrayed in books, it is a cycle of the cell. -That the behaviour of chromosomes is different at each phase.	-That at the end of meiosis four haploid cells which are genetically different are produced.
Why is it important for students to know this?	-That meiosis facilitates stable sexual reproduction; it keeps the number of chromosomes from doubling each generation. -Without the halving of number of chromosome, fertilization would result in zygotes that have twice the number of chromosomes as the zygotes from the previous generation. -Successive generations would have an exponential increase in chromosome count. -Most importantly, recombination and independent assortment of homologous chromosomes allow for a greater diversity of genotypes in the population resulting in genetic	-That as the cell completes the two phases, the number of chromosomes will be half the number of chromosomes the cell initially started with. -That in prophase 1 chromatids from the homologous chromosomes cross- over and exchange segments so that each chromatid contains both maternal and paternal DNA. -Crossing over and independent assortment is what makes gamete different.	-It is the only process in which gametes are produced. -Is the main source of variation in organisms. -Is what makes meiosis different from mitosis.

	variation in gametes that promote genetic and phenotypic variation in a population of offspring. -Meiosis is a process of gamete formation.		
What else you know about this idea (that you do not intend students to know yet).	-That at times chromosomes may fail to separate resulting in some kind of disease and in some cases the failure (non-disjunction) of chromosomes can be advantageous to farmers. -That some cells do not have chromosomes because they do not have nucleus, e.g. red blood cells. -That some cells like muscle cell are multinucleated and so have extra sets of chromosomes and still normal, natural, healthy cells. -The role that science is playing in modifying genetic makeup.	-How homologous chromosomes find each other for them to crossover.	-That sex linked diseases are in sex cells.
Difficulties/limitations connected with teaching this idea.	-There is a lot of terminology involved in teaching cell division which can make teaching the topic tricky. -Terminology used is too abstract for learners. -The diagrams of meiosis portray the cell division phases as stagnant.	-It is very difficult to imagine the minute chromosomes crossing over. -Terminology used is not common in everyday language.	
Knowledge about students' thinking which influences your teaching of this idea.	-This concept is a difficult one to understand particularly when teaching the different phases of meiosis.	-That chromosomes can be shuffled and cross-over in the cell.	
Other factors that influence your teaching of this idea.	-Students' prior knowledge of cell division: some students may struggle with the concept if they have never come across the idea before,	-Learners might have no knowledge "things" which crossover in real life.	

Teaching procedures (and particular reasons for using these to engage with this idea).	-Use of diagrams and pictures from microscope images of cells undergoing cell division. -Use of worksheet activities that include questions with pictures where the learners must identify the different phases.	-Use diagrams to show crossing over in Meiosis. This will help learners to know what cross over is and that it occurs in Prophase 1 only.	-Use diagrams to show four haploid cells and how the chromosome numbers are different to the original cell.
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).	-In small groups learners are made to brainstorm what they already know about cell division. -Learners use clay or pipe cleaners to make models of meiosis processes. This will help to ascertain any confusion they may have. -Give learners worksheets where the phases are not correctly arranged and ask them to put them in order. This will help to relate what they see in diagrams to the changes taking place during meiosis. -Pictorial representations of the stages of meiosis. It can be useful so that a visual representation is available as well as the theoretical background behind the pictures.	-Give learners different diagrams on meiosis and ask them to identify Prophase 1 and the other phases of meiosis. -Learners to describe processes which cause gametes to become different.	-Learners write about the effects of non-disjunction of chromosomes during meiosis.

4.8.2 Discussion of CoRe 1 (big ideas) with team

Even before we had discussed, Anna had written on her copy of the CoRe the comment "these are not big ideas". See appendix B 1. As we sat to discuss the CoRe, the first questions I got from Simon were: *What exactly is a 'big idea'? What do you consider when developing a 'big idea'?* I had not explicitly considered such questions when I completed my CoRe. I failed to explicitly define what a big idea is. In my mind as I constructed the CoRe, it made a lot of sense to follow textbook topic layout and produce big ideas from it. I said, ***'these are the only three areas of focus I use when teaching meiosis'***. The discussions revealed that big ideas cannot be in the form of questions. If it is in the form of a question, it can be answered in one or two statements. From the discussion we had I could see that what I had considered as big ideas were not big ideas at all. On big idea 2, Anna wrote, *"What is a process?"* In response I said, *'**these are the phases through which chromosomes pass through to result in the formation of gametes'***. Simon: *'Yes but do you see yourself producing any new explanations besides repeating what is said in the textbook?*' I was stuck. As we continued to discuss, my big idea 3 again came to the spot light. Simon: "But *in what way is the statement 'products of meiosis' a big idea or it needs to be rephrased*." '***But these are the three steps in the teaching of meiosis'***. I argued. ***'Isn't it that in the teaching of meiosis I just need to define the term meiosis and then explain what happens in each of the phases and lastly we see what is produced?'*** This is how I teach meiosis. Simon: *'As with the identification of concepts, you need to think again on what you might consider as big ideas in the teaching of meiosis because with the way you have phrased your big ideas they do not show the concepts you might want learners to learn'*. We could not continue to discuss prompts as we had agreed that I needed to be clear on the big ideas first.

4.8.3 Reflection from discussion on big ideas

As I went back, I said to myself ***'that challenge like I had with concept maps is starting all over again. I have spent long hours constructing concept maps. Many more hours and days I have to spend again with CoRes.'***

In CoRe 1 above, it can be noted that the first misunderstanding was writing my first big idea as a question, which says 'What is meiosis?' I was not able to group concepts which are related to bring out one idea as was reflected in my concept map. Even though I had managed to eventually produce a concept map, relating the concepts to a CoRe is not easy. I went back to Anna's comments. She had written a definition of a big idea. A 'big idea' is a statement

that encompasses a number of concepts and brings to the fore what teachers see as crucial to develop an understanding of a particular topic or concept (Loughran *et al.* 2012). The big ideas I have in my first CoRe represent how the topic on meiosis is presented in the textbook. By definition my proposed big ideas are not big ideas at all. What I had proposed to be big ideas had fallen short of being big ideas because as I analysed them closely I could see that the question 'what is meiosis?' can be answered in one statement or two; so it does not encompass a number of concepts as proposed by Loughran *et al.,* (2012). Both big ideas 2 and 3 failed to bring out a number of concepts besides the process of meiosis being narrated and products mentioned. Using the word process does not bring out a concrete aspect of what I wanted learners to know like meiosis brings about variation. If I just explain the process of meiosis, the importance of variation might not come out explicitly. ***'What words should I then have which can bring out this knowledge?*** From the questions I was asked, I could see that my CoRe needed to be revised. I was just summarising the topic as was presented in the textbook. With reference to Mavhunga (2011) model of TSPCK, my first CoRe was representing the raw untransformed knowledge I had. What I had is the common content knowledge which can be used by any other teacher to teach meiosis. I was failing to organise the concepts from my final concept map or organise the knowledge I had into groups which can stand out as ideas which need to be known about meiosis. ***'If I come out with different wordings of big ideas as in CoRe 1 it then means that most of the information in prompts will also change'***.

With the knowledge that a big idea is a statement that encompasses a number of concepts and brings to the fore what teachers see as crucial to develop an understanding of a particular topic or concept, I then decided to analyse each of my prompts in CoRe 1 to see if what I had written in each of them was bringing out what is required in the prompt. The prompts were not discussed with critical friend because the discussions on the big ideas had required me to produce meaningful big ideas first. Therefore before I constructed the second CoRe I analysed the prompts. I think the knowledge I had gained on what constitutes big ideas would now help me to see meaning in each of my prompts. I referred to the guidelines in Table 4.3 above which show each of the five components and their explanations.

4.8.4 Analysis of CoRe 1

Curricular saliency:-The CoRe shows that I had failed to identify the big ideas needed in the teaching of meiosis. The discussion I had with team had indicated that what I had put forth as

big ideas were not encompassing concepts which would bring to the fore what is crucial to learn in meiosis. However to some extent I had identified and described the content on meiosis which I wanted known by learners but the organisation of the content was not clear because I had failed to identify the big ideas. Failure to identify the big ideas caused me to fail to have information on my last big idea 'Products of meiosis'. The CoRe also shows that I had not brought out reasons why it was important for learners to know the content I wanted them to know. For example I wanted learners to know that meiosis involves the division of a single parent diploid cell to produce four haploid daughter cells but I could not give the reason why it was important. I also had failed to identify what else I knew which I did not want the learners to know then. Under one of the big ideas I had written: that some cells do not have chromosomes because they do not have the nucleus. This statement had no relationship with the big idea which was 'What is meiosis?' Under curricular saliency I had therefore failed to identify the big ideas and most of the content knowledge. I had only managed to identify some content under big idea 1.

Student prior knowledge: - The CoRe shows that I did not know the prior knowledge students have on meiosis. What I had written as student prior knowledge was not prior knowledge at all. Under big idea I 'What is meiosis?' the prior knowledge I had suggested was that the concept is difficult to understand particularly when teaching about the different phases of meiosis. This is not students' prior knowledge at all. What I had written as prior knowledge is what literature on teaching meiosis says is difficult for students to understand. This statement had nothing to do with student thinking. The reason why I could not identify students' prior knowledge is because I had not researched much to find out what literature says are some of the prior knowledge learners have. However learners might not bring prior knowledge about meiosis because of the abstract nature of the concept.

What makes the topic easy or difficult to teach: - This component speaks of the difficulties or limitations connected with teaching the topic. The CoRe shows that I had some idea of what makes the teaching of meiosis difficult. Under big idea 1 'What is meiosis?' I had written that there is a lot of terminology involved in the teaching of cell division which can make teaching the topic tricky, and under big idea 2 'Processes involved during meiosis' I had written that the terminology used is not common in everyday language. Under big idea 3 I had not managed to write anything because the identified big idea was not encompassing any concepts which needed to be known. Literature in the teaching of meiosis says that the teaching of meiosis is made difficult because of the terminology used (Knippels *et al.* 2005).

Teaching strategies: - Under this component it shows that I had not identified what I would do as a teacher or the questions I would ask in the teaching of the big ideas. There is nothing which shows the teaching aspect. All I had identified was what I would use. However in identifying what diagrams and pictures to use show that I had some knowledge of the teaching aids to use which makes the topic be understood better. Anna: How do you know that diagrams and pictures you identified will make the topic be understood better? The CoRe however shows that I had not identified any questions I would consider important to ask as I teach.

Knowledge of representations: - This component was adapted from the prompt: what specific ways of ascertaining students' understanding or confusion around this idea. In some areas of the big ideas, the CoRe reflects that I had some idea of ascertaining students' understanding. Under big idea 1, I had written; give learners worksheets where the phases of meiosis are not correctly arranged and ask them to arrange in correct order. Though I had shown some knowledge of ascertaining learners' understanding, some of the methods of ascertaining I had identified were not ascertaining methods at all such as the one under big idea 3: learners write about non-disjunction of chromosomes during meiosis. When asked to write about non-disjunction, learners might reproduce what is in the textbook without engaging much into the causes and the effects non-disjunction has. Failure to identify suitable big ideas had caused me to find it difficult to find suitable ways of ascertaining learners' understanding.

From the insights I had and from the discussions I had with the team and my own analysis of the big ideas and prompts of my first CoRe, it made me to realise the need to construct a second CoRe. I then did the second CoRe starting from the big ideas and completed all the prompts. I sent it again for discussion with the team. Table 4.5 below shows CoRe 2.

Table 9: CoRe 2

Grade 12 Life science (Meiosis)	Important science ideas/concepts		
	A Concept of meiosis	B Process of meiosis	C Products of meiosis
What do you intend <u>students</u> to learn from this idea.	That meiosis is a nuclear division that in humans occurs only in male testes and female ovary tissues. (It also occurs in plants), and is characteristic of sexual reproduction. -In meiosis the nucleus divides twice unlike in mitosis -That meiosis involves the division of a single parent diploid cell to produce four daughter haploid cells. -That meiosis is a reduction in the amount of genetic material – that is one half the original genetic material of the original cell.	-that it occurs during prophase 1 of meiosis 1. -occurs when two homologous chromosomes pair up and exchange segments of their genetic material. -that crossing over allows for variation within offsprings. -that crossing over occurs on matching regions of homologous chromosomes. -crossing over results in new combinations of genes.	That at the end of meiosis four haploid cells which are genetically different from each other are produced. That gametes are only produced by meiosis in sexually reproducing animals and plants.
Why is it important for students to know this?	-That meiosis keeps the number of chromosomes from doubling in each generation. -that meiosis is the only cell division in animals which results in formation of gametes. That the behaviour of chromosomes during meiosis is different at each phase.	-Crossing over is essential for the normal segregation of chromosomes during meiosis. -Crossing over also accounts for genetic variation, due to the swapping of genetic material between the paternal and maternal chromosomes. It is non sister chromatids which cross over in prophase 1. Sister chromatids do	That gametes are the carriers of genes which cause variations in organisms.

	That they know or understand how cells with half the number of chromosomes are produced.	not cross over.	
What else you know about this idea (that you do not intend students to know yet).	-that meiosis can be faulty i.e. chromosomes may fail to separate in humans so resulting in genetic disorders or diseases. -Non disjunction of chromosomes can be advantages to farmers in that large fruits can be produced.	That selection of useful recombination's by geneticists has brought about green evolution (a significant increase in agricultural productivity resulting from the introduction of high-yield varieties of grains etc.), cloning etc. -Crossing over can occur at more than one part. The breaking and repairing of synapsed chromosomes is controlled by an enzyme. -The frequency of crossing over helps in the mapping of chromosomes. i.e., determining the location of the genes in the chromosomes.	That some genetic diseases can be passed on to offsprings through gametes (sex linked).
Difficulties/limitations connected with teaching this idea.	-there is a lot of abstract terminology, phrases and concepts to learn and difficult to link so making the teaching of cell division difficult to teach. -the diagrams of meiosis used in textbooks portray the cell cycle as not occurring within the same cell.	-learners find it difficult to imagine microscopic chromosomes lining up and exchanging parts of their chromosomes.	Gametes are microscopic and learners always think that the girl inherits traits from the mother and the boy inherits from the father. Learners do not understand the role of chance in producing new heritable characteristics by forming new combinations of existing genes.
Knowledge about students' thinking which influences your teaching of this idea.	Learners will not see the diagrams of phases as one cell going through different phases of the cell cycle.	Learners may only be aware that one can have traits of both the mother and the father.	

		Learners think that the trait which appear to be dominant in the child means that the parent who has that trait is stronger that the other.	
Other factors that influence your teaching of this idea.	The availability of materials to use when teaching meiosis other than textbooks. The sequencing of the topic of mitosis and meiosis which are done in different grades may make the topic appear new. Learners enjoy learning about what causes differences in a family.	Learners enjoy watching videos when learning.	
Teaching procedures (and particular reasons for using these to engage with this idea).	Group discussion: The introduction serves as a basis to find out what learners think cause children of same parents to be different. Group work which is followed by class discussions: In groups learners discuss on what they think makes sex cell be different from somatic cells. This procedure is done to determine whether learners have some knowledge of some differences between sex cells and somatic cells and if they there are any differences how do they come about. Class discussion: on meiosis as what causes the difference between somatic cell and sex cells. The stages of meiosis 1 and meiosis 11 will then be discussed. The discussion is done to show learners how sex cells are produced as chromosomes separate.	In groups learners made models of metaphase 1 of meiosis 1 showing crossing over. A video showing crossing over in metaphase 1.	Learners in groups cross genetically different eggs and sperm to show the genotype variations they produce. This will help the learners to see that it is gametes which bring about variation in organisms.

	Making models of phases in groups. Learners in groups make models of phases of meiosis as assigned by the teacher using bostick/sticky stuff dipped in two different chalk colours to resemble maternal and paternal chromosomes. The activity is meant to help learners to demonstrate what they thought were the key features of meiosis. The learners models where then discussed in class as each group presented its model. Watch video showing the phases of meiosis.		
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)	In their groups learners will identify the key features of meiosis, its importance and products. The teacher will move from group to group 'listening' to the descriptions being given by the learners. Each group will then share their discussions/findings with the class. This will help the teacher to identify aspects which will be difficult for learners and so assists them. Learners might not be able to have noticed that meiosis 1 separates chromosomes yet meiosis 11 separates chromatids. Have learners develop their own concept maps of meiosis. Concept mapping may also help the teacher identify and correct student misconceptions. Concept mapping is a procedure for helping students organize concepts into	Teacher asks questions like: (1) What is the importance of crossing over in organisms? (2) What might be some of the effects where the chromosomes fail to separate during meiosis? Such questions will help the teacher to find out whether the learners will have understood the concept and what assistant they might need.	In pairs learners to write down what causes the sex cells to genetically different and why it is important.

	meaningfully connected, as opposed to loosely connected, entities. Explain how meiosis allows organisms to maintain their chromosome numbers from one generation to the next.		

4.8.5 Discussion of CoRe 2 with team

Curricular saliency: - As we discussed the big ideas with the team, a question was raised about the big ideas. The question was; when you write your big idea as 'Concept of meiosis', *what are the concepts you want to bring out when you write your big idea like that*? The big idea was not bringing out the crucial concepts which need to be taught in meiosis. Simon commented: *the big ideas in meiosis cannot be brought out by only looking at the concept of meiosis* or *the processes of meiosis* or the *products of meiosis. Much more is required.* As we analysed all the big ideas we agreed to the comment from Anna: *These are not big ideas. From which concepts did you formulate your big ideas*? I again had failed to identify the big ideas in my second CoRe. See appendix B 2.

The failure to identify the big ideas in CoRe two caused me to fail to identify the content I intended the learners to learn about each of the big ideas. The content I brought out in all the big ideas was not very clear because of the big ideas I had used. The content under big idea 1 for example was no longer linked to meiosis. I had written, meiosis is a nuclear division that in human occurs in testes and ovaries. The content was rather speaking of where meiosis takes place rather than how it occurs. Anna: *The big idea and the content are not related.* Across all the other big ideas I had, there was no relationship between the big ideas and the content to be learnt by learners. Under curricular saliency very little had changed between CoRe 1 and CoRe 2. We agreed that most of the information needed to be changed as most of the information in content prompts was not related to the big ideas.

Student prior knowledge: - The information in the CoRe shows that I had good ideas about learners' thinking under big idea 1. I had mentioned that learners will not see the textbook diagrams of meiosis as one cell going through different phases of the cell cycle. However though what I had assumed about the learners' thinking under big idea 2 is not a scientifically approved thinking, most learners in the African cultures have beliefs that the traits which appear on the child means that the parent who had that trait is stronger than the other. Under the third big idea I had left it blank. The comment from Anna was that if I had managed to identify the big idea correctly I could have found information to write under the big idea. We then agreed that I should relook into what I had written under big idea 2. The statement was not in agreement with the big idea.

What makes the topic easy or difficult to teach: - What I had written under big idea 1 shows that I had some idea of what makes the topic difficult to teach. I had identified that there is a

lot of abstract terminology which makes the topic difficult to teach. Under the other big ideas I had identified, I had failed to identify what might make the topic difficult to teach. The agreement I had with the team members was that I needed to think deeply about what makes topic difficult to teach.

Teaching strategies: - In all the prompts I had not mentioned what I would do to make what I wanted the learners to do explicitly. I had only talked of what the learners will do. Anna had written a comment on her copy of the CoRe to say; *what is a teaching procedure? You need to make everything explicit before you ask learners to work in groups because they need to know what to discuss. What you base the group work on is what falls under teaching procedure.* I had taken teaching procedure to be centred on what learners do. Across all the prompts I had made the same assumption that teaching procedure is writing about what learners ought to do in the lesson.

Knowledge of representations: - The mentioning of making models of the phases of meiosis and watching a video shows that I had some idea of what might be needed to make the abstract topic on meiosis be understood by learners. However Anna questioned: Is showing a video a representation? It only becomes a representation when you explain to us what is in the video. The correct ideas I had however needed to be improved to make explicit what the learners will do.

4.8.6 Reflection from the discussion

As I went back in my journal I wrote: *So Anna seems frustrated that I am failing to think critically about the big ideas I can have? Doesn't she see that I am even more frustrated by lack of progress in the development of my PCK? If it's not that these CoRes are for study, I could have aborted their use. I can't keep on going in circles without showing much progress. If the next CoRe I fail to produce any meaningful big ideas then I stop using CoRes in the study.* My first two CoRes were not showing progress in development of PCK. Failure to identify correct big ideas were causing me to fail to identify the content learners need to know. Failure to identify big ideas has effect on the type of representations and strategies I will use in my teaching. The CoRe had failed to bring out what Shulman (1986) described as the use of most powerful analogies, illustrations, examples, explanations, simulations and demonstrations. With some of these comments from the team, I realised I had to go back again and do another CoRe.

From the input of the team, I began to see that there was no difference between the big ideas in CoRe 1 and the big ideas in CoRe 2. Although most of the information in the prompts was correct, the big ideas in meiosis are not about the concept of meiosis or the process of meiosis. I was still struggling with the organisation of meiosis concepts into groups I can call the big ideas of teaching meiosis. *'So does it mean that all these years of teaching I was not thinking deeply about what I was to teach. My teaching is all rote teaching.'* I wrote in my journal.

In this second CoRe, I could see that I had not said anything about how I was to teach. My teaching had been reduced to narration of what is written in the textbook. Narration represents the common content knowledge as said by Ball *et al*. (2008). My teaching was aiming to complete the syllabus and make learners write exams and pass. *'So the use of CoRes as a planning tool is now showing me the flows and inadequacies of my PCK in the teaching of meiosis.* The two CoRes have revealed that I do not know much about learners' prior knowledge on meiosis. From the way I had been teaching I had no difficulty at all because I would just define meiosis, I describe the stages and mention the products. I never thought of what could be difficult or about learners' thinking or what could be the best representations I can use to make the topic to be understood better by learners.

4.8.7 Construction of CoRe 3

The discussion and reflection from the second CoRe dictated the construction of my third CoRe which became my last.

I then sat again to produce the third CoRe. I had to relook at my big ideas again. I had to think about what learners really needed to know about meiosis. I had to think of what meiosis does which cannot be done in mitosis. I had to go back and read literature on meiosis. I read books and journal articles on meiosis. I read about why the topic is difficult to teach. I read about what best teacher do and how they plan. I went to study the three concept maps I had done to note their differences and what I had done to make one different from the other. I had to ask myself lots of questions. ***What makes meiosis unique? Which topics do I teach before and after meiosis? Why these topics follow one after the other***? From this personal debate I came out with two ideas which are: (1) meiosis forms gametes and (2) meiosis causes variation. With these two big ideas I could encompass all what I had considered big ideas in my CoRe 1 and 2. From the readings I further had, it came to me that I could also talk of what happens if meiosis goes wrong. This idea became my third big idea. I then started

completing the prompts. Like in the other CoRes I had done, completing the prompts was still a challenge. I had no fixed way of completing the prompts. At one point I had to complete the prompts of one big idea one at a time and in some cases I had to look at one prompt and complete all the information about it for all the three big ideas. In some cases I had to leave some prompts blank only to come back to it having got the idea as I completed another prompt. Completing the prompts made me to keep working forward and backward, deleting and adding information at all times. Table 4.6 below shows CoRe 3.

Table 10: CoRe 3

Grade 12 Life science

(Meiosis)	Important science ideas/concepts		
	Meiosis results in the formation of gametes	Meiosis causes genetic variation	Meiosis can go wrong
What do you intend students to learn from this idea.	That gametes are only produced by meiosis in sexually reproducing animals and plants. That cells with half the number of chromosomes are produced by meiosis. How the formation occurs in meiosis 1 and meiosis 2 i.e. how it halves the number of chromosomes That meiosis results in the reduction in the amount of genetic material – that is one half the original genetic material of the original cell will be left in each cell at end of meiosis and cytokinesis.	That crossing over is one of the causes of genetic variation in animals. That random assortment or segregation is also another cause of genetic variation in animals.	That during meiosis chromosomes can fail to separate. That the failure of chromosomes to separate can be an advantage in plants and a disadvantage in other animals especially humans.
Why is it important for students to know this?	That they can know and appreciate the significance of meiosis in sexually reproducing organisms.	That they can understand that the differences which exist among organisms belonging to the same family or organisms of the same species is a result of what happened during meiosis mainly.	That they can know that some diseases in humans are genetic caused by failure of chromosomes to separate during meiosis. That they can understand that in plants where chromosomes fail to separate during meiosis it can results in large fruits.

What else you know about this idea (that you do not intend students to know yet).	That in some organisms meiosis occurs when fertilisation has taken place. That not all gametes are produced by meiosis for example in mosses and ferns. That Prophase 1 can be divided into five sequential stages.	That in some cases, genetic variations are caused by mutations. That genetic variation is a source of evolution.	That plant breeders are able to form polyploidy plants by using chemicals such as colchicines which prevents the formation of spindle fibres from forming and as a result chromosomes cannot separate during cell division. As a result the cells that are formed have twice the total number of chromosomes.
Difficulties/limitations connected with teaching this idea.	There is a lot of abstract terminology, phrases and concepts to learn and difficult to link so making the teaching of cell division difficult to teach. The diagrams of meiosis used in textbooks portray the phases of meiosis as not occurring within the same cell.	To understand that the tiny microscopic chromosomes cross-over. To understand that homologous chromosomes find each other in order to cross-over.	To understand or appreciate that some of those errors which occur in meiosis can be taken advantage off by scientists e.g. non-disjunction of chromosomes to produce larger seedless fruits. (Scientists are manipulating errors to their advantage).
Knowledge about students' thinking which influences your teaching of this idea.	Learners will not see the diagrams of phases of as one cell going through different phases of the cell cycle.	Learners in African cultures believe that differences can be caused by the people the mother loved or hated when she was pregnant.	Some learners believe that it is witchcraft which cause what we call genetic diseases in science e.g. albinism.
Other factors that influence your teaching of this idea.	Learners do not know that it is meiosis which keeps the number of chromosomes from doubling in each generation.	It can be difficult for learners to understand that the tiny microscopic chromosomes cross-over and pair up randomly so bringing about genetic variation.	For learners to understand that some diseases people have were inherited from parents through gametes formed by meiosis.

Teaching procedures (and particular reasons for using these to engage with this idea).	Class discussion – (Testing of learners' prior knowledge). I will be asking learners questions what they know about somatic cells they did in grade 10. I also find out what they know about sex cells and see if they know any differences between the somatic cells in mitosis and sex cells. Exposition – I will then explain to the learners that we are going to learn about meiosis which results in the formation of sex cells. Here I teach about the purpose of meiosis and the processes involved in the two phases of meiosis which result in the division of the cell nucleus. A practical demonstration. In groups using pipe cleaners or strings, learners demonstrate how chromosomes in meiosis 1 & 2 behave which results in their separation to form sex cells. The demonstration is then followed by groups explaining to class what was happening to the chromosomes at each stage.	In groups learners study and identify some variations among themselves including tongue rolling, left-handed and right-handed, darkly pigmented eyes and blue eyes, hitchhiker's' thumb and straight thumb and ear lobes. They can also consider variation in shells of snails (mollusc) and some variation in fruit flies (Drosophila Melanogaster).	Class discussions on some disadvantages of meiotic division such as Down Syndrome, Klenefelter's syndrome where the male has an extra X e.g. (XXY); Tuner syndrome where the cell has only one X (monosomy X) and some advantages of polyploidy (non-disjunction) in plants such as production of large seedless fruits.

Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)	In their groups of threes learners will identify the key features of meiosis, its importance and products. The teacher will move from group to group 'listening' to the descriptions being given by the learners. Each member of the group will then share their discussions/findings with the class e.g. of the three members, one reports on key features of meiosis, the other on importance and the third one on products of meiosis. This will promote participation of all members of the group and so will help the teacher to identify aspects which will be difficult for learners and so assists them. Learners might not be able to have noticed that meiosis 1 separates chromosomes yet meiosis 11 separates chromatids. As a class we identify and make a list of the concepts important in meiosis and then ask the learners to construct the concept maps in their groups. I will give earners micrographs on meiosis and ask them to identify various stages of meiosis. Class work. In their class-work books learners, learners explain how halving the number of chromosomes is achieved.	Class-work 1. Explain in their class-work books how meiosis brings about variation.	1. Identify two genetic disorders e.g. Down Syndrome and Klenefelter's syndrome and answer the following questions in each of the disorder: (a) What causes the disorder? (b) How is it inherited? (c) What are the symptoms of the disorder? (d) How does the disorder affect the health of the person?

4.8.8 Discussion of CoRe 3 with the team

Curricular saliency: - The first comment I got from Simon was: *I want to adapt the way you have presented your CoRe for my teaching. I now see the topic on meiosis differently. The big ideas in CoRe 3 now speak of what we need to know about meiosis. These big ideas you have identified now are bringing out to the fore what learners need to know about meiosis. Now you can tell your learners that meiosis produces gamete and how it is done. You can tell them that meiosis brings about variation and how. You can tell them that meiosis can go wrong and what the effects are'*. I agreed with the critical friend and I said, '***Yes now I see the difference***. ***The three big ideas in CoRe 3 are different from the big ideas in both CoRe 1 and CoRe 2 in that they are now specific of the content which learners need to know about meiosis. It is what meiosis does which learners need to know and this is what big idea 1 will bring out.'*** However as we discussed this first big idea we agreed that I should change the wording from: *Meiosis forms gametes* to *Meiosis results in the formation of gametes.* See appendix B 3. We discussed the change giving reference to content learnt in concept maps which said that meiosis ends when the two nuclei reach opposite ends of the cell. The first big idea '*Meiosis forms gametes'* through the prompts 1 & 2 will reveal to learners that it is only in meiosis that sex cells are produced or is the only way in which cells with half the number of chromosomes are produced in sexually reproducing organisms for example. *Anna: Do you see that the way you will present meiosis using big these ideas will be very different from how it is done in the textbook'?* In CoRe 3, I had now managed to identify the big ideas that could promote conceptual teaching and understanding of meiosis. The big ideas were now different from how the topic is laid or presented in the textbook. There was agreement among the members of the team that the big ideas were well thought and need no changes. Simon: *Do you now see that there is a very big difference between these big ideas and the big ideas in both CoRe 1 and CoRe 2?* The big idea now shows what meiosis does. The content which learners need to learn was also made specific. Some of the content which then became clear was that meiosis brings about genetic variation in organisms and that when meiosis goes wrong it can cause genetic diseases. Anna felt that there was some content missing in each of the big idea. She explained what the content was and I added it. For big idea 1 the content was that learners may not know what gametes are and what their functions are and therefore may not appreciate the importance of meiosis. In big idea 2 the content was that learners need to know what crossing over is and how it occurs as well as what random assortment is. In big idea 3 the content was that learners need to know how chromosomes may fail to separate and

what the possible causes are. Anna's input helped me to develop my PCK in terms of knowing what to teach under each of the big idea. In both CoRe 1 and 2 this information was not revealed. In CoRe 2, the second big idea I had 'Process of meiosis' could only describe the processes of meiosis without revealing the cause of the variations. Both the big ideas and content to be learnt was very clear in CoRe 3.

Student prior knowledge: - There was clear identification of what I assumed about learners thinking across all the three big ideas. Under big idea three 'Meiosis can go wrong' I had said that some learners believe that it is witchcraft which causes what we call genetic diseases in science e.g. Down syndrome or Albinism. To the majority of African belief systems having an Albino in the family means the family has been cursed. These are some of the commonly held misconceptions in African cultures. I wrote *'learners in African cultures believe that differences in members of the same family can be a result of people the mother loved or hated when she was pregnant'*. Though this thinking of learners is not documented in literature, it is commonly held as correct in African cultures.

What makes the topic easy or difficult to teach: - The CoRe shows that under all the big ideas I had identified what meiosis literature agrees to be what makes the teaching and understanding of meiosis difficult. Under big idea 1 for example I had said, there is a lot of abstract terminology, phrases and concepts to learn and difficult to link to everyday life so making the teaching of cell division difficult. I also identified that learners might find it difficult to understand or appreciate that some of the errors which occur in meiosis can be taken advantage off by scientists e.g. non-disjunction of chromosomes to produce larger seedless fruits. (Scientists are manipulating errors to their advantage). For big idea two Anna said that from her experience of teaching meiosis-what makes the concept of crossing over difficult to teach is that learners do not know what homologous chromosomes are and that chromatids carry genes and therefore it is the genes that are exchanged during crossing over. The proposed additions I had greatly helped to develop my PCK.

Teaching strategies: - Most of what the teacher was to do was only made explicit for big idea 1. I also had clearly explained the type of questions I will ask them prior to grouping them for activities. A variety of relevant activities had been prepared for the learners. The team however highlighted that there was no conceptual teaching under big idea 1 and 2. The highlighted point was noted and included in the final CoRe which can be used by other teachers. See appendix B 4.

Knowledge of representations: - Under this component across all the three big ideas, I did not have representations at all. The team agreed that what I had suggested as representations were not representations at all. We agreed on what the representations should be and I added. Some of the representations proposed were the use of karyotypes and diagrams showing genes on chromatids. A karyotype would further show to learners the specific chromosome number where the error could have occurred. Specific ways for ascertaining learners' understanding would then be shown. The CoRe was however showing understanding in the form of examples and samples of questions which would be asked. A variety of ways were used. Under big idea 1 for example four activities to ascertain understanding were used. Bringing out specific examples or representations is an indication of PCK. In bringing out specific examples and representations, the teacher will not be using the common content knowledge which Ball *et al*. (2008) spoke of, rather Ball *et al*. called it specialized content knowledge. This is knowledge for effective teaching. With reference to Mavhunga (2011) model of TSPCK the raw content knowledge I had, had now been transformed into content knowledge which could to be understood by learners. Although the prompt says include likely range of responses, I had not previously thought about documenting the possible responses so I had not provide any.

4.8.9 Reflection and discussion on CoRe 3

In my journal I wrote: So being able to bring out the big ideas is very important. It makes the teaching become organised and so learners will know explicitly the content knowledge you want them to learn. The organisation of content in the teachers' head is very important. Now I can see that meiosis can be taught without following the textbook layout which is all about defining meiosis, describing the process and identifying the products. If meiosis is learnt as is presented in my third CoRe learners might not struggle to understand the topic and it becomes meaningful. Learners will now clearly know that meiosis results in formation of sex cells; that meiosis causes variation and that meiosis can go wrong and what the effects of going wrong are. In a way learners can be motivated to learn.

So identifying big ideas makes completing prompts easier. It is therefore important to identify big ideas first when using CoRes. CoRes helped me to think critically and I had to read more literature so that I could get information to complete the prompts. Reading about what I teach is one thing I had stopped doing. My knowledge was no longer developing at all. The CoRe played an important role in guiding me how and why I go about planning for my teaching.

The use of CoRes in this self-study showed that for the past years I had been teaching meiosis I was rote teaching. I had not engaged myself in the critical thinking of the main concepts and ideas which learners needed to know. It also revealed that I was not using the most appropriate examples and representations to make the content comprehensible. So if the teachers' PCK for teaching a specific topic is not well developed, the teacher cannot bring out what Shulman (1986, p. 7) referred to as '...the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word, the most useful ways of representing and formulating the subject that make it comprehensible to others...' The lack of adequate PCK on meiosis I had probably contributed to the failure of my learners to understand the topic on meiosis better as was reflected in my Honours study.

The recommendations and input I got from the team were then added in the CoRe I feel teachers can now use as an example of a CoRe on meiosis. This CoRe is in appendix E.

4.10 Conclusion

In this chapter I discussed how the concept maps and CoRes helped me to develop my content knowledge and pedagogical content knowledge (PCK) on meiosis.

A concept map can be seen as a diagnostic tool if used in collaboration with others in the discipline. Concept maps can diagnose level of content knowledge and misconceptions among others. Construction of concept maps helped to organise knowledge meaningfully. If content knowledge is organised meaningfully, it makes features of particular content become visible and understood by learners. Exposing my content knowledge to a friend helped me to identify misconceptions. Knowledge of misconceptions develops the teachers' PCK.

The concept maps helped me to develop content knowledge needed in teaching meiosis. CoRes were helpful in the development of both content knowledge and pedagogy. The identification of big ideas and the quizzing I had with prompts helped to develop my PCK on meiosis. When I look back at professional development workshops that we attend that are organised by the DoE, some of them focus on developing our content knowledge i.e. what to teach. Others workshops focus on how to plan. Through the construction of concept maps, my content knowledge of meiosis improved and through constructing CoRes with the help of expert critical friends both my content knowledge of meiosis and how to teach that content

developed. Therefore, the construction of concepts maps and CoRes through the critical guidance of friends was a form of professional development.

In the next chapter I present my reflections on the use of concept maps and CoRe in this study as well as the implications and recommendations.

CHAPTER 5

REFLECTIONS, IMPLICATION AND RECOMMENDATIONS

5.1 Introduction

In this chapter I write about what I learnt from the use of concept maps and CoRes as well as some reflections, implications and the recommendations from the study.

5.2 Concept maps and PCK

Three concept maps were constructed in this study. Concept maps were seeking to answer the following research question:

(a) How does the use of concept maps improve my content knowledge of meiosis?

This self-study established that my content knowledge on meiosis was developed as I constructed each of the three concept maps. The use of concept maps helped me to identify the content gaps, misconceptions and how best to organise the concepts of meiosis so as to improve the quality of my content knowledge.

5.2.1The content gaps

The content gaps that I had were in terms of not knowing the important concepts and the subordinate concepts for meiosis. The initial content knowledge I had was more of a *"maze"* but after doing the concept maps I am now clear on the main concepts, I now know the subordinate concepts and even the concepts linked to meiosis such as natural selection and evolution. This is in agreement with Novak (1998) and Gowin (1984) who defined concept mapping as an educational tool developed specifically to tap into one's cognitive structure and to externalize, for both the learner and the teacher to see, what the learner or teacher already knows. The concept maps showed that I had not been including some of the most important concepts in the teaching of meiosis such as segregation of chromosomes and homologous pair. My content knowledge for teaching was initially limited.

5.2.2 Insights from the construction of concept maps

Teaching is a thinking job. I had to think critically during the construction of concept maps something that I had not longer been doing in my teaching. My teaching was textbook based. I was following how the topic was presented in the textbook. The thought I had was that

teaching has been simplified. The way the topic on meiosis is presented in the textbooks might be some of the reasons for my failure to think about my teaching any more. The topic is presented such that one knows what meiosis is, processes involved and the products but without critical thinking, one may fail to identify and explain the main concepts which need to taught. I had stopped to practice the most critical component of teaching which is thinking until I started constructing the concept map and I am sure it also applies to other colleagues of mine. Concept mapping made me to be able to organise meiosis concepts in ways which can help me to understand the topic better. Some of the ways were the ability to group related concepts and identification of concepts which needed to be emphasised when teaching.

The construction of concept maps showed me that concept maps encourage deep thinking when you think about the relationships among items in this case among the concepts related to meiosis. Without giving much thought into the concepts to be taught, I could not be able to identify fundamental concepts which make the learning of meiosis meaningful. Concept mapping thus promotes more critical thinking. As a teacher I did not seem to have been applying this critical thinking – *I was reduced to a "parroting"* type of teacher.

The use of concept maps made me to interrogate my own understanding of meiosis which resulted in the identification of content gaps and misconceptions I had before this study. The identification of content gaps motivated me to do further readings on meiosis which is one thing we do not do anymore as teachers. Nature of science says knowledge changes. There are new discoveries, there are new things, there are new challenges in teaching, new challenges facing the learners' way of studying such as internet but I and other teachers are stuck with the textbook. The more I read the more I developed my content knowledge.

5.2.3 Concept maps and learning – implications

The use of concept mapping made me to learn again. If used as a teaching tool by the teacher, concept mapping can have great impact in the development of the teachers' content knowledge of that particular topic which can translates into improved teaching and learning of learners. By doing this research for the first time in fifteen years I consulted seven books and reading five journal articles on meiosis only something I had stopped doing and something that teachers should do.

Concept mapping required me to make effort to understand concept meanings, organize concepts hierarchically and form meaningful relationships between concepts to form a

coherent, integrated network of the material needed to understand meiosis. Equipped with such quality knowledge is likely to improve my teaching and so help learners to understand the topic on meiosis better. The engagement in such constructive and transformative cognitive operations during the construction of concept maps enhances memory and recall on the concepts learned.

This study also revealed to me the importance of collaborative learning which I did with Simon my critical friend and Anna my supervisor. The team helped me to compare concepts and challenge my understanding of meiosis. The role of a critical friend in the study was to ask question and compare quality of concepts and propositions. The team facilitated scaffolding which in turn facilitates the social nature of knowledge building and in-depth inquiry. Where concepts maps are used for teaching, I would again argue that learners will not rely too much on information from teacher and other resources rather than engaging themselves in deepening inquiry. Concept maps helped me to be able to organise my knowledge on meiosis without necessarily following how the topic is presented in the textbook.

Concepts acquisition is a very important aspect of learning. Knowing concepts of meiosis deepened my subject matter. Without concepts all we call subject matter would practically not exist according to Moreira (2011). Learners write exam and pass but is it all we aim in teaching? There is much subject matter which teachers should have than what is described in the textbook. In my first concept map my content knowledge was very poor as was seen by the limited number of concepts I managed to identify. This showed me that knowledge acquisition has a direct relationship with concepts acquisition. As I improved on my concept maps, I was integrating new knowledge in what I already had. Most new learning occurs through derivative and correlative subsumption of new concept meanings (Moreira 201). I was then able to place related concepts in hierarchy and relationships.

While research on concept maps centred on learners, I see their importance in use by teachers. They should form part of a teacher's preparation tools. When used by teachers, they eliminate blind following of the syllabus or teaching schedule. Concepts should form and be at the centre of all teaching activities. When concepts maps are used as a teaching tool, it eliminates rote learning where one memorize chunks of knowledge and automatically apply them to situations which could be familiar. Use of concept maps when used for teaching, they foster long term learning. Where rote learning is used, one might not be able to solve

problems that offer minimal differences from the ones worked in textbooks. In the classroom situation, with rote learning, Moreira (2011) argue that the learners will complain or argue that the topics were not presented in class.

Concept mapping should be used both as a planning tool by the teacher and for teaching. It helps important concepts in a specific topic to be brought out and be understood better by the teacher and by learners.

However, meaningful learning does not depend solely on concept mapping. Learning may and may not occur with the use of concept maps. The argument that I am making is that concept learning is fundamental for one's cognitive development and that concept mapping can help a lot in this process. The use of concept mapping promoted the development of my content knowledge for teaching meiosis.

5.3 CoRes and PCK

Three CoRes were constructed in the study. By constructing CoRes I was seeking to answer my second research question which is:

(b) In what ways does the use of Content Representations (CoRes) if used as planning tools improve my pedagogical content knowledge for teaching meiosis?

5.3.1 Identification of big ideas

The use of CoRes as a planning tool helped me to be able to explicitly identify the big ideas which needed to be taught in meiosis. The three big ideas that I identified are:

1. Meiosis results in the formation of gametes
2. Meiosis causes genetic variation
3. Meiosis can go wrong

The identification of these big ideas coupled with the prompts will help present my teaching in ways which promote conceptual understanding. Previously before this study I would start my teaching by defining meiosis then explain the process; but after engaging in this study I will began to teach meiosis by making the learners to work first on aspects of sexual reproduction like fusion of gametes so that they can see the purpose of meiosis in real life which is used to prevent the doubling of chromosome number in sexual reproduction. In line

with big idea number two, students will do an exercise which shows that there is variation within human beings first in class then among family members and then from there I will move on to teach big idea number two.

5.3.2 The first four prompts in the CoRe

The first four prompts in a CoRe are:

1. What do you intend learners to learn from this idea
2. Why is it important for students to know this
3. What else do you know about this idea (that you do not intend students to know yet)
4. Difficulties/limitations connected with teaching this idea

As explained in chapter two, these prompts focus on content knowledge. By adequately responding to these first four prompts I improved my common content knowledge (CCK) and developed specialised content knowledge (SCK) required to teach meiosis. Some of this specialised content knowledge is summarised below.

- that gametes are only produced by meiosis in sexually reproducing animals and plants
- that cells with halve the number of chromosomes are produced by meiosis
- that crossing over is one of the causes of genetic variation in animals
- that random assortment and segregation is also another cause of genetic variation in animals
- that during meiosis chromosomes can fail to separate
- that the failure of chromosomes to separate can be an advantage in plants but is a disadvantage in animals

To come to understand the knowledge summarised above, I had to interrogate my own knowledge of meiosis. I had to read literature on meiosis. I had to expose my knowledge and thinking to others for critical feedback and re-organise my knowledge of meiosis in my head differently from the way it is presented in the textbook. This showed me that as a teacher the only way to keep abreast with new developments in the scientific world and new knowledge, I need to keep thinking about what I teach and to keep reading especially research literature

on the topics that I am responsible for teaching. If we as teachers abandon reading and thinking about what we are teaching, we will be reduced to parrots which just repeat what is written in textbooks verbatim.

The use of CoRes gave me a different perspective of my teaching the topic on meiosis. The research showed me that PCK develops with practice and through experience as was shown as I constructed the three CoRes. The development of PCK requires a rich conceptual understanding of the particular subject content to be taught and this can only be obtained by reading around and thinking about what is to be taught. This rich conceptual understanding of the topic content knowledge brought about by reading and the quizzing of big ideas and prompts in CoRes is purposefully linked to create the amalgam of knowledge of content and pedagogy that Shulman (1986, 1987) described as PCK.

5.3.3 The last four prompts of my CoRes

The last four CoRe prompts focus on a teacher's pedagogical knowledge. These prompts are:

5. Knowledge about student's thinking which influences your teaching of this idea

6. Other factors that influence your teaching of this idea

7. Teaching procedures (and particular reasons for using these to engage with your idea)

8. Specific ways of ascertaining student's understanding or confusion around this idea (include likely range of responses)

Completing these four prompts of the CoRes made me to see that teaching is not about mastery of content only; it is about the mastery of content and the mastery of pedagogy to make the content be understood by others. Abel (2008, p1414) maintains that "learning to teach effectively is not about acquiring a bag of tricks based on general pedagogies, it is about developing a complex and contextualized set of knowledge to apply to specific problems to practice". A teacher therefore does not only need to know his/her subject matter very well but to be able to transform it into subject matter for teaching. Content knowledge need to be transformed. To transform subject matter requires the teacher to have some understanding of all domains of teacher knowledge as is shown in Mavhunga's (2011) model of TSPCK.

To teach effectively is not a simple undertaking. A teacher needs to be able to develop appropriate teaching strategies and representations which would enable the topic to be understood. With the use of prompts in CoRes, I was able to think about what makes the topic difficult to learn such as the words or concepts associated with the teaching of meiosis. I was also able to think about the misconceptions that learners are likely to bring to class that are associated with meiosis concepts. Once I was clear on what makes the topic difficult to teach and the misconceptions or ideas learners bring to class, I was in a position to think of ways of teaching that would help learners to understand the difficult content, to develop a better understanding of the ideas that they bring to class and to clear misconceptions. The completion of prompts seven and eight was now purposeful. I was no longer focussing on the routine activities that I have been doing with learners. The activities targeted achievement of something specific e.g. making students understand why meiosis is necessary.

5.3.4 Insights from the use of CoRes

By constructing CoRes with the help of experts, I came to know better how to come up with a big idea and how to choose teaching procedures that will make a particular big idea become clearer to understand. I was able to think about what is important in a big idea and why. As I reflected on my teaching plan using CoRes as a tool, it revealed that teaching requires more than collecting a set of activities to use in the lesson. I needed to know the factors which could impinge on my learners' understanding of the topic and think about procedures which are appropriate. This knowledge helped me greatly to improve content knowledge and pedagogy of teaching meiosis.

5.4 Self-study as a methodology

A self-study is a very important methodology one can use to study and improve one's practice. It does not only improve self but it also helps to improve the practice of other teachers in the profession by highlighting some of the subtle bits of knowledge which are not emphasised in textbooks such as cytokinesis is not part of meiosis. However in using this methodology, there are challenges I encountered throughout the study. One of the biggest challenges with self-study is to get a critical friend. It is difficult to find someone who knows what the role of a critical friend is. A self-study cannot be done without a critical friend. So getting someone who is an expert and willing to commit time for discussions has been challenging throughout my study.

5.5 Reflections on concept maps

The initial discussion I had with my critical friend was the most difficult encounters where I had to show what I knew about meiosis. When I was asked to write down the concepts I had considered for concept map, I felt bad as I struggled to identify the concepts. I felt like I was showing to the public my inadequacies in my content knowledge. The use of a critical friend in this study made me to feel embarrassed at first as I exposed my knowledge. It was only later as we continued with the discussion that I began to regain some confidence. I had embarked on this study when I had not read enough on what concept maps are. This made it difficult for me to define what a concept map is. I found it very difficult to develop my first concept map because I was for many years not thinking about what I teach. My teaching was all about following how the textbook is written. I had no time to think about my teaching and organise the teaching in any other way which I could see as making the learners understand the topic better. I found myself with scattered ideas about the topic. I could not think of why I had chosen some of the words as concepts at all. During the development of my second concept map, I began to find it easier to identify concepts and to link them meaningfully. I now had better understanding of what concept maps are and their purpose. My confidence of what I wanted to do had also developed much. The more I exposed my knowledge on meiosis to the critical friend, the more I gained confidence and content knowledge of the topic.

5.6 Reflections on CoRes

The use CoRes in this study to capture my PCK was one of the most challenging and frustrating processes in the study. Initially I had not thought I was going to have problems doing my first CoRe, but I struggled to come up with big ideas. It took me more than two days to come up with what I first considered to be big ideas. I further had frustrations in completing the prompts of each of the big ideas. Completing each of the prompts required me to write and delete many times. Sometimes after completing the first three prompts and reading them, I would think I had not said anything about what the prompt requires and then delete everything. The situation was worsened after I had gone to meet the critical friend and supervisor where all the comments on the big ideas were *"these are not big ideas"*. After the second CoRe I felt that if it was not for the course I would have abandoned it. I could feel like telling the critical friend that you are making all these nasty comments and arguments because you do not know what I am going through when I do these CoRes. It was only after the third CoRe that I began to see and understand the whole topic on meiosis differently. I

could then understand meiosis from a very different perspective. I had a completely new understanding of the topic.

From the knowledge I had gained from the use of concept maps and CoRes, I started to reflect on my own teaching and my research at Honours level. My Honours research study was to investigate my learners' understanding of meiosis. I had required them to write what they know about meiosis. The findings from the study revealed that my learners had difficulties in identifying the key concepts of meiosis like meiosis occurs in two phases and that crossing over takes place in meiosis 1 for example. I had failed to understand why the learners had difficulties writing about what they knew about meiosis after all the teaching I had done. It is only now after doing this self-study that I begin to relate my learners' understandings with what this study revealed about my own content knowledge and teaching on meiosis. I now feel that the failure of the learners to have a good understanding of meiosis was not all their own. I had also contributed to their failure to understand the topic well. This study revealed that my content knowledge of meiosis had gaps and misconceptions. I was not thinking and organising the concepts of meiosis well. The misconceptions I had were passed on to the learners. After I had completed the CoRe section of my study, I could not help seeing how much I had not been doing and not saying and not making explicit in my teaching of meiosis. Because I had already taught meiosis earlier in the year, I decided to do a revision lesson in which I had to re-teach meiosis. I could not record this lesson because I did not have ethics clearance. By using what is in my third CoRe my teaching was very different. I used different activities which focused on developing learners' conceptual understanding. I was also very enthusiastic and confident. Even learners' responses to the exercise question that I used for my honours' study were more complete and reflected a better understanding of meiosis concepts. One may however argue that this was a different group and were doing meiosis for the second time.

5.7 Recommendations

From the findings it came out that the use of both concept maps and CoRes in planning a topic for teaching play an important role in the development of both content knowledge and pedagogy for that particular topic. The development of content knowledge and pedagogical knowledge is the focus of many professional development workshops that are organised by the Department of Education. Having seen that the use of CoRes will make the teacher to engage with the content knowledge for teaching, I am of the idea that the use of concept maps

and CoRes in small cluster groups can effectively develop teachers' content and pedagogical knowledge topic by topic. This will however require the appointment and involvement of experts and an investment of time for the teachers. Reading helped me to improve my content knowledge. I would encourage teachers to read much about what they teach as this will keep them abreast with new knowledge. Teachers will think critically if they do not stop reading. The mastery of concepts is fundamental in understanding of knew knowledge being learnt. I would encourage teachers to in-cooperate concept maps when planning their teaching as concept maps will force them to see new connections in concepts to be taught and their importance well before they teach.

I have also seen in my study the importance of prompts in CoRes which not only focus on content knowledge but also give attention on the learners so bringing about a holistic approach in planning particular topics. I would encourage teachers to use CoRes at all times. I also would encourage teachers to team up and produce CoRes they can use for teaching in their clusters. Teaming up to produce a teaching tool like a CoRe or concept map helps the teachers to develop themselves without necessarily going for in-service. I think that it is important for the teachers to expose the challenges they encounter and share them with other teachers for their benefit.

REFERENCES

Asan. A. (2007). Concept maps in Science Class: A case study of fifth grade students. *Educational Technology & Society*, *10*, 186-195.

Abbott. S. (2014). Hidden Curriculum: The Glossary of Education Reform. http://edglossary.og/hidden-curriculum Retrieved 15/8/2014.

Adamczyk, P. & Willson, M. (1996). Using concepts maps with trainee physics teachers. *Physics Education, 31,* 374-381.

Ahuja. A. (2013). Concept Mapping as an effective teaching practice in science education. Techno Learn: *An International Journal of Educational Technology. Techno, 3*, 27-32.

Archavarungson, N., Saengthong, T., Riengrojpitak, S., Panijpan, B., Ruenwongsa, P., & Jittam, P. (2011). An experiential learning unit for promoting conceptual understanding and skills in diagnostic laboratory in undergraduate students. *International Journal of Learning, 18*, 203-217.

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View* (288-320). New York: Holt, Rinehart and Winston.

Austin, T. & Senese, J.C. (2007). Self-study in school teaching: Teachers' perspectives. In J. Loughran, L. Hamilton, V. LaBoskey and Tom Russell (Eds.) *International Handbook of Self-Study of Teaching and Teacher Education Practices* (pp. 1231-1258). Netherlands: Springer.

Bahar, M., Johnstone, A. H. & Hansell, M. H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education*, 33, 84-86.

Bahar, M., Ozel, M., Prokop, P. & Usak, M. (2008). Science student teachers' ideas of the heart. *J. Baltic Science Education*, 7, 78-85.

Ball, D., Bass, H. & Hill, H.C. (2004). Knowing and using mathematical knowledge in teaching: Learning what matters. In A. Buffler and R.C. Laugksch (Ed.) *Proceedings of the 12th Annual conference of the Southern African Association for Research in Mathematics, Science and Technology Education.* Cape Town, South Africa: SAARMSTE.

Ball, D. L., Thames, M. H. & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59, 389.

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of pedagogical content knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *PCK and science education* (pp.147-161). The Netherlands: Kluwer Academic Publishers.

Bell, J. (1999). *Doing Your Research Project* (3rd ed), Milton Keynes: Open University Press.

Beyerbach, B. A. (1988). Developing a technical vocabulary on teacher planning: Preservice teachers' concept maps. *Teaching and Teacher Education*, 4, 33-347.

Bishop, K. & Denley, P. (2007). *Learning Science Teaching: Developing a professional Knowledge Base*. Maidenhead: Open University Press.

Borda, E. J., Burgess, D. J., Plog, C. J., DeKalb, C. N., & Luce, M.M. (2009). Concept maps as tools for assessing students' epistemologies of science. *Electronic Journal of Science Education, 13*, 160-185

Borko, H. & Putnam, R. (1996). Learning to teach. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 673-708). New York: MacMillan.

Bowker, R. (2007). Children's perceptions and learning about tropical rainforests: An analysis of their drawings. Environ. *Education Research* 13, 75-96.

Brown, P. Friedrichsen, P. & Abell, S (2013). The development of prospective secondary biology teachers PCK. *Journal of Science Teacher Education*, 24, 133-155

Burton, N., Brundrett, M. & Jones, M. (2008). Doing education research project. SAGE Publications Ltd

Cañas A. J. & Novak, J. D (2012). Freedom vs. Restriction of content and structure during concept mapping – possibilities and limitations for construction and assessment. Concept Maps: Theory, Methodology, Technology Proc. of the Fifth Int. Conference on Concept Mapping A. J. Cañas, J. D. Novak, J. Vanhear, Eds. Volletta, Malta.

Canas, A., Leake, D., & Maguitman, A. (2001). Combining concept mapping with CBR: Experience-based support for knowledge modelling. In *proceedings of the fourteenth international Florida Artificial intelligence research society conference (*pp. 286-290). Menlo Park, CA: AAAI Press

Canas, J. D., Novak, F. M. & Gonzalez, F. M. (2004). Linking phrases in concept maps: A study on the nature of inclusivity. Concept Maps: Theory. Methodology, Technology. Proc. of the First Int. Conference on Concept Mapping. Eds. Pamplona, Spain 2004

Canas et al. (2003). A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support. The Institute for Human and Machine Cognition. The Chief of Naval Education and Training. Pensacola.

Carvajal, R., Cañas, A. J., Carballeda, M., & Hurtado, J. (2006). Assessing Concept Maps: First Impressions Count. In A. J. Cañas & J. D. Novak (Eds.), *Concept Maps; Theory, Methodology, Technology. Proceeding of the Second International Conference on Concept Mapping,* 1, 28-31.

Cochran, F. K., De Ruiter, J.A. & King, R.A. (1993). Pedagogical Content Knowing: An Integrative Model for Teacher Preparation. *Journal of Teacher Education,* 44, 263-272

Coffey, J. W., Carnot, M. J., Feltovich, P., Hoffman, R. R., Feltovich, J. & Novak, J. D. (2003). A summary of literature pertaining to the use of concept mapping techniques for education and performance support. The institute of human machine cognition. Alcaniz St. Pensacola. www.ihmc.us

De Jong, O. (2001). Exploring Science Teachers' Pedagogical Content Knowledge. *Journal of Research in Science Teaching,* 42, 947-964.

Douma, M., Ligierko, G. & Romano, J. (2009). Creating online mind maps and concept maps. 25th Annual conference on distance teaching & learning.

Elijah, R. (2004). Voice in self-study. In Loughran, J. J., Hamilton, M. L., LaBoskey, V. K. & Russel, T. *International handbook of self-study of teaching and teacher education practices,* 1, 247-271.

Feldman, A. (2003). Validity and quality in self-study. *Educational Researcher, 32,* 26-28.

Fernandez-Balboa, J. & Stiehl, J. (1995). The generic nature of pedagogical content knowledge among college professors. *Teaching and Teacher Education, 11,* 293-306.

Geddis, A.N. & Wood, E. (1997). Transforming Subject Matter and Managing Dilemmas: A Case Study in Teacher Education. *Teaching and Teacher Education,* 13, 611-626.

Gess-Newsome, J., & Carlson, J. (2013). *An international perspective on pedagogical content knowledge.* Paper presented at the Association for Science Teacher Education Conference, Charleston, SC. http://pcksummit.bscs.org

Glasersfeld, E. (1991). A constructivist's view of learning and teaching. Proceedings of an international workshop. *Kiel, Germany*, 29-39.

Gown, D. B. (1984). *Learning How to Learn.* Sydney, AU: Cambridge University Press.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*, New York, Teachers College Press.

Grossman, P. L., Wilson, S. M. & Shulman, L. S. (1989). Knowledge base for effective teaching pedagogical content knowledge. Philosophy of recruit. http"//education.illinois.edu/recur. (05/05/2014)

Halim, M. & Meerah, S. M. (2002). Science Trainee Teachers' Pedagogical Content Knowledge and its Influence on Physics Teaching. *Research in Science and Technological Education,* 20, 215 -225.

Hallden, O. (1990). Questions asked in common sense contexts and in scientific contexts. *In: Relating macroscopic phenomena to microscopic particles. A central problem in secondary science Education, ends.*

Hasweh. M. (1987). The Effect of subject content knowledge. *European Journal of Teacher Education, 4*, 138-153.

Hume, A. & Berry, A. (2010). Constructing CoRes- a strategy for building PCK in pre-service education, *Research Science Education*, 41, 341-355.

Hill, H. E., Ball, D. E. & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in mathematics Education*, 39, 372-400.

Hoban, G.F, Buttler, S. & Lesslie, L. (2007). Facilitating self-study of professional development: Researching the dynamics of teacher learning. *Studying Teacher Education, 3*, 35-51.

Jamieson, P. (2012) "Using modern graph analysis techniques on mind maps to help quantify learning," in *Frontiers in Education Conference (FIE), 2012*, Oct. 2012. [Online]. Available: http://www.users.muohio.edu/ jamiespa/html papers/fie 12.pdf

Jonassen, D. H. (1996). *Computers in the Classroom: Mind tools for Critical Thinking*. New Jersey: Prentice- Hall.

Jonassen, D. H., Beissner, K., & Yacci, M. A. (1993). The Effects of concept mapping on learner's metacognitive skill in problem solving. New Jersey: Prentice-Hall.

Jonassen, D. H., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. Handbook of Research on Educational Technology. New York.

Jurgen Bostler, J. (Unpublished). *Relational Scoring of Concept Maps.*

Kagan, D. M. (1990). Ways of evaluating teacher cognition: Inferences concerning the Goldilocks Principle. *Review of Educational Research*, 60, 419–469.

Keles, O. & Saglam, N. (2012). Examination of Elementary Teachers' Views about Concept Maps. *Journal of Studies in Education*, 2, 1314-1333.

Keppens, J. and Hay, D. (2008). *Concept map assessment* for *teaching computer programming*, 18, 31-42.

Kharatmal, M. (2006). Concept mapping for eliciting students' understanding of science. Homi Bhabha Centre for Science Education, (TIFR), V.N. Purav Marg, Mumbai.

Kind, V. (2010). Pedagogical content knowledge in science education: perspectives and potential for progress. *Studies in Science education*, 45, 169 – 204.

Kinchin, M. I. & Hay, D. H. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Researcher, 42*, 42-57.

Knight, J. F. & Smith, M. K. (2012) Using the genetics concept assessment to document persistent conceptual difficulties in undergraduate genetics courses. *Journal of teacher education*, 4, 25-35.

Knippels, M. P. J., Waarlo, A. J. & Boersma, K. T. (2005). Designing criteria for learning and teaching genetics. *Journal of Biological Education,* 39, 108-112.

Koehler, M. J. (2011). Measuring teachers' learning from a problem-based learning approach to professional development in science education. *Interdisciplinary journal of problem- based learning*, 2, 432-447.

Kose, S. (2008). Diagnosing student misconceptions: Using drawings as a research method. *World Application Science Journal,* 3, 283-293.

Kosnick, C., Beck, C. Freese, A. R,. & Samaras, A. P. (2006). Making a difference in teacher education through self-study: Studies of personal, professional, and program renewal. Dordrecht: Springer.

Kosnick, C., Beck, C. Freese, A. R,. & Samaras, A. P. (2004). Making a difference in teacher education through self-study: Studies of personal, professional, and program renewal. Dordrecht: Springer.

Loughran, J., Berry, A. & Mulhall, P. (2012). Understanding and developing science teachers' pedagogical content knowledge. 2nd ed. Sense Publishers: Rotterdam.

Loughran, J., Mulhall, P. & Berry, A. (2004). In Search of Pedagogical Content Knowledge in Science: Developing Ways of Articulating and Documenting Professional Practice. *Journal of Research in Science Teaching, 41,* 370-391.

Loughran, J., Berry, A., & Mulhall, P. (2006). Understanding and developing science teachers' pedagogical content knowledge. AW Rotterdam, The Netherlands: Sense Publishers.

Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. *PCK and Science Education,* 18, 95-132.

Mass, J. D. & Leauby, B. A. (2005). Concept mapping – exploring its value as a meaningful learning tool in accounting education. *Global Perspectives on Accounting Education,* 2, 75-98.

Mass, J. D. & Leauby, B. A. (2005). Concept mapping – exploring its value as a meaningful learning tool in accounting education. *Global Perspectives on Accounting Education,* 2, 75-98.

Mavhunga, M. E. (2011). Developing a qualitative topic specific PCK tool. *PhD weekend presentation.* University of Witwatersrand.

Mavhunga, M. E. & Rollnick, M. (2011). *Topic Specific Knowledge For Teaching As A Construct For Investigating The Development Of Chemistry PCK In Pre-Service Science Teachers.* Conference paper.

Mclure, J. R, Sonak, B. & Suen, H. K. (1999). Concept Map Assessment of Classroom Learining: Reliability, Validity and Logistical Practicality. *Journal of research in science teaching,* 36, 475-492.

Moran,-E, J., Alexander, V. D., Cronin, A., Dickinson, M., Fielding, J., Sleney, J., & Thomas, H. (2006). Triangulation and integration: processes, claims and implications. *Qualitative Research, 6,* 45-59.

Moreira. M. A. (2011). Why concept maps, why meaningful learning, why collaborative activities and why concept maps? *Aprendizagem Significativa em Revista/Meaningful Learning Review,* 3, 1-11.

Moseley, B. & Brenner, M. E. (1997). Learning by understanding. *American Educational Firesearch Journal,* 663-689.

Nilsson, P & Loughran, J (2012). Exploring the development of Pre-Science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education,* 23, 699-721

Nilsson, P. (2008a). Recognizing the needs - Student teachers´ learning to teach from teaching. *Nordina,* 4, 284-299

Novak, J. D. (1998). *Learning, Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations.* Trenton, NJ: Lawrence Erlbaum Associates, Inc.

Novak. J. D. (1991). Introduction to concept mapping. Retrieved from http://uwf.edu/jgould/conceptmappintro.pdf 27-05- 2014.

Novak, J. D., & Gown, D. B. (1984). Learning how to learn. New York: Cambridge University Press.

Opie, C. (2006). Doing educational research. A guide to First Time Researchers. Sage. London. Sage Publications.

Ozcan, T., Yildirim, O. & Ozgur, S. (2012). Determining of the university freshmen students' misconceptions and alternative conceptions about mitosis and meiosis. *Procedia – social and behavioural sciences,* 46, 3677 – 3680.

Oztap, H., Ozay, E. & Oztap, F. (2003). The teaching of cell division to secondary school students: an investigation of difficulties experienced by Turkish teachers. *Journal of Biology Education,* 38, 378-387.

Padilla et al. (2008). The relationship between PCK components: the case of quantum chemistry professors. *Chemistry education research and practice,* 16, 987-1009.

Popova-Gonci, V. (2013). Concept mapping and PLA: Assessment of tacit and non-linear learning. *Inside Out,* 2, 904-999.

Prokop, P. & Fanèovièová, J. (2006). Students' ideas about human body: Do they really draw what they know? J. *Baltic Science Education,* 2, 86-95.

Quinn, F., Pegg, J. & Panizzon, D. (2009). First-year biology students' understanding of meiosis: An investigation using a structural theoretical framework. *International Journal of Science Education,* 31, 1279-1315.

Ravichandran, S. (2010). Master's Thesis in Computing Science. Umea University, Umea SWEDEN.

Rennie, L. J. & Jarvis, T. (1995). English and Australian children's perceptions about technology. *Research Science Technology Education,* 13, 37-52.

Reynolds, C. (1999). The advantages of concept maps. from *http://www.ehow.com/how_5662122_make-science-concept-map.html 11/06/2013.*

Robert, V., Bullough, Jr. & Pinnegar, S. (2001). Guidelines for quality in autobiographical forms of self-study research. *Educational Researcher,* 30, 13-21.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N. & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: a Case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education,* 30, 1365-1387.

Ruíz-Primo, M. (2000). On the use of concept maps as an assessment tool in science: What we have learned so far. *Revista Electrónica de Investigación Educativa,* 2 (1) http://redie.uabc.mx/vol2no1/contents-ruizpri.html

Ruiz-Primo, M. A. & Shavelson, R. J. (1996). Problems and issues in the use of Concept Maps in science assessment. *Journal of Research in Science Teaching, 33,* 569-600.

Samaras, A. P. & Freese, A. R. (2006). *Self-study for Teaching Practices Primer.* New York: Peter Lang.

Scaife, J. (2004). Reliability, Validity and Credibilty. In C. Opie (Ed). *Doing Educational research.* (pp 58-72). Sage: London.

Scherz, Z. & Oren, M. (2006). How to change students' images of science and technology. *Science Education.* 90, 965-985.

Schumacher, S. & McMillan, J. H. (2010). Research in education: Evidence – Based Inquiry (7th Ed.) Pearson Education. New Jersey USA.

Schwendimann, B. A. (2006). Digital Knowledge Maps is Education: Teaching-Enhenced Support for Teachers and Learners. D. Ifenthaler & R. Hanewald (eds). Springer & Business Media. New York

Segall, A. (2004). Revisiting pedagogical content knowledge: the pedagogy of content/the content of pedagogy. *Teaching and Teacher Education,* 20, 489-504.

Shavelson, R. (1993). On concept maps as potential "authentic" assessments in science. Indirect approaches to knowledge representation in high school science. National Centre for Research on Evaluation, Standards and Testing, Los Angeles, C.A. Washington, DC:

Shavelson, R. J., Ruiz-Primo, M. A., & Wiley, E. W. (2005). Windows into the mind. *Higher Education,* 49, 413-430

Shulman, L.S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*, 4-14.

Shulman, L.S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review,* 57, 1-22.

Smith, B. R. & Knight, D. B. (2012). Genetics and Society – Educating Scientifically Literate Citizens. Retrieved: 23/06/2014) *http://biologue.ch/fr/wpcontent/uploads/sites/2/2012/10Kamourakis-et-al.-Genetics*

Stodolsky, S. S. & Grossman, P. L. (1995). The Impact of Subject Matter on Curricular Activity: AN Analysis of Five Academic Subjects. *American Educational Research Journal,* 32, 227-249.

van Driel, J.H., Verloop, N. & de Vos, W. (1998). Developing Teachers' Pedagogical Content Knowledge. *Journal of Research in Science Teaching, 35*, 673-695.

Wallace, J. D., & Mintzes, J. J. (1990). The concept map as a research tool: Exploring conceptual change in biology. *Journal of Research in Science Teaching,* 27, 1033-1052.

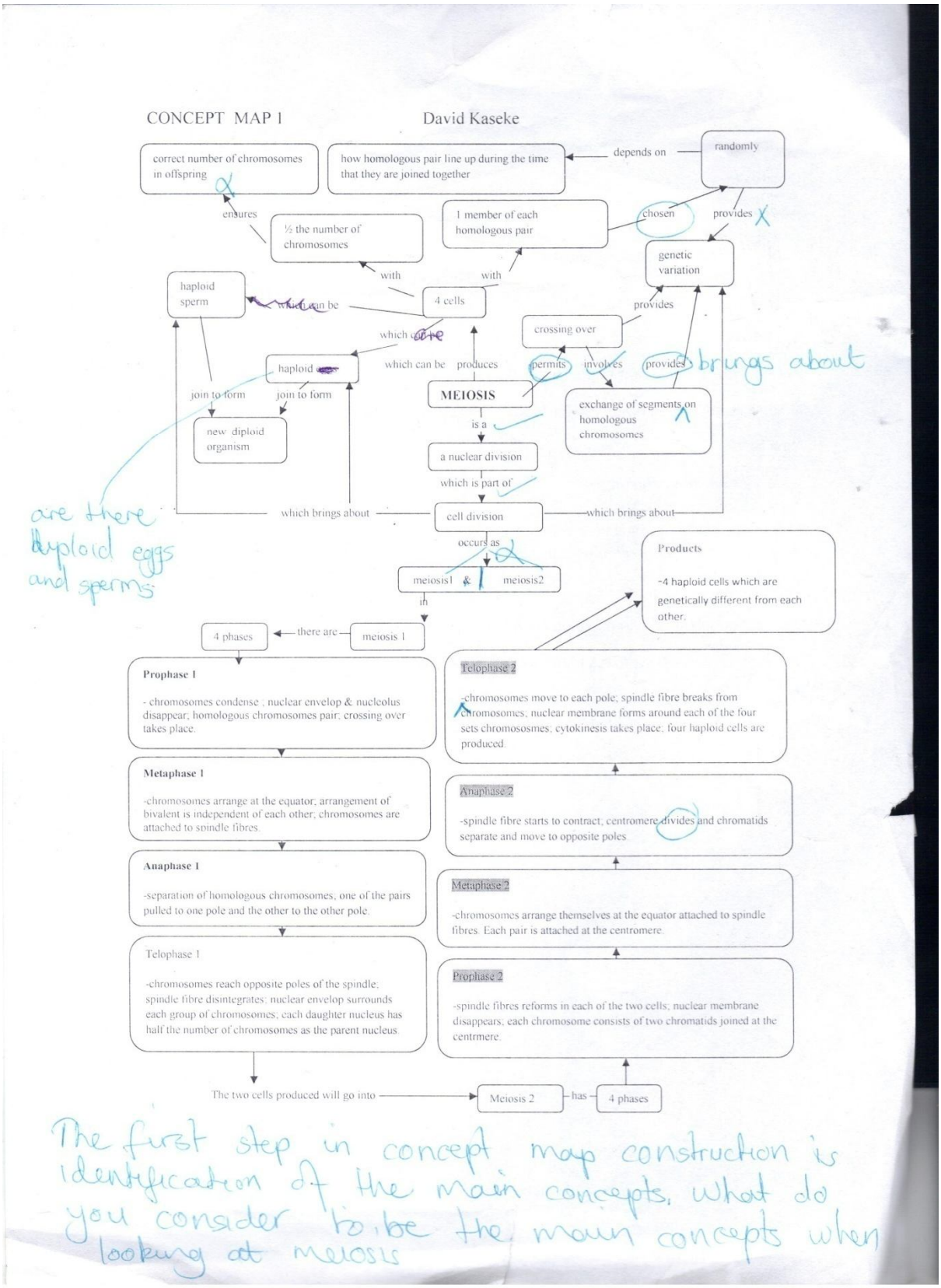
White, R. & Gunstone, R. F. (2000). Probing understanding. London, UK, Falmer Press.

William, J. & Lockley, J. (2012). Using CoRes to develop the pedagogical content knowledge (PCK) of early science and technology teachers. *Journal of technology Education.* 24, 675-683.

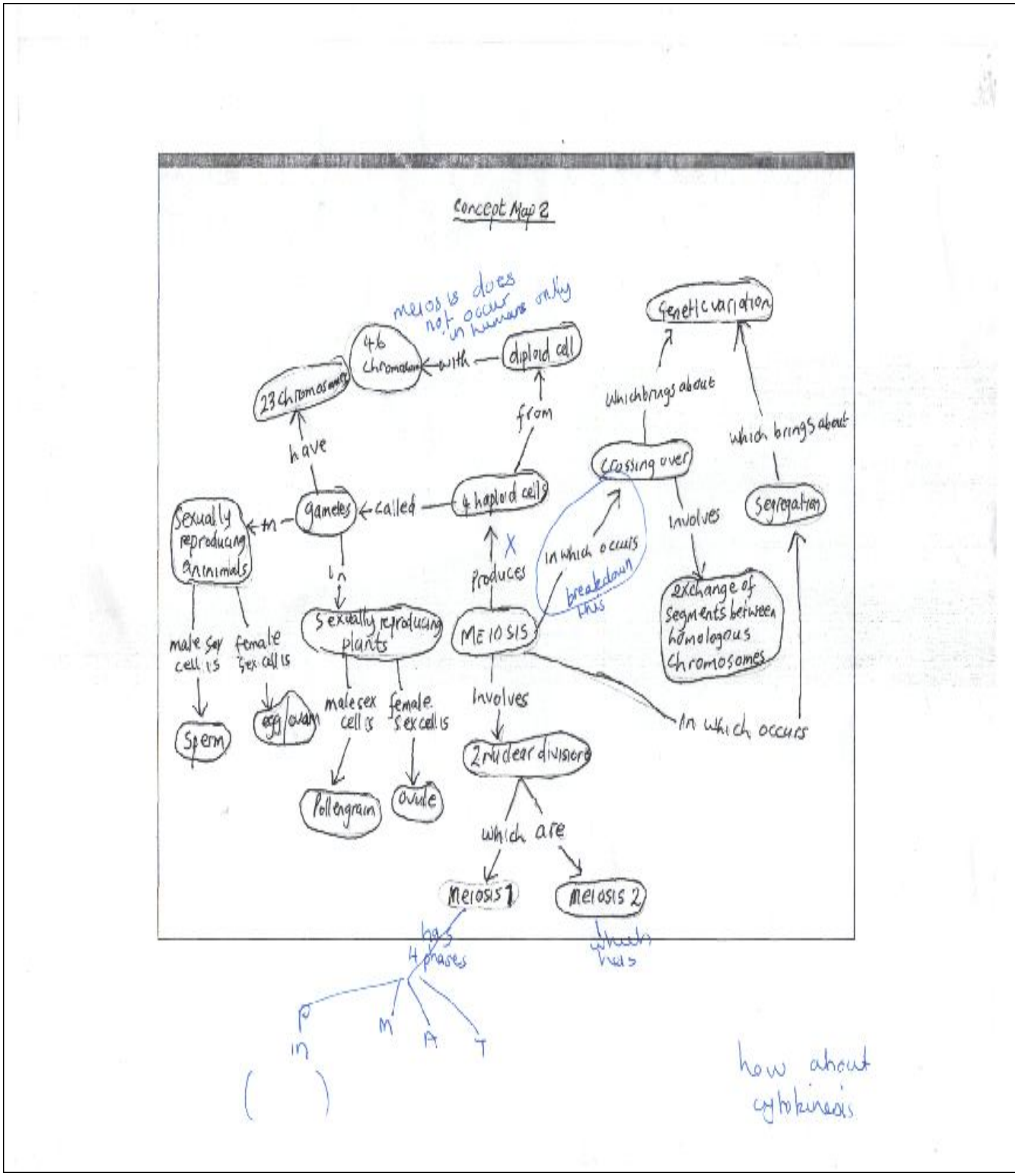
Yesilurt, S. & Kara, Y. (2007). The effects of tutorial and edutainment software programs on students' achievements, misconceptions and attitudes towards biology on the cell division issue. *Journal of Baltic Science Education*, 6, 5-15.

APPENDIX A: Concept maps

Appendix A 1 – Concept map 1



Appendix A 2 – Concept map 2



APPENDIX B: CoRes

Appendix B 1 – CoRe 1

Grade 12 Life Science (Meiosis)	Important science ideas/concepts		
	What is meiosis?	Processes involved during meiosis.	Products of meiosis
What do you intend students to learn from this idea.	-That meiosis is a nuclear division that in humans occurs only in male testes and female ovary tissues. (It also occurs in plants), and is characteristic of sexual reproduction. -In meiosis the nucleus divides twice unlike in mitosis -That meiosis involves the division of a single parent diploid cell to produce four daughter haploid cells. -That meiosis is a reduction in the amount of genetic material – that is one half the original genetic material of the original cell. -That meiosis is different from mitosis. -That meiosis is the great process that shuffles the cell's genes around.	-Learners to know that meiosis involves two phases meiosis 1 and meiosis 2, which makes it different from mitosis. -That the phases of meiosis are not stagnant as might be portrayed in books, it is a cycle of the cell. -That the behaviour of chromosomes is different at each phase.	-That at the end of meiosis four haploid cells which are genetically different are produced.
Why is it important for students to know this?	-That meiosis facilitates stable sexual reproduction, it keeps the number of chromosomes from doubling each generation. Without the halving of ploidy, or chromosome count, fertilization would result in zygotes that have twice the number of chromosomes as the zygotes from the previous generation. Successive generations would have an exponential increase in chromosome count.	-That as the cell completes the two phases, the number of chromosomes will be half the number of chromosomes the cell initially started with. -That in prophase 1 chromatids from the homologous chromosomes cross over and exchange segments so that each	-It is the only process in which gametes are produced. -Is the main source of variation in organisms. -Is what makes meiosis different from mitosis.

Appendix B 2 – CoRe 2

Grade 12 Life Science (Meiosis)

	Important science ideas/concepts		
	What is meiosis?	Processes involved during meiosis.	Products of meiosis
What do you intend students to learn from this idea.	-That meiosis is a nuclear division that in humans occurs only in male testes and female ovary tissues. (It also occurs in plants), and is characteristic of sexual reproduction. -In meiosis the nucleus divides twice unlike in mitosis -That meiosis involves the division of a single parent diploid cell to produce four daughter haploid cells. -That meiosis is a reduction in the amount of genetic material – that is one half the original genetic material of the original cell. -That meiosis is different from mitosis. -That meiosis is the great process that shuffles the cell's genes around.	-Learners to know that meiosis involves two phases meiosis 1 and meiosis 2, which makes it different from mitosis. -That the phases of meiosis are not stagnant as might be portrayed in books, it is a cycle of the cell. -That the behaviour of chromosomes is different at each phase.	-That at the end of meiosis four haploid cells which are genetically different are produced.
Why is it important for students to know this?	-That meiosis facilitates stable sexual reproduction, it keeps the number of chromosomes from doubling each generation. Without the halving of ploidy, or chromosome count, fertilization would result in zygotes that have twice the number of chromosomes as the zygotes from the previous generation. Successive generations would have an exponential increase in chromosome count.	-That as the cell completes the two phases, the number of chromosomes will be half the number of chromosomes the cell initially started with. -That in prophase 1 chromatids from the homologous chromosomes cross over and exchange segments so that each	-It is the only process in which gametes are produced. -Is the main source of variation in organisms. -~~Is what makes meiosis different from mitosis.~~

Appendix B 3 – CoRe 3

CoRe 3

Grade 12 Life science

(Meiosis)

	Important science ideas/concepts	
	Meiosis causes genetic variation	Meiosis can go wrong
1 What do you intend students to learn from this idea.	That the main cause of genetic variation in animals is variation. That crossing over is one of the causes of variation in animals. That random assortment or segregation is also another cause of genetic variation in animals. That variation is caused by random fertilisation in the formation of zygotes.	That during meiosis chromosomes can fail to separate. That the failure of chromosomes to separate can be an advantage in plants and a disadvantage in human beings. That they can understand that in plants where chromosomes fail to separate during meiosis it can results in large fruits. That plant breeders are able to form polyploidy plants by using chemicals such as colchicines which prevents the formation of spindle fibres from forming and as a result chromosomes cannot separate during cell division. As a result the cells that are formed have twice the total number of chromosomes.
2 Why is it important for students to know this?	That they can know that meiosis is the only way in which sex cells are produced in sexually reproducing organisms. That they can know/understand how cells with half the number of chromosomes are produced.	That they can understand that the differences which exist among people of the same family or organisms of the same species is a result of what happened during meiosis mainly.
3 What else you know about this idea (that you do not intend students to know yet).	That in some organisms meiosis occurs when fertilisation has taken place. That not all gametes are produced by meiosis for example in mosses and ferns.	That in some cases, genetic variations are caused by mutations. That genetic variation is a source of evolution.

Cofa 2 | 35:40

312

4	Difficulties/limitations connected with teaching this idea.	Read literature Terminology used in meiosis teaching,	To understand that the tiny microscopic chromosomes cross-over. To understand that homologous chromosomes find each other in order to cross-over.	49,00 To understand that science has taken advantage of non-disjunction of chromosomes to produce larger seedless fruits. to understand or appreciating that we are labeling ea is being wrong meiosis is taken as an advantage
5	Knowledge about students' thinking which influences your teaching of this idea.		Learners in African cultures believe that differences can be caused by the people the mother loved when she was pregnant.	some Learners believe that it is witchcraft which cause what we call genetic diseases in science eg albinism.
6	Other factors that influence your teaching of this idea.	Learners do not know that it is meiosis which keeps the number of chromosomes from doubling in each generation.	It can be difficult for learners to understand that the tiny microscopic chromosomes cross-over and pair up randomly so bringing about genetic variation.	For learners to understand that some diseases people have were inherited from parents through gametes formed by meiosis.
7	Teaching procedures (and particular reasons for using these to engage with this idea). What is a teaching strategy	A practical to be done in groups using pipe cleaners or strings to show the behaviour of chromosomes as they separate to form sex cells.	In groups learners study and identify some variations among themselves including tongue rolling, left-handed and right-handed, darkly pigmented eyes and blue eyes, hitchhiker's' thumb and straight thumb and ear lobes.	Class discussions on some disadvantages of mutations in humans such as Albinism and genetic diseases such as Down Syndrome, cystic fibrosis and haemophilia and some advantages of polyploidy (non-disjunction) in plants such as production of large seedless fruits.
8	Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)	Class work X 1. To identify various phases of meiosis from diagrams.	Class work ✓ 1. To identify prophase 1 and metaphase 1 as the phases of	1. ✓ Identify two genetic disorders eg. Down Syndrome and Albinism and answer the following

39.45

1, Explain how halving is achieved

Explain how meiosis brings about variation

APPENDIX B 4: Final CoRe

Grade 12 Life science

(Meiosis)	Important science ideas/concepts		
	Meiosis results in the formation of gametes	Meiosis causes genetic variation	Meiosis can go wrong
What do you intend students to learn from this idea.	That gametes are only produced by meiosis in sexually reproducing animals and plants. That gametes which are cells with half the number of chromosomes are produced by meiosis. How the formation occurs in meiosis 1 and meiosis 2 i.e. how meiosis halves the number of chromosomes That meiosis results in the reduction in the amount of genetic material – that is one half the original genetic material of the original cell will be left in each cell at end of meiosis and cytokinesis.	That crossing over is one of the causes of genetic variation in animals. What is crossing over and how does it occur What is random assortment That random assortment or segregation is also another cause of genetic variation in animals.	That during meiosis chromosomes can fail to separate. How does failure to separate happen What are the possible causes That the failure of chromosomes to separate can be an advantage in plants and a disadvantage in other animals especially humans. Some genetic diseases are a result of chromosomes failing to separate during meiosis
Why is it important for students to know this?	That they can know and appreciate the significance of meiosis in sexually reproducing organisms.	That they can understand that the differences which exist among organisms belonging to the same family or organisms of the same species is a result of what happen during meiosis mainly.	That they can know that some diseases in humans are genetic caused by failure of chromosomes to separate during meiosis. To understand that in plants where chromosomes fail to separate during meiosis it can results in the formation of large fruits or seedless fruits.

What else you know about this idea (that you do not intend students to know yet).	That in some organisms meiosis occurs when fertilisation has taken place. That not all gametes are produced by meiosis for example in mosses and ferns. That Prophase 1 can be divided into five sequential stages.	That in some cases, genetic variation is caused by mutations. That genetic variation is a source of evolution.	That plant breeders are able to form polyploidy plants by using chemicals such as colchicines which prevents the formation of spindle fibres from forming and as a result chromosomes cannot separate during cell division. As a result the cells that are formed have twice the total number of chromosomes.
Difficulties/limitations connected with teaching this idea.	There is a lot of abstract terminology, phrases and concepts to learn and difficult to link so making the teaching of cell division difficult to teach. The diagrams of meiosis used in textbooks portray the phases of meiosis as not occurring within the same cell.	That chromosomes contain genes and it is the genes that are exchanged during crossing over	To understand or appreciate that some of those errors which occur in meiosis can be taken advantage off by scientists e.g. non-disjunction of chromosomes to produce larger seedless fruits. (Scientists are manipulating errors to their advantage).
Knowledge about students' thinking which influences your teaching of this idea.	Learners will not see the diagrams of phases of as one cell going through different phases of the cell cycle.	Learners in African cultures believe that differences can be caused by the people the mother loved or hated when she was pregnant.	Some learners believe that it is witchcraft which cause what we call genetic diseases in science e.g. albinism.
Other factors that influence your teaching of this idea.	Learners don't know what gametes are and what their functions are and therefore may not appreciate the importance of meiosis.	Learners may not know that chromosomes carry genes .	For learners to understand that some diseases people have were inherited from parents through gametes formed by meiosis.

Teaching procedures (and particular reasons for using these to engage with this idea).	Class discussion – (Testing of learners' prior knowledge). I will be asking learners questions what they know about somatic cells they did in grade 10. I also find out what they know about sex cells and see if they know any differences between the somatic cells in mitosis and sex cells. Exposition – I will then explain to the learners that we are going to learn about meiosis which results in the formation of sex cells. Here I teach about the purpose of meiosis and the processes involved in the two phases of meiosis which result in the division of the cell nucleus. A practical demonstration. In groups using pipe cleaners or strings, learners demonstrate how chromosomes in meiosis 1 & 2 behave which results in their separation to form sex cells. The demonstration is then followed by groups explaining to class what was happening to the chromosomes at each stage.	Teaching - Teacher explains to learners that chromosomes are made up of genes. (Teacher draws a pair of chromosomes so that the learners can see the positions of the genes controlling the same characteristic). A pair of chromosomes has a pair of genes controlling the same characteristic e.g. two genes control eye colour eye and that the dominant gene is that which controls the outward appearance of the organism. This explanation will help the learners to understand that variations are caused by genes. In groups learners study and identify some variations among themselves including tongue rolling, left-handed and right-handed, darkly pigmented eyes and blue eyes, hitchhiker's' thumb and straight thumb and ear lobes. Teacher provides pictures of shells of snails and fruit flies and asks learners in their groups to identify some small variations in shells of snails (mollusc) and some variation in fruit flies (Drosophila Melanogaster). This activity is done to let learners know that organisms are different despite belonging to the same species.	Class discussion – (Testing prior knowledge) I will be asking learners questions like why some people are albinos when both their parents have dark pigmentation. Here I wanted to find out about the learners' belief systems. The knowledge will help to bring about conceptual change in learners.. Exposition – I will teach learners for example what Down Syndrome is. I will then explain to learners that all the chromosomes in human beings can be mapped up in a karyotype to show the twenty three pairs. I then teach using karyotype to show where the cause of some genetic diseases like Down Syndrome is for example. This will help to show the learners that some of the diseases some people have are genetic. Class discussions on some disadvantages of meiotic division such as Down Syndrome, Klenefelter's syndrome where the male has an extra X e.g. (XXY); Tuner syndrome where the cell has only one X (monosomy X) and some advantages of polyploidy (non-disjunction) in plants such as production of large seedless fruits. The discussion will help learners to understand some of the dangers of meiosis going wrong. as well as the advantages it has in agriculture.

			Group work – I will give each group one karyotype with normal chromosomes and some karyotype showing Down Syndrome, Klenefelter's syndrome and Tuner syndrome. They will then identify the karyotype showing each of the three genetic diseases. Exposition – I will then explain to the learners that maybe at Anaphase 1 or Anaphase 2 the splitting or separation of chromosomes did not occur, both chromosomes went to one side. The reason behind exposition is make learners understand what will have happened for some of the genetic diseases to occur.

Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)	In their groups of threes learners will identify the key features of meiosis, its importance and products. The teacher will move from group to group 'listening' to the descriptions being given by the learners. Each member of the group will then share their discussions/findings with the class e.g. of the three members, one reports on key features of meiosis, the other on importance and the third one on products of meiosis. This will promote participation of all members of the group and so will help the teacher to identify aspects which will be difficult for learners and so assists them. Learners might not be able to have noticed that meiosis 1 separates chromosomes yet meiosis 11 separates chromatids. As a class we identify and make a list of the concepts important in meiosis and then ask the learners to construct the concept maps in their groups. I will give earners micrographs on meiosis and ask them to identify various stages of meiosis. Class work. In their class-work books learners, learners explain how halving the number of chromosomes is achieved.	Class-work 2. Explain in their class-work books how meiosis brings about variation.	Identify two genetic disorders e.g. Down Syndrome and Klenefelter's syndrome and answer the following questions in each of the disorder: (a) What causes the disorder? (b) How is it inherited? (c) What are the symptoms of the disorder? (d) How does the disorder affect the health of the person?

APPENDIX C: Study Consent Documents

Appendix C 1 – GDE Research Approval letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2013/071

GDE RESEARCH APPROVAL LETTER

Date:	5 June 2013
Validity of Research Approval:	5 June 2013 to 20 September 2013
Name of Researcher:	Kaseke D.
Address of Researcher:	10 Marinda Court
	3 Park Street
	Randfontein
	1759
Telephone Number:	011 414 0360 / 078 226 7185
Fax Number:	011 414 5702
Email address:	d.kaseke@yahoo.com
Research Topic:	Developing Pedagogical Content Knowledge (PCK) on meiosis through the use of Content Representation (CORes)
Number and type of schools:	ONE Secondary School
District/s/HO	Gauteng West

Re: Approval in Respect of Request to Conduct Research

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

2013/06/11

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

1

Making education a societal priority

Office of the Director: Knowledge Management and Research
2nd Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Mkhodo@gauteng.gov.za
Website: www.education.gpg.gov.za

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

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

Kind regards

.....

Dr David Makhado
Director: Knowledge Management and Research

DATE: 2013/06/06

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

Appendix C 2 – Wits Ethics Clearance

Wits School of Education

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

Student Number:
510143

Protocol Number:
2013ECE089M

Date: 10-07-2013

Dear David Kaseke

Application for Ethics Clearance: Master of Education

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

Developing Pedagogical Content Knowledge of meiosis through the use of Content Representations (CoRes)

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

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

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

All the best with your research project.

Yours sincerely

M Mabeta

Mats'e Mabeta
Wits School of Education
011 717 3416

CC Supervisor: E Nyamupangedengu