Faculty of Science

Developing the act of knowledge transformation through self-study: Teaching about stars

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Declaration

I hereby declare that this research report is my own unaided work. It is submitted for the degree of Masters of Science (Science Education) at the University of Witwatersrand, Johannesburg. It has not been submitted for any other degree or examination in any other university, nor has it been prepared under the guidance or with the assistance of any other body or organization or person outside the University of Witwatersrand, Johannesburg.

Tshiamiso Makwela

Date: 17 July 2017

Abstract

The research study focused on me as a teacher: how I went about learning the content knowledge of stars and also learning how to transform that content knowledge into the knowledge of teaching. In addition, it also looked at how my own pedagogical practices may influence the learning and understanding of the topic of ‘stars’ to pre-service teachers; in serving the goal of enabling me as a teacher to improve my own practice.

A self-study research methodology was employed in this study where an action research approach was used in collecting data and analysing it. The data was collected through the use of concept maps, a questionnaire, and interviews with students as well as video recording of the lesson. During this research study, I was in a continuous reflective process, whereby I was going through the stages of an action research study (plan, act, observe and reflect) to enable me to improve and develop both my content knowledge and how I transform it in ways that will be accessible to the students.

According to Shulman (1987) Pedagogical Content Knowledge (PCK) is a special kind of knowledge which makes the teacher to be different from other professions. Shulman (1987) argued that the transformation of subject matter knowledge (Content knowledge) is the process which leads to the development of a teachers’ PCK. More so, PCK is a product of transformation of content knowledge. Therefore, when that transformation is done in a particular topic “e.g. stars” then the version of PCK generated is the “Topic Specific PCK”. Topic Specific Pedagogical Content Knowledge (TSPCK) was the theoretical framework which underpinned the study. This is because it is through the components of TSPCK as stipulated by Mavhunga and Rollnick (2013) in which the transformation of Content knowledge can occur.

Concept maps were an effective tool in ensuring progressive learning. The concept maps which I constructed in this study made me aware of my own misconceptions, errors and missing knowledge gaps in my content knowledge of stars. Therefore, the concept maps helped me to move to more accurate conceptions with the assistance of the interventions such as planetarium visits, astronomy evenings as well as visits to the library. The interventions enabled me to acquire new content knowledge which was then captured by the concept maps. Gaining content knowledge was necessary for me to be able to transform it for the purpose of teaching. The components of knowledge transformation were identified from the critical incidents, which were moments abstracted from the lesson which I taught. PCK is in two forms, there is planned and enacted PCK. The planned PCK was yielded by the construction of the CoRe and acted PCK was yielded by the lesson which was taught twice (for improvement). The questionnaire results show that although students may gain confidence after attending a lesson, some of their initial conceptions may not be altered.

From the study, it shows that as a teacher being more reflective of my own practice improves my content knowledge and my pedagogical practices (teaching); thus contributing to my development of PCK.

Dedication

To my mother Louisa Mpule Makwela my pillar of strength.

To my family, Thabang and Lesego. To my friends, Amo, Lindo, Motsoane, Lesego;

I cannot thank you enough for your support.

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Acronyms

- AR – Action Research
- CAPS – National Curriculum Assessment Policy Statement
- PCK – Pedagogical Content Knowledge
- TSPCK – Topic Specific Pedagogical Content Knowledge
- CK – Content Knowledge
- SMK – Subject Matter Knowledge
- CS – Curriculum Saliency
- LP – Learners' Prior Knowledge
- RP – Representations
- WD – What is difficult to teach
- CTS – Conceptual Teaching Strategy
- WAC – Wits Astronomy Club
- WRAC- West Rand Astronomy Club
- HartRAO – Hartebeesthoek Radio Astronomy Observatory
- CM – Concept Map
- CoRe – Content Representation

Chapter 1

Introduction to the study

1.1 Introduction

When we look up at night, we see things that shine which are called stars, 'dinaneledi' in Setswana and 'izinkanyezi' in Zulu. These stars are fascinating to our eyes and yet we do not fully understand them. A star is one of the things that everyone gets to experience in their lifetime through seeing it in the night sky, however most people do not actually know what or how to describe a star. Usually people hold ideas that 'stars shine by reflected light from the Sun' or that 'the Sun is not a star' (Agan, 2004). These ideas may be referred to as errors or misconceptions about stars as they are not true but are very important to note because if they are not dealt with, they may impede the development of a deep conceptual understanding of the concepts taught. Hence, these ideas which are held by people inform what they perceive as well as their future understanding of stars.

Learning and teaching are two processes which are normally used simultaneously in an environment in which one is gaining content knowledge. Meaning that when one person teaches the other learns although it is not always that teaching leads to learning. I call the two terms processes because they are not events which only occur once, they are not static but they are rather continuous practices. Teaching is not an easy task (Loughran et al., 2008); before one can teach she/he needs to know what they are teaching and how to teach it. Therefore, teacher knowledge is important in these two processes; hence as a teacher I needed to look at my own knowledge of the subject as well as my knowledge for teaching the subject in order to improve my practice. Improving my practice as a teacher means improving my content knowledge as well as how I teach it. This study attempts to capture my learning of content knowledge of stars and how I transform that knowledge for the purpose of teaching.

1.2 Background

My own ideas about natural phenomena influence my understanding about them, meaning that my own ideas are in coherence with my experiences as well as the mental representations that I have constructed which I use when explaining scientific concepts. Vosniadou and Brewer (1994) mentioned that students may hold naïve conceptions which may be reasonably consistent and empirically accurate models which they use to describe and explain scientific concepts. Similarly, Plummer and Slagle (2009) argue that students' initial understanding of natural phenomena is grounded by their own personal observations and interactions of the world. Therefore, it can be argued that in teaching and learning; the student and the teacher both have their own experiences and models which they use to explain natural phenomena. However, studies in astronomy education (Vosniadou & Brewer 1994; Sharp, 1996; Plummer et al., 2010) have explored only one 'end' which is the students' prior knowledge, experience and models that influence how they understand natural phenomenon and little is said about how teachers understanding influence their teaching about astronomical concepts. 'Stars' or 'the stars' are the astronomical concept which has not been largely explored in astronomy education; unlike the other concepts such as the moon, day and night as well as the solar system which have been largely explored in the field of astronomy education. Lelliott & Rollnick (2010) suggested that a star is one of the big ideas in the learning of astronomy in which little research has been done. Bailey, Prather, Johnson and Slater (2009) argue that a considerable amount of research on students' understanding about some astronomy concepts such as moon faces as well as day and night has been conducted. However, there is relatively small amount of research on students' understanding pertaining to stars and students' pre-instructional ideas about stars exists. Similarly Bailey & Slater (2003) contend that there exists almost no research on students' pre-existing beliefs and reasoning difficulties about stars, star formation, or star death.

Agan's (2004) study explores the understanding about the stars in students of different levels of study. Students' knowledge about the stars is enhanced through their understanding of basic astronomy, and the students who are not enrolled for astronomy tend to focus on the macroscopic characteristics such as the size of the star (Agan, 2004). In addition the study by Taylor, Baker & Jones (2003) looks at how pedagogical practices can promote mental model building in astronomy education for our students. Taylor asserts that students' own ideas followed by the revision of those ideas can enable students to interrogate their prior ideas. However, teachers' ideas about conceptions in astronomy remain a mystery, meaning that research focused on teachers' ideas about stars is limited. Thus this study is centred on the teachers' pedagogies in teaching about stars, as well as exploring the ideas that pre-service teachers have about stars.

Additionally, Taylor et al. (2003) mentions that the field of the teachers' pedagogies which may promote understanding has not been sufficiently explored in astronomy education. This shows that my study is of importance as it seeks to fill in this existing gap. Hence, my study aims at gaining content knowledge in order to explore my own pedagogical practices (how I teach); in the pursuit of promoting conceptual understanding.

1.3 Context

This study was carried out with pre-service teachers doing natural science and physical science respectively in one of the South African university. These groups of pre-service teachers get do to an astronomy section and stars are covered in that section. The year 2 pre service teachers' have done an astronomy section in their natural science course. The natural science course consists of three parts; life sciences, physical sciences and astronomy. The year 4 students have also done the natural science which the year 2 students have done in their second year of study; however they have also done an introduction to cosmology in their physical science (IV) course. The physical science course is made up of chemistry and physics. Pre-service teachers are on both ends of learning and teaching, as they are both students and teachers; hence their contribution to my study is very important as it seeks to explore their prior ideas as I am teaching as well as the impact of an intervention lesson to their prior knowledge. Therefore, both these groups of pre-service are of relevance to my self-study.

1.4 Rationale

The aim of this self-study research was to develop and improve my own teaching as well as my learning about the stars and their properties. In addition to that, the aim was to improve my own pedagogical practices in the teaching of astronomy. The reason for doing this self-study research was to get knowledge and to communicate that knowledge in order to inform my practice as well as the practice of the pre-service teachers. This was also an opportunity for me to improve on my own knowledge about the concept of stars.

A self-study research is all about the development of the act of knowing through observations, analysis and being involved in constructing one's own knowledge (Koshy, 2005). The reason I was interested in conducting a self-study was to learn from my experiences and reflect on them so to gain confidence in my subject. Therefore, this self-study was of importance to me as a teacher as it enabled me to teach an unfamiliar complex topic in astronomy which is the stars.

For pre-service teachers taking part in this study, it is an opportunity for them to interrogate their existing knowledge in order to construct the new knowledge that is being brought to their attention. More so, any learning taking place in pre-service teachers is towards assisting me in improving my Topic Specific Pedagogical Content Knowledge (TSPCK) of the concept of stars. The curriculum (CAPS) which is currently in place in South Africa covers the topic of stars (See appendix E), which shows that there is a need for natural science pre-service teachers to take part in learning more about stars. In the field of science education this study will enable some teachers to believe that they can learn any topic and teach it sufficiently well, while they also undergo a process of improving their pedagogical practices in the teaching of that topic. For research in science education, my research study contributes to the current literature on astronomy, self-study and most importantly the topic of stars.

1.5 Research problem

Teachers are important agents in the teaching and learning of any curricula discipline, more so in the science discipline they play a very critical role in ensuring that learners understand the way of explaining the world that science possesses. The purpose of this self-study research was to develop and improve the teaching as well as the learning about the concept of stars. The concept of stars is very complex for most people to comprehend, hence this self-study sought to bridge the gap between the content of stars and the conceptions that people hold about stars. Furthermore, this study aimed at developing my ways of knowing and understanding science (astronomy "the star"), in a way that it could be taught sufficiently well so to bring about an interest in the field of astronomy for pre service teachers. Thus, the theoretical framework of this study was on ensuring that the content knowledge of stars is transformed effectively for the purpose of deep conceptual understanding of the content.

1.6 Research questions

I conducted a self-study of my learning and teaching of stars to pre service teachers, in order to improve my content knowledge and how I teach it. The study aimed to answer the following questions:

1. How does my content knowledge about the topic of stars develop as I learn about them?
2. In what ways can I transform my content knowledge of stars into knowledge for teaching?
3. Which of my pedagogical practices can enable the development and understanding of stars in pre-service teachers?

1.7 Theoretical framework for the study

Teachers' content knowledge and pedagogical practices work hand in hand to yield good teaching and learning. However, Shulman (1987) argued that there is a special feature that makes a teacher different from all other professions, which is the ability to transform content knowledge (CK) or rather subject matter knowledge (SMK) in a way that the learners are able to understand it. That special feature is Pedagogical Content Knowledge (PCK). Due to my research study being on a particular topic in science (stars); the theoretical framework is then Topic Specific Pedagogical Content Knowledge (TSPCK). This framework is a modification of PCK where, Geddis and Wood (1997) stipulated the agents of transformation. These agents were then modified by Mavhunga and Rollnick (2013); in which they built a model on the components which enable the transformation of knowledge within a specific topic.

1.8 Research design

The purpose of this study was to determine whether I was able to learn a topic and also learn how to teach it well enough to promote conceptual understanding. The study therefore is focused on my improvement in content knowledge, my planning as well as how I teach it (pedagogical practices); in order to improve my own professional practice. Thus the study took on a self-study methodology approach, as I was studying my practices and how they influence the deep conceptual understanding of the topic. My self-study took an action research approach in which I was critically going through stages of development to help me in improving both my content and how I teach it. The action research spiral by Kemmis and McTaggart (2000) in Koshy (2005) was used as the guiding tool in both my learning of content (see chapter 4) as well as learning to teach it (see chapter 5). The development of content knowledge was captured using the concept maps; the development of transformation of the content knowledge was captured by a CoRe (Content Representation) and video recording of me teaching the lesson on stars, for the first time and second time after I had reflected on the first lesson with my supervisor and critical friends. A pre and a post questionnaire was answered by the students who attended the lesson which I taught on stars; and interviews with some of the students (see criteria in chapter 3); in which students commented on my teaching and what they have learnt. In addition, I kept a journal in which I recorded my feelings, challenges and any thoughts which encountered throughout my study.

1.9 Analysis

Data collection instruments are used so to collect information, however the information does not make sense unless it is broken down in ways that it can answer the questions which one has. The action research spiral was used in order to analyse the data yielded by the concept maps and critiquing the video recording of me teaching as I was going through its stages in both the learning of content knowledge and learning to transform it. The video recordings were analysed using the Topic Specific Pedagogical Content Knowledge (TSPCK) components which were visible in particular critical incidents (see chapter 5).

1.10 Outline of research report

Chapter one gives an overview of the introduction of the research study. This incorporates the background and rationale of the study; a brief context as well as the research problem. The research questions are also stated in this chapter so to know the direction which the research leads to.

Chapter two covers the literature which I found relevant to my study. The chapter reviews the selected literature about stars from previous research studies as well as literature on gaining the knowledge of teaching, thus covering the theory of Pedagogical Content Knowledge (PCK).

Chapter three outlines the methodology and research design of this study. The description of the self-study methodology in research is thoroughly provided. The data collection instruments, piloting and sample of the study are also described. Furthermore, matters of rigour, ethics and analysis are addressed.

Chapter four shows how I gained the content knowledge of stars by looking at the analysis of the findings which the concept maps have yielded. This serves to capture how my content knowledge has developed throughout the research study.

Chapter five looks at how I learnt how to teach, by developing the CoRe and creating a lesson plan. The features of the domains of PCK (TSPCK) which emerged from the lesson on stars that I taught are discussed in this chapter.

Chapter Six consolidates the findings which the analysis yielded by answering the research questions. This chapter gives a conclusion of the research study by critically reflecting on the whole research study and giving recommendations of what I can improve on as well as future research studies.

Chapter 2

Literature review and theoretical framework

2.1 Introduction

The generation of new knowledge does not happen in isolation, it is dependent on the past knowledge which was generated by other people through research (Koshy, 2005). Knowledge generation involves reviewing and revising what has been done as well as what was found in order to identify the existing gaps along with what is still to be done. In this chapter I have focused on the literature that is currently available that relates to this self-study research which is embedded in astronomy education. There is a wide range of literature in astronomy education that looks at different topics, different people that are involved and different impacts it has in education. Firstly, I summarised the recent reviews of astronomy education, stars conceptions and misconceptions, concept inventories in astronomy, and then I finally looked at the theoretical framework that underpins my action research study which is the Topic Specific Pedagogical Content Knowledge (TSPCK).

2.2 Important concepts

Astronomy is one of the branches of science that are concerned with the study of celestial objects and their motion in space (Paschoff, 1983).

Stars are balls of gas held together by the force of gravity (Paschoff, 1983). Large amounts of gas and dust are compressed into dense spheres which we call stars; they also radiate heat and light.

An action research is a process of inquiry in which I was constantly observing, analysing and reflecting on my own practices, so to improve them as well as to be effective in my practices (Koshy, 2005).

Self-study research is when teachers sequentially and critically examine their actions in a classroom context as a way of improving their own professional development (Samaras, 2002 cited in Samaras, 2010).

Conceptions in this study refer to ideas and perceptions that people hold with regard to stars.

Pedagogical practices in this study refer to the teaching strategies that may be employed in the effective teaching of the concepts of stars.

2.3 Astronomy education

We live in a world of ever changing technologies and scientific discoveries. Bailey and Slater (2003) wrote a review of the studies that have been conducted in astronomy education since it is a field which is rapidly growing. Lelliott and Rollnick (2010) also wrote a review of studies in astronomy education that underpin the framework of big ideas over a 35 year period. The reviews by Bailey and Slater (2003) as well as Lelliott and Rollnick (2010) argue that astronomy has always been at the forefront of the public's attention and interest which increases the value of science in the society. This is because the field of astronomy education has shown tremendous growth in recent years both within and outside of the definition of research as stated by Bailey and Slater (2003); meaning that astronomy has grown in the academic field and also in social conversations between people. Lelliott and Rollnick (2010) report that research in astronomy yielded that people hold attitudes such as 'remoteness', 'unknowingness' as well as excitement of discovery which contribute to their level of interest in the field. Astronomy education involves issues around the impacts of astronomy in the learning and teaching environment in ways that can improve or solve the challenges within the teaching of concepts in astronomy. However, some aspects of astronomy education and its implications are spoken about and researched within the science education studies. More so, as established by Jarman and McAleese (1996, p. 225) cited in Lelliott and Rollnick (2010) "there seems to be something inherent in the subject of astronomy itself which appeals to many of our young people"; hence it is important for teachers to also immerse themselves into learning more about astronomy.

Astronomy by nature exhibits both molecular and observable characteristics; by this I mean that it involves an understanding of microscopic particles such as dust and gas, which when combined forms stars which we see (observable) in the night sky. Lelliott and Rollnick (2010) argue that the most readily experienced astronomy phenomena such as day and night, Moon phases, stars as well as the seasons can only be understood and explained by using complex and non-intuitive explanations that are content based. The psychologist Piaget contended that the development of knowledge occurs as a spontaneous process concerned with the totality of structures of knowledge occurring in the mind (Piaget, 1964). Moreover Lelliott and Rollnick (2010, p. 1772) assert that the work of Piaget "has helped to shape our understanding of how the non-intuitive phenomena around us can be explained, particularly prior to instruction on the topic". This means that Piaget gives us a lens of understanding how one builds their own knowledge and ideas (conceptions) without receiving any instruction on that knowledge. However one's knowledge or ideas (conceptions) are not sufficient to explain anything beyond what we see. Students therefore, as stated by Vosniadou (1999) "change their mental models in a way that allows them to retain as many as possible of their experimental beliefs without contradicting adult teachings" cited in Bailey and Slater (2003, p. 7).

All people hold ideas about the natural phenomena which I refer to as conceptions. Bailey and Slater (2003, p. 4) mention that "deeply held alternative conceptions before instruction and after instruction" can be integrated with the newly learned information. Thus this enables personal constructivism; in which one is involved in constructing meaning and building on their knowledge which is what Piaget's theory addresses (Lelliott & Rollnick, 2010). Therefore, students' conceptions in astronomy are important facets which have been explored by a few researchers. Bailey and Slater (2003) states that in one study by Klein (1992) it was found that students' held a number of conceptions that are contrary to the knowledge that they were being exposed to in the classroom, and this influences their understanding of the content. Plummer, Zahm and Rice conducted a study in which they examined the impact of an open inquiry experience on science students' understanding of celestial motion (2010). It was found that most participants improved their inquiry skills, although they may require an induction into science content for them to improve their understanding of celestial motion (Plummer et al., 2010). Therefore, both learners and teachers often hold alternative conceptions with regards to astronomy. Although they learn how to explain the apparent patterns of motion of the sun, moon, and stars; however the transition from everyday knowledge to scientific knowledge is not an easy one.

Plummer and Krajcik (2010) carried out a study in which they focused on the ideas in astronomy which serve as a foundation for students' understanding of the astronomy discipline. Plummer and Krajcik infer that studies which have been conducted across numerous areas of astronomy indicate that basic astronomy phenomena are not really understood by most students; in relation to their observational qualities and explanatory models. It is also mentioned in Bailey and Slater (2003) that students hold inaccurate conceptual understanding of certain topics which may not be scientifically true, especially in this topic of astronomy. Students' ideas and conceptual understandings may be referred to as misconceptions; that are internally consistent and which can be interpreted and used as they serve a fundamental element of knowledge as well as reasoning (Bailey & Slater, 2003).

Hence, it is said that students' ideas may hinder their understanding of the acceptable science content (Plummer & Krajcik, 2010).

According to Bailey and Slater (2003) research studies found that students are able to increase their understanding of moon phases by having a scientifically complete understanding after experiencing a series of lessons. It is for that reason that the teaching or intervention in which scientific content is being covered can serve as a way to improve students' understanding of phenomena. As a result the concept of knowledge restructuring is of importance, which asserts that changes in knowledge involve the creation of new ideas or concepts in order to either reinterpret prior information or to justify the new information (Bailey & Slater, 2003). One of the studies outlined by Bailey and Slater (2003) states that students' demonstrated a positive conceptual change over an instructional intervention lesson. Hence refining students' explanations can result in more scientifically accurate ideas about natural phenomena. This is supported by Lelliott and Rollnick (2010) in which they mention that an intervention for conceptual change improves the teachers' scientific understandings. However not all interventions improves understanding, some intervention may confuse people and add on their misconceptions as seen from the study by Plummer and Krajick (2010). Therefore, it can be concluded that scientifically inaccurate ideas and conceptions can persist over a longer period of time. For students still in school misconceptions might precede to university and for teachers, ideas might be imparted in their classrooms as they teach. This is due to the fact that students' tend to prefer misconceptions over the scientific concepts (Bailey and Slater, 2003). In most cases the misconceptions are aligned with their value systems, cultural beliefs and experience, hence students are comfortable with them.

However, teachers' limited understanding of scientific concepts is most likely to have a negative impact in their teaching of astronomy concepts; more especially because teachers (both novice and expert) do not hold these scientific concepts. They (teachers) are therefore unable to provide scientific explanations for the patterns occurring in nature (Plummer et al., 2010). This leads to a conclusion that some teachers may have misconceptions that are also held by their students when it comes to scientific concepts of astronomy (Lelliott & Rollnick, 2010). Similarly, Bailey and Slater (2003) assert that in most cases teachers avoid astronomy topics due to their lack of confidence their content knowledge. Hence, Lelliott and Rollnick (2010) suggest that there is a need for teachers to improve their content knowledge and pedagogical practices when it comes to astronomy. More so "teachers should learn about the excitement and process of inquiry, with adequate content background and an appreciation for the philosophical, historical, and cultural importance of science just like their students" (Bailey and Slater, 2003, p. 11); and this will improve the teachers' knowledge and instil confidence in teaching about astronomy.

Furthermore, science teachers are expected to know these scientific concepts although Plummer et al. (2010) asserts that they may not be able to carry out in-depth investigations of these scientific concepts on their own. As a result, for teachers to improve the teaching of astronomy and their classroom practices; "there is a need for carefully planned teaching activities which use physical models as a key part of the pedagogy" (Lelliott & Rollnick, 2010, p. 1791). Therefore, teachers need to adopt the notion of big ideas in science that enables them to make connections among isolated scientific concepts as they will develop learners understanding better (Plummer and Krajcik, 2010).

Pre-service teachers' conceptual understanding of astronomical concepts needs to be improved by increasing their science process skills around inquiry (Plummer et al., 2010). Although my self-study research is not about science process skills; pre-service teachers through this self-study research will be able to reflect on their own ideas about concepts in astronomy which also increases their conceptual understanding. It is also important to note that "teacher beliefs, experiences, and understanding have not yet been studied at a great deal in the general educational research literature" (Bailey and Slater, 2003, p. 11). Therefore, it is important as teacher beliefs have an impact in their teaching.

2.4 Stars conceptions and misconceptions

The astronomy topic for this study is "stars". I chose stars because we are all amazed by the wonder they possesses. From childhood we all sing 'twinkle twinkle little star how I wonder what you are'; this rhyme is evidence to me that stars have always been a curiosity. Since the concept of stars in astronomy education has not yet been fully explored, there is a need to find out more about this phenomenon which my research study examined.

Stars are defined to be a ball of gas held together by the force of gravity which is the force that we as humans also experience as the force that pulls us toward the centre of the earth (Pasachoff, 1983). It is a "self-luminous ball of gas that shines or has shone because of nuclear reactions" (Pasachoff, 1983, p. A.30) this means that a star in itself has the property of emitting light on its own due to the reactions taking place in the core of a star. In addition

Agan (2004) asserts that "astronomers define stars by their ability to fuse lighter elements into heavier elements to create energy" (p.8); which means that during nuclear reactions smaller atoms fuse to become bigger atoms, for example hydrogen to helium. The study by Agan (2004) focused on exploring the ideas that students have about the stars; these ideas include how they describe the stars and whether they recognise that the sun is also a star as well as the formation of the star. The study consisted of 3 groups of students of different levels of study who have had prior instruction in astronomy and those did not (Agan, 2004).

Bailey, Prather, Johnson and Slater (2009) investigated science non-majors undergraduates' pre-instructional ideas about stars in the United States; the results yielded that students have some ideas about stars although their ideas are not accurate. Therefore, Bailey et al. (2009) assert that a great number of stars populate our universe which make the study of their nature and their evolution a primary sub-discipline of astronomy. Space on its own is made up of a large number of particles such as dust and gas that make up galaxies which are estimated to be over one hundred billion in the whole universe and billions of stars are found in each of those galaxies (Pasachoff, 1983). Therefore, the Milky Way as our galaxy also consists of billons of stars some of which we see in the night sky. Furthermore taking in consideration the significance of stars in our cultural and scientific history, it is clear that stars are considered a central topic in astronomy (Bailey et al., 2009).

Bailey et al. (2009) suggest that even though students often have some prior knowledge about stars that knowledge maybe incomplete or even incorrect. Regardless of the correctness of knowledge it is important to note that it has an impact in instructional objectives. This means that students' prior ideas have an impact in the teaching and learning objectives and goals both made by the teacher as well as those stated in the curriculum. The prior knowledge of students about stars may be determined by the relationship between the concepts formed from everyday experience and observations; as well as through scientific knowledge learned from a textbook or the teacher (Agan, 2004). In addition, Bailey et al. (2009) states that students' come to the classroom with tenacious, deep-seated conceptions and fundamental reasoning processes that can serve to either help or hinder the incorporation of new concepts. Meaning that students have ideas that are firmly established from prior knowledge which have been existing for a long time, thus making it difficult for students' to change them as they tend to hold tightly to them.

Comins (2001) lists the common misconceptions that are held by students with regard to stars. These are some misconceptions that are mentioned in the Heavenly errors by Comins (2001), these misconceptions are closely related to the opinions that people hold with regard to stars; and they are as follows:

Stars really twinkle.

Polaris, the North Star, is the brightest star in the sky.

A shooting star is actually a star falling through the sky.

The Sun is a unique object, not a star.

The Sun/stars will last forever.

Stars explode and become black holes.

All stars end their lives as supernova.

Stars are same distance from Earth (celestial sphere)

The Sun shines by burning gas or from molten lava.

The Sun is solid.

All stars are yellow.

There are many stars in the Solar System.

Sharp (1996) carried out a study on children's astronomical beliefs in England, in which he conducted interviews and observations with the 10 – 11 year olds. Sharp (1996) mentions that students' ideas about stars include that stars are like a ball or fire with gases or that the shape of stars is round and does not have edges; these are all said to be descriptive. In addition Lelliott (2007) conducted a study with grade 7 and grade 8 students' who were visiting sites of informal learning such as the planetarium as well as the Hartebeesthoek Radio Astronomy Observatory (HartRAO) and how that experience contributed to their understanding of astronomy concepts. Lelliott (2007) suggested cognitive levels on which students' knowledge could be located. Prior to the visit to the informal learning site, a small number of students in the group held naïve ideas about the composition of the sun relative to the stars; thus these students knowledge were located in the lower level (level 1). While the most students' in that group had a more sophisticated idea of the Sun being a star, were then located in the second level group (Lelliott, 2007). A smaller number of students' in the same group (smaller than students in level 1) were located in the third level, as these students' had substantial knowledge of the Sun relative to its accompanying concepts such as stars, size and distance. After the visit most students improved to the third level. Hence, concluding that more students in his study were able to understand that the Sun is a star, although these students carried other misconceptions pertaining to the size, composition and positions of stars in space (Lelliott, 2007). Therefore, Lelliott shows that an intervention enables students' to change their initial ideas and move towards more scientifically correct notions when it comes to astronomy. Sharp (1996) and Agan (2004) reported similar findings that students who have had an astronomy induction or teaching exhibit more scientifically correct conceptions about stars than those who are not inducted. In addition to that students' knowledge with regard to stars is "enhanced through their own understanding of nuclear fusion as a process of energy production in stars" (Agan, 2004, p. 93). Additionally, the results of Bailey et al. (2009) reported that students' have appreciable prior knowledge about stars; though that prior knowledge is inconsistent when associated to the scientific understanding. This means that although students have some knowledge about stars, it often contrasts the scientific content which students' are confronted with in class. Therefore, Bailey et al. (2009) maintains that as teachers the understanding of students about stars is an important step in enabling us to design effective astronomy lessons.

Furthermore, considerable research on student understanding has been conducted for many other science education topics; however, research pertaining to stars and how they are understood has not been sufficiently done (Bailey et al., 2009). In addition, Lelliott and Rollnick (2010) also argue that studies done in astronomy education are more focused with testing the knowledge that people have as well as frameworks that are applicable in astronomy than with astronomical knowledge about stars. More so, Bailey et al. (2009) assert that teachers need to begin to place more emphasis on understanding what their students' already know about the topic when they enter a learning environment.

2.5 Concept inventories

A way to explore peoples' ideas about a certain concept is through a concept inventory. Bailey, Johnson, Prather and Slater (2011, p.1) define a concept inventory as a "multiple choice instrument that focuses on a single or small subset of closely related topics containing numerous questions on each idea in order to gauge a student's understanding of the content in a variety of ways". This means that a concept inventory is tool which enables an individual to think about what they know with regard to certain concepts. Bardar, Prather Brecher and Slater (2007) assert that concept inventories produce a form of a standardized instrument that can be used to evaluate individuals' conceptual understanding of a topic. More so, it can also be used as a tool for measuring conceptual change and for also comparing the effectiveness of different teaching strategies (Bardar et al., 2007; Bailey et al., 2009).

Concept inventories have been used in science education especially in astronomy education. The existing concept inventories are on: The Lunar Phases (Lindell 2001; Lindell & Olsen, 2002), Star formation (Bailey 2006), Light and Spectroscopy (Bardar et al., 2007), Star properties (Bailey et al., 2012), and Solar System (Hornstein, Duncan, & Collaboration of Astronomy Teaching Scholars, 2009, 2010). All these concept inventories are validated before they can be used to ensure that they actually serve the purpose that the researchers were aiming at. Bailey et al. (2012) argues that concept inventories are useful, not only in astronomy but in other science topics. More so, the use of concept inventories is spread across the astronomy field such that; they consistently measure change in students understanding over time as confirmed by Bailey et al. (2012).

Concept inventories help us as individuals to interrogate our own prior knowledge about phenomenon, thus enabling us to undergo a form of conceptual change. However, the most important role of concept inventories in research is to serve as a measure of student learning in different topics one of them being about the properties and formation of stars (Bailey et al., 2009). Therefore, my data collection uses a concept inventory in developing a questionnaire. In addition, concept inventories give me as a teacher the ability to measure not only students' learning but the effectiveness of my teaching (instructional and pedagogical practices).

2.6 Theoretical Framework

The work of Lee Shulman has been cited by many researchers as his work has influence teaching and learning especially in science education. The work of Shulman is of significance in my study because it enables me to look at different ways of transforming knowledge and owning that knowledge which according to Shulman (1986) is what distinguishes the teacher from the subject matter specialist such as an astronomer.

Learning can be seen as a process in which one acquires knowledge, and teaching can be a form of transforming knowledge that will be acquired. The knowledge acquired by one who learns is what we can call content knowledge or subject matter knowledge and it refers to the amount and organization of knowledge that the teacher has (Shulman, 1986). Therefore this knowledge needs to be transformed in a way that learners can make sense of it; as Shulman (1987) asserts that "comprehended ideas must be transformed in some manner if they are to be taught” (p. 16). Hence the notion of Pedagogical Content Knowledge (PCK) which Shulman (1987) described as “the capacity of a teacher to transform the content knowledge she or he possesses into forms that are pedagogically powerful” (p. 15). This suggests that PCK serves as a way for a teacher to think about how they are going to teach a particular topic and why they teach it like that, which makes it an effective way of teaching. Shulman (1986) argues that the teacher need not only to understand that something is so, the teacher must further understand why it is so. Furthermore, Shulman (1987) maintained that the most important role of a teacher lies in the teachers’ ability to ensure the effective, fruitful transformation of subject matter knowledge to ensure accessibility for learners.

Different researchers have come up with different models to demonstrate Shulmans work; Kind (2009) mentions that the different views that researchers have with regard to PCK can be characterised as either transformative or integrative. The transformative model is that of Shulman (1986, 1987), Magnusson et al. (1999) as well as Grossman (1990), in which PCK transforms content knowledge (CK). Toerien (2013, p. 4) asserts that “PCK is an integration of some or all of the other knowledge areas outlined by Shulman”; hence the integrative model holds that PCK is a term used to give a description of the knowledge of the teacher which includes subject matter knowledge, together with pedagogy and context.

Models that are of interest to me are shown by Toerien (2013) where she looked at different representations of PCK. One of the models is shown in figure 2.1 which is by Cochrane et al., (1993) as cited in Toerien (2013). This model views an effective PCK as emerging from the knowledge of pedagogy, knowledge of the subject matter (SMK or CK), knowledge of the students as well as the knowledge of environmental contexts. These components overlap with each other and could expand (Toerien, 2013). In a sense, I can conclude that this is broader way of looking into PCK. Although as a science teacher I prefer the transformative model of PCK in which subject matter can always be alternated to suit the needs of the learners.

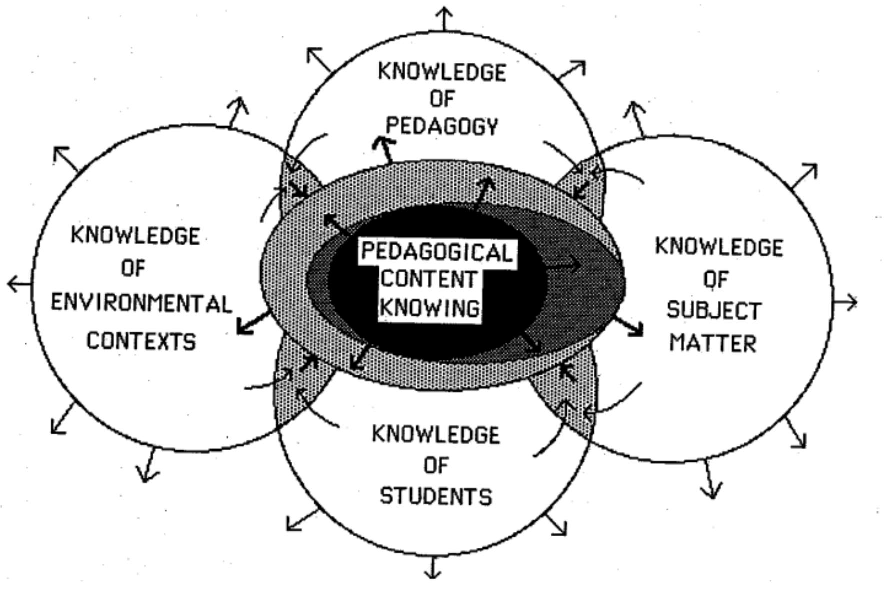


Figure 2.1: A developmental model of pedagogical content knowing (PCKg) (Cochrane et al., 1993 in Toerien 2013).

In addition, due to my study being on a particular topic in astronomy being stars an appropriate model would be the one by Mavhunga and Rollnick (2013). Mavhunga and Rollnick assert that there is a PCK with a specific topic, thus the notion of Topic Specific Pedagogical Content Knowledge (TSPCK). Figure 2.2 represents the model of Mavhunga and Rollnick (2013) in which the transformation of knowledge emerges from 5 components shown in the diagram. The TSPCK model was very much influenced by an assertion which Shulman (1987, p.16) suggested in which he stated that 'comprehended ideas must be transformed in some manner if they are to be taught'. This assertion suggested that PCK can be used to transform content knowledge into a form that is pedagogically influential, so to ensure accessibility to students (Mavhunga & Rollnick, 2013). Therefore, arguing that instead of looking at a full spectrum of knowledge influencing PCK at discipline level we can look at PCK on topic by topic (Mavhunga & Rollnick, 2013).

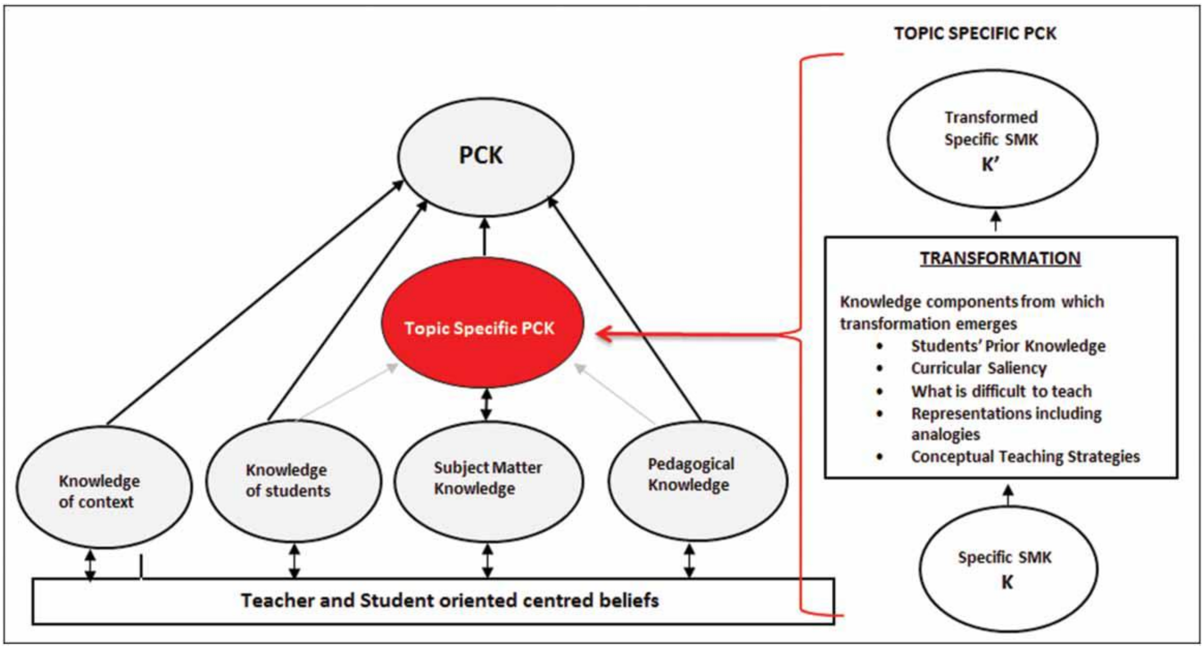


Figure 2.2: A model for Topic- Specific PCK (Mavhunga & Rollnick, 2013)

This idea of TSPCK was influenced by the intersection between PCK within a topic as well as the transformation of concepts in the topic that is being dealt with (Mavhunga & Rollnick, 2013). TSPCK is the ability to transform subject matter knowledge (SMK) of any topic in from that will be accessible to students; which includes how it taught as well as the examples used (Mavhunga & Rollnick, 2013). This takes into account that it is not possible for all topics to be taught in the same way. Looking at the 5 knowledge components in the model, it shows that within PCK there is TSPCK; in which its transformation outcomes are different in each and every topic. Therefore, this means when teaching kinematics and force, there are some procedural aspects that could be the same while there are other that differ and thus they cannot be taught in the same way.

Mavhunga and Rollnick (2013) devised a model which was initially derived from Davidowiz and Rollnick (2011) based on Geddis and Wood (1997) which brought about the idea of 'a multiple particular things' with regard to SMK (Mavhunga & Rollnick, 2013). The 'particular things' are the ones stipulated in the category of transformation; which include students' prior knowledge that encompass misconceptions which students hold, curricular saliency, what makes the topic easy or difficult to teach; representations used as well as the analogies used and conceptual teaching approaches; these components are referred to as content-specific components which were initially suggested by Geddis and Wood (1997) which they called the agents of transformation.

TSPCK in the model is influenced by the four general knowledge domains for teachers which include: subject matter knowledge, pedagogical knowledge, knowledge of students and knowledge of context (Mavhunga & Rollnick, 2013). It is however important to note that the knowledge domains of PCK may be generalised but the model is topic specific. The four knowledge domains mentioned, impact beliefs of both teachers and students; as Grossman (1990) argues that knowledge basis of teacher's beliefs about the way they teach plays a significant role in how they teach. The emphasis of this model is the ability of transforming concepts within a particular topic by sorting them for the purposes of teaching; this ability can be developed by aiming on the selection of knowledge constituents which are in support of the content knowledge that is taught (Mavhunga & Rollnick, 2013). The TSPCK model shows both knowledge and practice; the knowledge aspects are the four knowledge components or rather constituents which emerge from the Davidowitz and Rollnick's (2011) model.

Furthermore, this model also goes along with what Loughran et al. (2006) called a CoRe (Content Representation) (figure 2.3) which was suggested as a tool that can portray and also capture PCK. A CoRe is a generalised form of a teachers' pedagogical content knowledge (PCK), which suggests modes in which content knowledge can be organised in teaching. Loughran et al. (2006) further contends that a CoRe gives solid ideas of how a teachers' PCK can be articulated by proving insights into the decision making processes which a teacher goes through for every topic. The components of knowledge transformation from Mavhunga and Rollnick (2013) are all aligned with the prompts which have to be answered for every big idea which a teacher teaches (figure 2.2). Therefore, the CoRe by Loughran et al. (2006) forms a big part of knowledge transformation and of PCK in general, which also supports the topic-specific nature of PCK; which Rollnick et al. (2008) has also highlighted. The CoRe and its prompts clearly show that the five components of TSPCK are aligned with it and hence the CoRe can be used to enable the capturing of PCK of a particular topic.

Big Ideas	1	2
A. Curricular Saliency		
A1. What do you intend the learners to know about this idea? - original A2.Why is it important for learners to know this big idea? - original A3. What concepts need to be taught before teaching this big idea? - adapted A4.What else do you know about this idea (that you do not intend learners to know yet)? – original		
B. What makes the topic easy or difficult to understand?		
B1. What do you consider easy or difficult about teaching this idea? (Original: Difficulties/limitations connected with teaching this idea)		
C. Learner Prior Knowledge		
C1.What are typical student misconceptions when teaching this big idea? (Original: Knowledge about students' thinking that influences your teaching of this big Idea)		
D. Conceptual Teaching Strategies		
D1.What effective teaching strategies would you use to teach this idea? D2. What questions would you consider important to ask in your teaching strategies? (Original: Teaching procedures)		
E. Representations		
E1. What representations would you use in your teaching strategy? adapted		
What ways would you use to assess students' understanding? (Original: specific ways of ascertaining understanding)		
What aspects of teaching and planning would you like to reflect on?		

Figure 2.3: Amended CoRe with Components of TSPCK (Rollnick & Mavhunga, 2016)

I used the CoRe to guide my planning and teaching about the content knowledge of stars. Incidents were extracted from the lessons taught in which the components of TSPCK were identified. These incidents portrayed elements of knowledge transformation of that particular lesson.

2.7 Conclusion

I have discussed the literature from previous studies in astronomy education in order to inform my current study on stars. From the literature reviewed it is evident that teachers' pedagogical practices as well as conceptions that they have with regard to stars is a mystery which my self-study research study seeks to unfold. Therefore, my study worked within this gap by documenting my own progress in the teaching and learning of stars. In this chapter I have also discussed the theoretical framework which underpins my study that helped me in documenting my planning and execution of the plan being the PCK. The next chapter takes us through the processes of how the data was collected and possible ways of assessing the information gathered.

Chapter 3

Research design and methodology

3.1 Introduction

Undertaking a self-study research enabled me as a teacher to be more aware of my own pedagogical practices which then allowed me to reflect on my teaching. A self-study does so by positioning me as a researcher and the researched (person being researched on) and how what I do in my teaching influences or even improves the learning of the topic.

Empirical research is done following certain procedures, choosing a group of participants as well as taking ethical precautions which ensure the confidentiality of the participants. Therefore, this chapter focuses on the research design, sampling as well as the instruments used for data collection and the ethics precautions.

3.2 Methodology

My research is self-study, in which I am both a researcher and a participant. Self-study research enables teachers to openly criticize their teaching in order to improve the quality of what and how they teach to their students (Pinnegar & Hamilton, 2009; Samaras, 2010). There are different approaches that have influenced self-study research which include: reflective practice, teacher inquiry and action research (Samaras, 2010). For my self-study I chose an action research approach because I went through the stages of action research in improving my content, how I plan to teach it as well as how I actually teach it. An action research approach is most relevant when a teacher identifies a problem in their practice in an attempt to improve it. As argued by Nyamupangedengu (2015) when a teacher studies his or her own practice (teaching) for the purpose of making a change and improving practice an action research approach is applicable.

Opie (2004) asserts that action research as a methodology collects its data using procedures such as tests, questionnaires, interviews and video recording; I followed these guidelines so that I could be able to evaluate the information in order to inform and improve my own teaching practices. An action research as defined by Koshy (2005) is an enquiry based on refining one's practice. Hence, the purpose of my self-study research using the action research approach is to be actively involved in improving my own knowledge and pedagogical practices with reference to understanding people's perceptions and ideas about stars. More so, this approach enables a researcher to be more reflective in terms of what they do and how they do it. In essence, action research entails learning by doing, thus for me as a researcher to be able to understand situations that people are in, I also need not only to position myself in that situation but to also be involved actively in that situation. Therefore, my study fits as self-study because it investigates my own conceptions and the conceptions of pre-service teachers with regard to stars; as well as how I can develop my teaching of stars such that these conceptions are interrogated and which pedagogical practices best inform the eliciting of such conceptions.

Conducting self-study using an action research approach positions me in the interpretivist paradigm in which I hold that knowledge is created by individuals based on their experiences. Koshy (2005) asserts that action research in the interpretivist paradigm emphasises on the fact that knowledge and understanding is solely subjective and it is influenced by history and culture. Similarly, Hatch (2002) also asserts that knowledge in the constructivist or interpretivist paradigm is not objective but it is constructed. Thus, the understanding of the world is based on social conventions. Self-study using an action research approach involves researching my own practice in a certain situation or context; focusing on improving situations and also constructing theory from practice. Koshy (2005) states that action research enables the researcher "to create new knowledge through enquiry" (p.3); the creation of new knowledge involves a reflective cyclic process which the researcher is always part of. Therefore, new knowledge is informed through planning, acting, evaluating and analysis, refining and learning from the experience; thus being a continuous learning process for me as a researcher (Koshy, 2005). Figure 3.1, shows the action research cyclic process which I was using in this self-study to enable me to develop content and how I taught it.

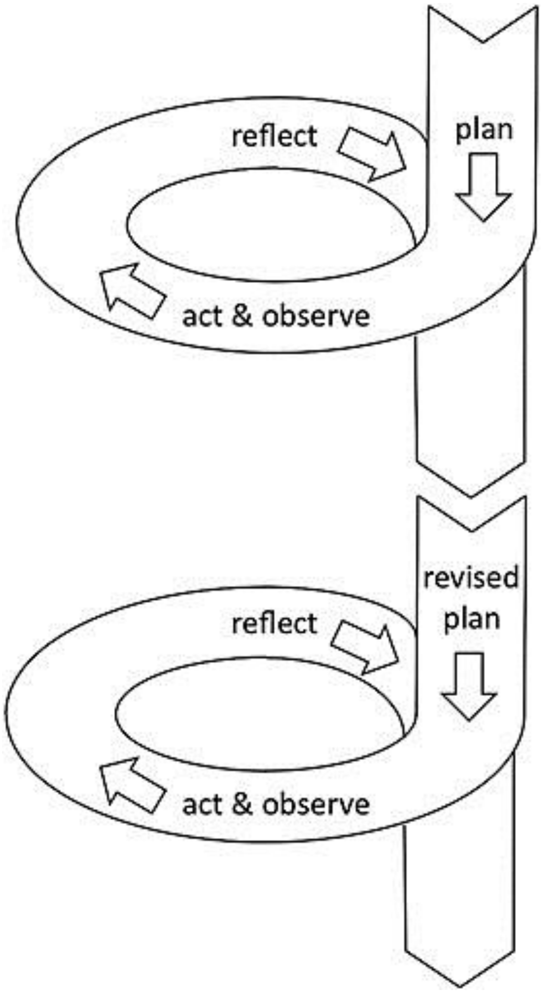


Figure 3.1: Action research spiral (Kemmis & McTaggart, 2000)

There is a thin line between action research and self-study in research, and they do overlap. Therefore, it is important to recognise that the aim of both action research and self-study is to improve one's teaching practices through stages of critical reflections. Pinnegar and Hamilton (2009) state that a "self-study is a study of one self" (p. 71), in which a person looks at their ideas, conceptions, engagements as well as practices that they often do. Hence a self-study is self-focused on an individual and how an individual becomes aware of their practices and making them better. In addition, Samaras (2010) maintains that in a self-study the most important aspect is the 'self' in which the goal is to understand the role of the self in improving others. In action research the goal of the action is toward a change in a particular context (Samaras, 2010). Therefore, the focus of my study is in improving my own knowledge and pedagogical practices (self) with reference to understanding people's perceptions, opinions and ideas about stars (context); thus having action research within a self-study.

3.3 Timeline

The timeline below (figure 3.2) shows most of things which I did in my study, such as when I drew the concept map, when the interventions took place as well as when I taught the lessons. The timeline best provides a picture of the 'when' I did the things in my study.

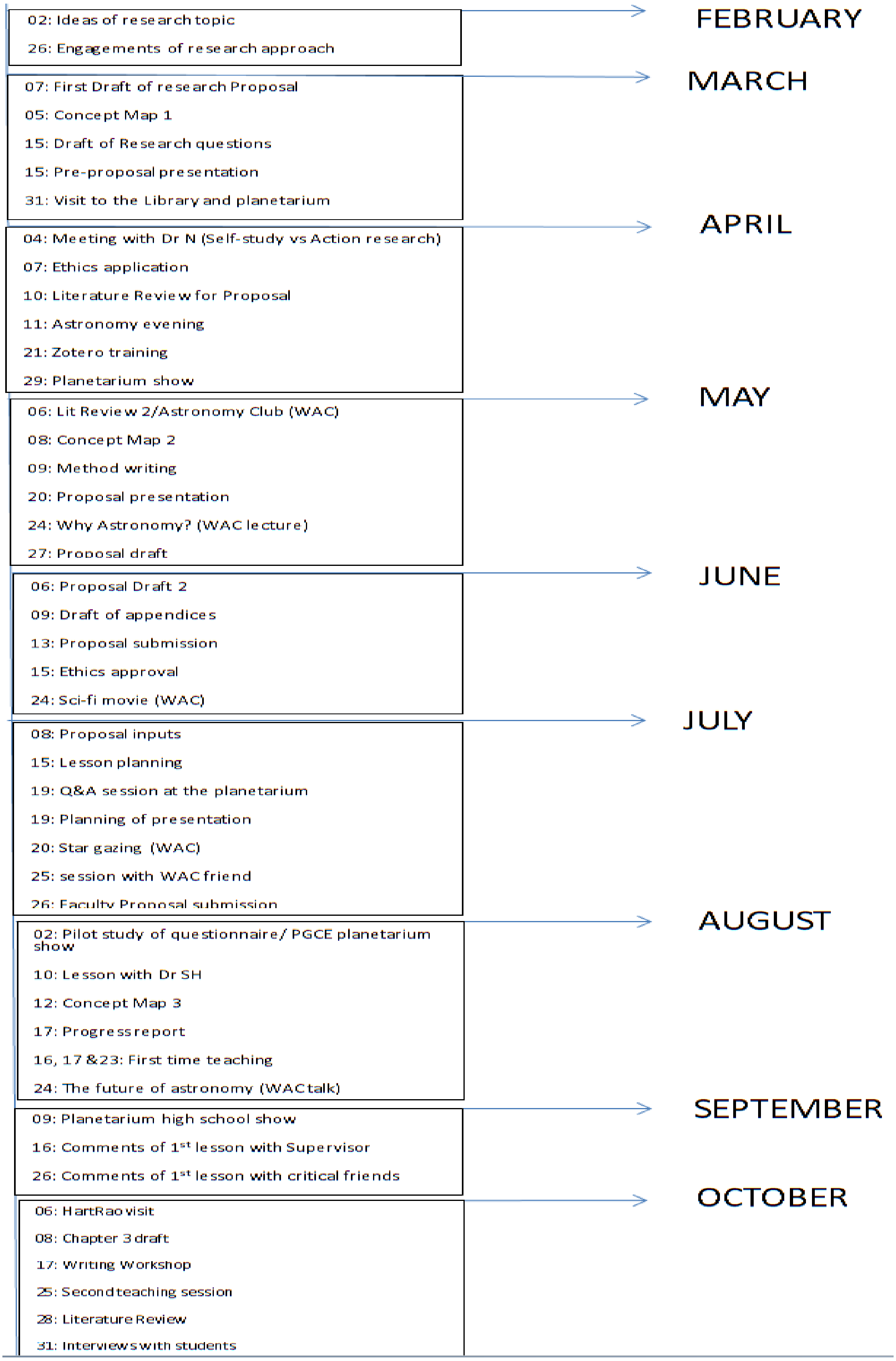


Figure 3.2: Timeline showing activities I did throughout the study

3.4 Critical friends

Although self-study is about the 'self', it was important for me to work with people who would help me in critiquing my own work; these people are called critical friends. They are trusted colleagues who help a researcher seek support and validation of the research (Pine, 2009); they are people who offer continuous support throughout the research process. Critical friends engage with a researcher in terms of defining a research problem, discussing data, analysing data, to help the researcher to deal with emerging problems during the research as well as to gain new perspectives in understanding and reframing of the interpretations (Pine, 2008; Samaras, 2010). Initially I had two critical friends; one who is a teacher enrolled for PhD and one who does research in the field of astronomy. Other people also helped me along the way in my study, one being a friend from the astronomy club (WAC), another who has worked with the PCK theoretical framework and my supervisor.

My supervisor was my main critical friend, as I treated the feedback from him as feedback from my other critical friends. However he was actively involved from the beginning of my study and in making major decisions about issues arising in my study; such as the changing of research approach.

3.5 Summary of the data collection methods used in this study

I used multiple methods for collecting data in my study. Below is a table which shows the methods of collecting data and when I used them in my study; as Nyamupangedengu (2015) also summarized.

Table 3.1: Summary of the methods used for data collection

Method of data collection	**When it was used in the study**
Journaling	Throughout the study as I was being confronted with new knowledge about stars (from the beginning which includes the learning about stars, reading astronomy books, visits to the library, astronomy clubs meetings, star gazing sessions, astronomy lectures as well as you-tube video's and meetings with lectures)
Concept Maps	During the planning of the lesson to be taught.
Video-recording	During the lessons which I taught
Questionnaire	Before and after the lesson I taught
Interviews	After the lessons on stars which I taught

3.6 Research instruments

My study used questionnaires, interviews, video-taping, concept maps and a journal as research instruments. Questionnaires and interviews are instruments that are mostly used in research to collect data. An open-ended semi-structured questionnaire was used in order to make sure that the participants are not limited in giving responses and also such questions seek to prompt respondents thinking with regard to the answers that they give (Opie, 2004). I administered pre-test and post-test questionnaires to year 2 and year 4 pre-service teachers who took part in my study as described in the sampling section (3.6). The pre-test questionnaire was given to the participants before the intervention lesson on stars which I taught and the post-test questionnaire was given to them after the lesson. The questionnaire solicits whether ideas and conceptions will change before and after an intervention lesson. The one great advantage of using a questionnaire is that it is standardized, meaning that all the participant are asked the same questions which are in the same order (Opie, 2004; Bertram & Christiansen, 2014). The questionnaire is shown in appendix F.

An interview is a face to face conversation between the researcher and the participant (Opie, 2004); although it is based on a set of questions which the participant is required to answer which are focused on a certain topic (Bertram & Christiansen, 2014). On average, 15 minute interviews were conducted with participants whose questionnaires brought ideas that I became curious about, found interesting or thought provoking. These interviews enabled me to understand the ideas of the participants better as Bertram and Christiansen (2014) suggests that interviews are a good way to interact and generate ideas between the researcher and the participants. However not all the participants took part in the interview, only those whose questionnaires fit the criteria (incorrect answers in both pre and post questionnaires; interest; altered conceptions/ideas); were of interest in taking part in the interviews as this study is of a small scale and is limited within a time frame. The interview questions are in appendix G.

A self-study is informed by practice in which one learns by doing. A videotape enabled me to revisit the lessons that I have taught in order to go back and revise my plan of action and then implement it again. Such a process requires to be documented through a video recording to ensure that nothing is being missed. The video recording was focused on me as I was teaching the lesson, hence capturing my content and pedagogical practices. The video recordings were scrutinized in order to look at things and ways I could improve my classroom practice.

Concept maps were also used in order to help me in gaining content knowledge. Novak and Gowin (1984) assert that concept maps are visual representations of what you know and what you want to know more about. A concept map is a tool that shows relationships between concepts within a topic (Rollnick, Mundalamo & Booth, 2008). The purpose of concept maps in my study was to capture the possible conceptual change that took place as I continued to develop my understanding of stars. The advantage of concept maps was that they highlighted the prior knowledge and misconceptions that I had with regard to stars. The concept maps were a great tool which enabled me to monitor how I developed the content of stars and gain confidence in communicating about them. I drew three concept maps before I could teach about stars and I went through a series of interventions in order to improve my content knowledge.

King and LaRocco (2006) assert that a journal helps one to record their ideas, thoughts and experiences in a form of writing. Throughout the course of the research study I kept a journal in which I wrote the information that I knew about stars as well as all the 'new' information that I came across as I continued to learn about stars. I also wrote about my feelings when I was doing something such as drawing the first concept map and any other events which I took part in I recorded in my journal. I did that because journaling is writing with a purpose (Pinnegar & Hamilton, 2009). I have used different modes of representation to learn more about stars, such as textbooks, planetarium visits, astronomy talks, consultation with lectures; astronomy clubs, social media as well as YouTube videos. As I interacted with these modes I learnt so many things with regard to stars and astronomy as a whole which I recorded in my journal that I could always re-visit. My journal captured my progress in learning about stars but not only that, it also captured the feelings and thoughts that I went through in this study. In addition, Pinnegar and Hamilton (2009) mention that journaling offers a space for researchers to expose their personal feelings and perspective; which is what I did in my journal.

3.7 Sampling

The chosen sample for my study were natural science year 2 and physical science year 4 pre-service teachers. These two specific groups were selected to participate in my self-study because they have completed a 3-4 weeks course in astronomy during the course of their studies; although they are unlikely to have a detailed knowledge about stars as stated in chapter 1. Also, the participants are science pre-service teachers that will be teaching in schools when they finish their qualification. The topic of stars is in the National Curriculum

Assessment Policy Statement (CAPS) from grade 4 to grade 9 (see appendix E) and as science teachers they need to know about it. The CAPS is a "single comprehensive, concise policy document" (Department of Basic education, 2011); which has replaced the National Curriculum Statement (NCS). There were 30 participants who answered the pre and the post questionnaire and they were also invited to attend the 1.5 hour lesson on stars which I taught. Interviews were conducted with only 4 (four) of the participants who fit the criteria mentioned in the interview section (3.4); few weeks after the lessons took place.

3.8 Pilot study

A pilot study was carried out in which the questionnaire was scrutinized in order for it to be improved before being administered to the participants. Oppenheim (1992, p.47) cited in Opie (2004) states that "piloting can help not only with the wording of questions but also with procedural matters such as the design of the letter and ordering of questions". Piloting also helped with ensuring that the questionnaire was representative of all individuals, and the people who took part in the pilot study were not part of the sample for the actual study (Opie, 2004). The pilot study was conducted with 2 PGCE students, 2 post-graduates and 1 in service teacher who are all teaching or training to teach natural science, life sciences and physical sciences. I chose them because they are aware of the topics and content that is covered in natural science grade 9.

As it was my first time carrying out a pilot study on people using a questionnaire I had to be sure of the aim of the study. As the students answered the questionnaire, the PGCE students complained or rather stated that it was hard although I had expected them to do better as they have done some introduction to astronomy course. The teacher stated that there are questions which were difficult for him to answer, and also he found that the questions were not fit for the level of the students which he teaches. The post graduate students stated that the questionnaire enabled them to be more curious about stars. The students from the pilot study wrote comments at the end of the questionnaire so I got a feel of the complexity of the questionnaire. None of the students spoke about the organisation of questions asked; however I changed the wording of some questions even changed some of the answers so that there would be more distractors. The distractors help to see how similar words can be used synonymously although they do not mean the same thing; especially words such as size and mass. The pilot study was effective, as I was able to make the necessary changes to my questionnaire.

3.9 The lesson

I planned to teach a 1.5 hour lesson on stars. The main aim of this lesson was to introduce pre-service teachers to the content knowledge of stars. My main concern was that people do not know the actual science involved in stars. Most of us saw them and some might still do see them as objects that twinkle and also fail to recognise the sun as a star. Therefore the idea was on understanding that there are misconceptions with regards to stars but my lesson aimed at rectifying those misconceptions and misunderstandings.

I wanted to improve how the content knowledge of stars can be taught; as well as to improve ways in which abstract concepts can be communicated to students. Studies such as Treagust et al. (2003) discuss the learning difficulties associated with abstract concepts and argue that the use of representations can enhance understanding of such concepts. Another reason for doing this lesson was to improve my general classroom practice as a teacher with limited teaching experience. I taught the lesson twice so that in the second lesson I could change and improve on the first lesson. This repeating of the lesson shows a reflective cycle (action research spiral).

In both lessons, I taught the content knowledge of stars; this included scientific concepts, theories, laws as well as equations. The content knowledge which I was focusing on was on star formation, life cycle of stars and the role of gravity. Teaching these concepts enabled me to recognise learners' prior knowledge; especially when I was asking questions, asking the students to share their thoughts on a certain concept or when the students were asking me questions. They helped me with eliciting misconceptions and also dealing with them through explaining the content. The content knowledge is very abstract and in my planning and teaching I tried thinking of ways in which these abstract concepts can be taught effectively. Hence, the content was presented hand in hand with a representation of some sort; whether a picture, video, analogy or model. However, although the representations are used to enhance understanding they may also give rise to a misconception, which is what I realised after teaching the first time. Thus, when I taught for the second time I had to constantly remind the students that the examples are not necessarily the reality. For example, the analogy of two gamblers and the analogy of a balloon (see lesson plan, appendix K)

In the lessons, I also tried to ensure that pre-service teachers know the correct conceptions for their own profession; hence introducing them to different forms of representing abstract concepts in their teaching. More so, to also enable myself together with the pre-service teachers to gain confidence in communicating about science topics that are also related to our indigenous knowledge (for example, the sun was used for telling time in the olden days).

3.10 Rigour

Trustworthiness involves establishing that the results of the study are credible, transferable, dependable and confirmable (Guba & Lincoln, 1985 in Opie, 2004). Therefore to ensure rigour in my study credibility and transferability were considered. Transferability refers to the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings (Opie, 2004 and Bertram & Christiansen, 2014). Transferability is enhanced by giving a thorough description of the research context as well as highlighting the assumptions which are central to my self-study, which has been done in chapter 1. A reflection on negative instances which I have come across during the study also increased the level of transferability. The limitations of the study and bias have also been stipulated which also contributed to the level of transferability in my study. Credibility answers the question 'do the findings reflect the experiences of the participants?' (Bertram & Christiansen, 2014); hence credibility was judged from the perspective of the participant in the research. Therefore, participants are the only ones who can legitimately judge the credibility of the results and the participants who were interested were allowed to read the analysis section of the research.

The questionnaire used was valid as it measured what it intended to measure in terms of the content required as well as identifying the misconceptions and exploring them. The pilot study and the comments from the critical friends validated the questionnaire for the study. More so due to the respondents anonymity, questions were answered truthfully hence increasing the validity of the questionnaire. In order for me to reduce bias in my data collection and questions asked in the questionnaire; I engaged with other people (my critical friends) that assisted me with the administering of the questionnaire. Whilst the development of the questionnaire was done by me and one of the critical friends, together with my supervisor went through it in order to help me in putting it in order. I also answered the questionnaire with my critical friends in order to see if we also understood the questions that I was asking. To ensure the rigour for the interviews which took place as well as the videos recorded, I went through the recordings in order to verify the events that took place; my critical friends as well as my supervisor also went through the interviews and videos gave critical feedback. The concept map and journal were all based on my experiences hence they are subjective. However my critical friends have gone through the concept maps as well as the journal, in order to limit the degree of bias in my study.

3.11 Ethical considerations

Self-study research is carried out in a practical context which involves communication between me as a researcher and my participants. Hence ethical considerations needed to be taken into consideration. Opie (2004) maintains that ethics are intended to prevent unfair treatment of others, to promote the good and respect throughout the data collection and writing of the research report. It was for this reason that I applied to the Human Research Ethics Committee (HREC) (non-medical) at the University of the Witwatersrand. My application was approved and the clearance to conduct the study was granted (appendix A).

This self-study research was based on voluntary participation no one was forced into taking part. Hence, participants received detailed consent forms (appendix B and appendix C) for them to read and understand what the research study is about. The participants' identities were kept confidential and have remained anonymous as pseudonyms were used to protect their identities. The data collected was also kept in a safe place and was only available to people who were directly involved in the study (me, supervisor and critical friends). The participants were allowed to withdraw from participating at any stage of the study without any barriers.

3.12 Data analysis

Data collection and data analysis in self-study are not completely separated from each other. Hence, Nyamupangedengu (2015, p. 96) mentions that "data collection and data analysis are not linear processes whereby you collect data first then do data analysis after". Rather, data analysis happens during the data collection process. The journal entries, which were a part of the data collection, were used in the analysis of the concept map as well as in my teaching as supporting evidence of my thinking throughout the study. I analysed the data using the action research spiral (see figure 3.1), in which after going through the first cycle I observed and then reflected on the plan (draw a concept map) and the act (drawing the concept map) in order to know what to improve on, in the second and third cycle. I went through the cycle in the process of gaining the content knowledge of stars, planning and teaching about them. A critique of each concept map was done through the stages of the action research spiral (Plan, Act, Observe and Reflect). The progression of the concept maps enabled me to trace my learning of content knowledge, which serves to answer research question1 (see chapter 4). The video recording of the lessons was analysed using the Topic Specific Pedagogical Content Knowledge model by Mavhunga and Rollnick (2013). This model enabled me to plan my teaching as well as to capture moments and incidents in my lessons that portrayed good TSPCK of the topic of stars. The purpose of analysing the video recording was to answer research question 2, in which I looked at ways to transform the learnt content knowledge for teaching (see chapter 5). Both the interviews and questionnaires served as a way to measure what the students gained in the lesson and if the misconceptions that they might have had were corrected by the learning of the content. The analysis of the interviews and questionnaires enabled me to understand what and how I can improve my teaching of the concept of stars thus, answering research question 3 (see chapter 5).

3.13 Conclusion

In this chapter I have discussed the most important information with regard to how my data for this study was collected. I have discussed the methodology of the research study and this included the research instruments, the sampling process and ethical issues which were taken into consideration. I have explained the research instruments that the research study used in detail as well as how these instruments helped me gather the data I needed. Furthermore, piloting was carried out in order to pull my research study in the direction of my main research questions. In addition, all the steps and procedures which I used enabled me to collect my data successfully.

Chapter 4

Analysis of Concept Maps (Gaining content knowledge)

4.1 Introduction

Teachers always encounter a challenge when they are confronted with the task of teaching a topic that is completely new to them or one they are not comfortable with (Rollnick, Mundalamo & Booth, 2008). One way to gain confidence in teaching topics that we are not comfortable with as a teacher, is through concept mapping. This chapter discusses how the concept maps have helped me with the development of my own content knowledge with regard to stars. A detailed description of what a concept map is and what I used concept maps for is provided in this chapter in order to show what it means to my study. An action research approach is used in helping me to construct the concept maps and analysing them which enables me to trace my learning of the content of stars.

4.2 Concept maps as sources of data

A concept map is an active learning tool that is used to identify gaps in knowledge, identify any misconceptions as well as to target prior knowledge in order to rectify it through activities (Adamczyk & Willson, 1996). Concept maps can be viewed as cognitive tools that allow one to realise and demonstrate conceptual connections between and within concepts (Samaras and Freese, 2006). In addition, a concept map comprises of concepts that are interlinked to one another; these concepts may be theories or facts that substantiate the main idea.

In my study concept maps are used as a tool that help me in developing ideas about the life of stars, as they capture my learning progress in this content area. The concept maps also enabled me to analyse the amount of content knowledge that I gained. I constructed three concept maps in my study in order to inform me about how much I knew. The first concept map was constructed right at the beginning of this study because I had to see how much I knew about this topic of stars. The second concept map that I constructed was before I submitted my research proposal and the third concept map was done before teaching the lesson on stars. A series of interventions took place in order to help me to develop more accurate ideas about stars. Each concept map was analysed using the action research spiral, because I was in a continuous learning cycle.

4.3 Results and Analysis

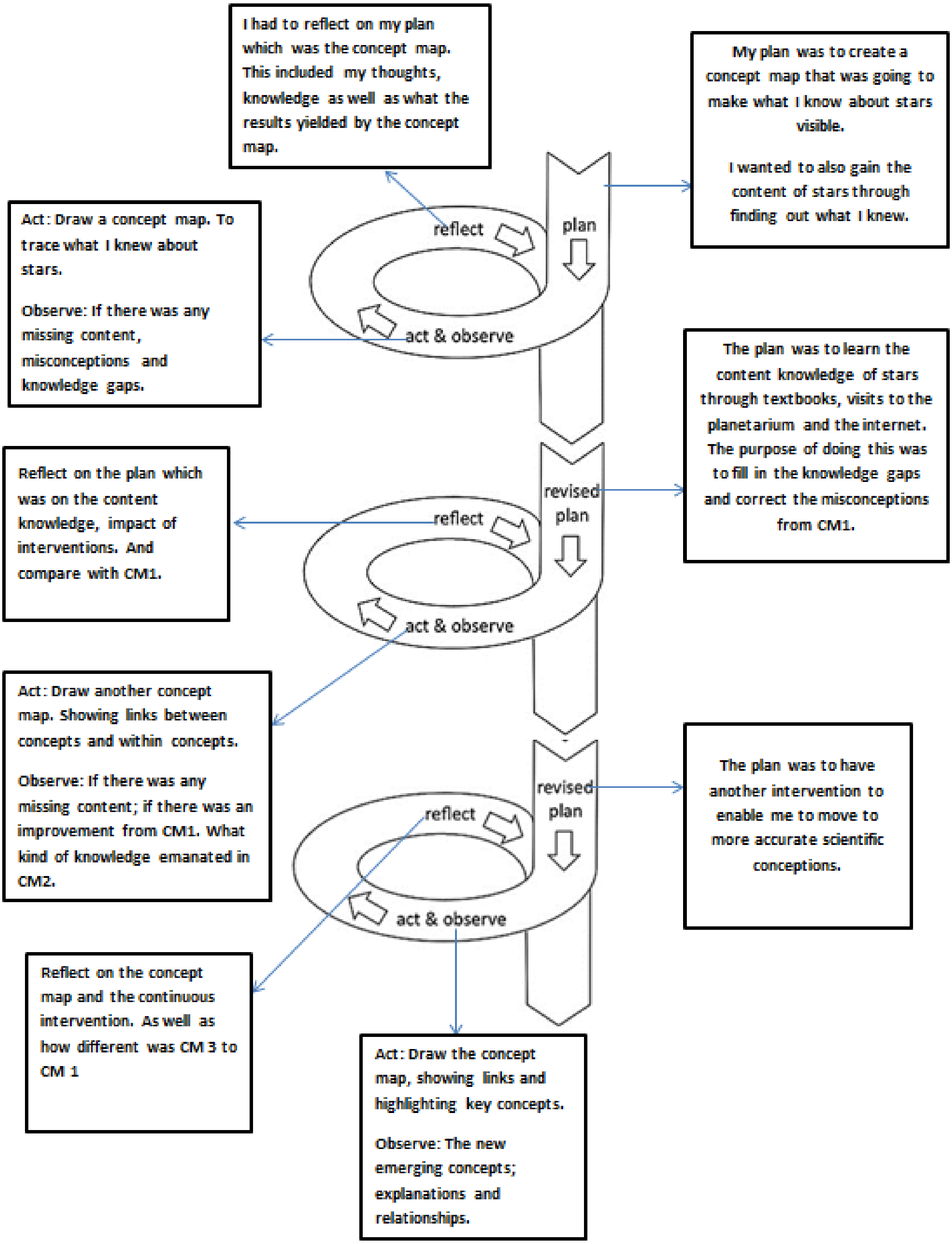


Figure 4.1: Action research spiral, adapted from Kemmis and McTaggart (2000)

4.4 Concept Map 1

Plan

The aim of the first concept map was to assess where I was in terms of content knowledge, as Novak and Gowin (1984, p.101) argue that "concept maps are a simple tool for assessing where the learners are". However, the main plan was to gain content knowledge about stars through finding out what I know. The plan was to also organise content knowledge in a systematic and logical way that shows links between concepts so to encourage meaning making. Percy as cited in Pasachoff and Ros (2008) asserts that learning factual knowledge does not automatically lead to a deep conceptual understanding of content, therefore whatever knowledge I have whether it is facts and theories does not say that I fully understand the content. Creating the first concept was challenging for me, I had no idea where to start. I recorded my initial thoughts about the first concept map in my journal.

> *'I am not sure where to start with my concept map. I feel like I don't know what stars are; the idea of writing what I know down makes me uncomfortable, what if I am wrong? What are the important concepts linked to with stars? Maybe I need to write them down first. I know and I am very sure that gravity plays a huge role in stars, but I don't really know the role it plays.' - Journal entry (04/03/2016)*

> *'I remember from my second year that stars are made up of dust particles and gas particles. This is another concept which I feel is important. This is what I will mention when start speaking about stars.' - Journal entry (05/03/2016)*

The idea of the first concept map was very unsettling as these journal entries show and this is because I was lacking confidence in the way I understood stars; hence being unable to communicate about them. Another issue raised by the entries was where should I start?; this was an important question because where I start needed to link with where I wanted to go. I had bits and pieces of words scatted all over in my notepad; but I did not know which one to start with and which word it will link with. I wanted my first map to be very raw so that it shows me what I actually think I know, as well as what I do know.

Act

I created the concept map (appendix E) with the word 'stars' in the middle, this concept map documented my prior knowledge and my thoughts. Prior knowledge refers to the knowledge and ideas which people have prior to the instruction of content knowledge or prior to receiving any information that will build onto the content. This prior knowledge is important as it can hinder or allow the development of conceptual understanding of the scientific content knowledge about stars. More so, prior knowledge affects how one receives new content; how they accept the information as well as how they become aware of this new information (Svinicki, 1994). Figure 4.2, is abstracted from my concept map in which I gave a definition of stars, noting that stars are objects that shine or twinkle. This premise was a base of my everyday knowledge of what I have observed in the night sky, 'stars twinkle'. Comins (2001) noted this as one of the common misconceptions that people hold with regard to stars, and it was part of my own knowledge. Therefore, this concept map opened opportunities for my prior knowledge to be confronted and to be corrected in order to form more correct conceptions.

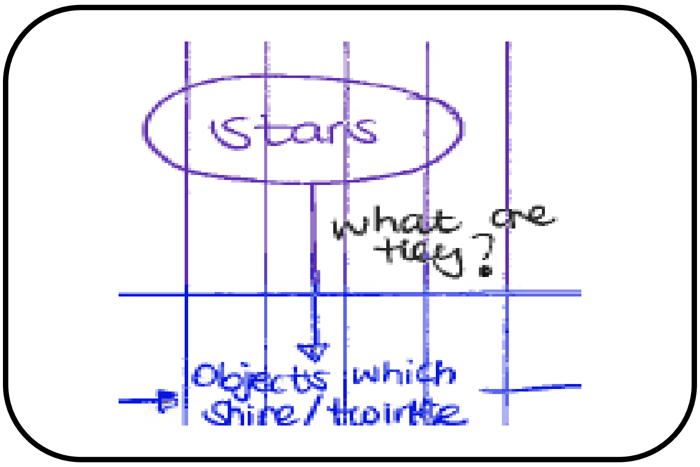


Figure 4.2: What are stars?

Observation

> *'The book I am reading about how the first stars and galaxies form does not really say anything about the big bang, is the big bang really central in star formation. So far I am not sure what this means yet. Maybe the big bang theory will come in later'.*
> *– Journal entry (30/03/2016)*

The concept map enabled me to see that the amount of content knowledge I had at that time was too little. This is because it emulates the depth of my understanding of the content of stars, hence coming to the conclusion that I held superficial ideas and a shallow understanding about stars. Figure 4.3 and Figure 4.4 depicts my superficial understanding, in a sense that the links and the difference between the concepts are dubious and illogical. My initial understanding was that '*stars are heavy bodies formed from the big bang theory with the dust and gas from space'*, seeing this made me realise that I do not fully understand what the big bang theory means and what space is exactly. Therefore not fully understanding the big bang theory hindered my conceptualisation of stars. For me at this point the big bang theory was the main catalyst in the formation of everything that is surrounding all bodies found in space this included stars as well as planets. The main question I was asking myself at that point was that *'what is the big bang theory?*'; looking at the concept map I found that I could not link the big bang theory with any solid facts besides dust and gas. This shows how much understanding I lacked of the big bang theory and also how I was unable to distinguish between 'the big bang and the big bang theory'. Clayton (1968) mentions that the big bang theory is a theory explaining the expansion of the universe and the big bang is the actual event. It is important for me to differentiate between these two because then I can be able to have a better understanding and create links between these concepts and other concepts related to it.

> *'Since I have been going through the books that I have taken from the library, I realise that I knew nothing about stars, I am learning a lot of things and I am also taking in a lot of things. Some of these things are making sense and some are really becoming hard to understand. The ones I understand have shown me how much knowledge I have lacked and many other people might be lacking the same knowledge. What are people's conceptions about stars?'- Journal entry (12/04/2016)*

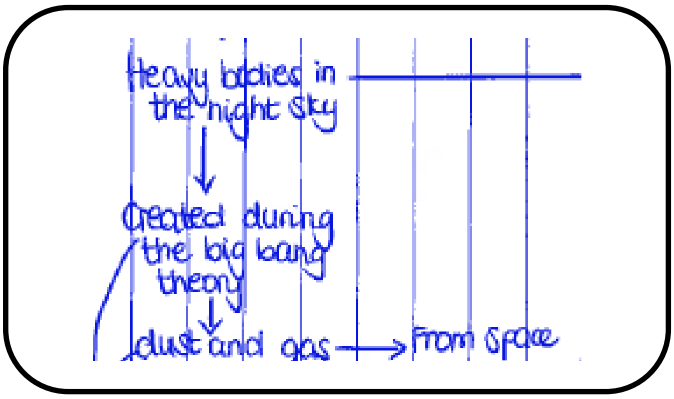


Figure 4.3: Superficial ideas

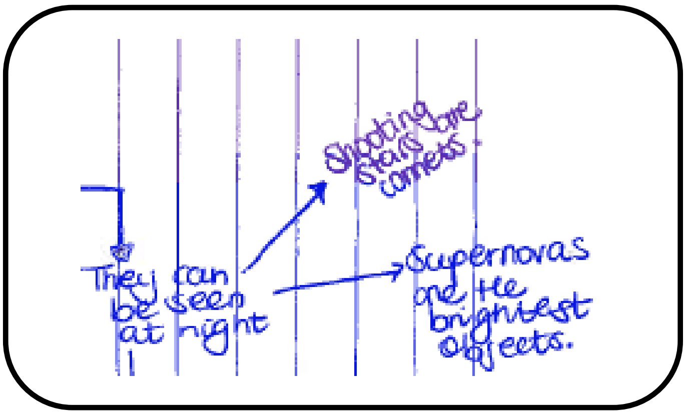


Figure 4.4: Illogical ideas and errors

Looking at figure 4.4 in which I have mentioned that *'Stars can be seen at night, shooting stars are comets'*, these chains of statements that are illogical and do not flow. Sharp (1996) found that most students hold a misconceptions that 'stars come out at night' and I had the same misconception. Figure 4.4 is evidence of a misconception and superficial understanding of the properties of stars; hence I was throwing random words which I have heard such as a *'shooting star is not really a star'* or that *'a supernova is the brightest object'*. These ideas are disjointed as they do not give a substantial connection with the main idea; hence giving rise to questions such as 'how is a star different from a supernova?'. At this point I felt that I had the correct scientific words such as comet and supernova but I did not have enough content to back them up and support them any further. Evidently I held the same misconception as the students from the study by Sharp (1996) and this allowed me to see the knowledge that I lacked.

Another feature emanated from the concept map, which was that most of the concepts are based on the macroscopic properties of stars. These properties include size, colour, temperature, distance and what is observable with a naked eye such as the Southern Cross or Sirius the brightest star; as Agan (2004) stated that students with a limited content knowledge relied most heavily on observable assumptions in their understanding of stars. However, deep conceptual understanding requires one to be able to move between different levels of representation of knowledge; which I was not able to do when I was creating this concept map. Being able to point out where things are at night as well as giving their names is all factual. Meaning that all the knowledge I have is made up of isolated bits of information (Percy as cited in Pasachoff & Ros, 2008).

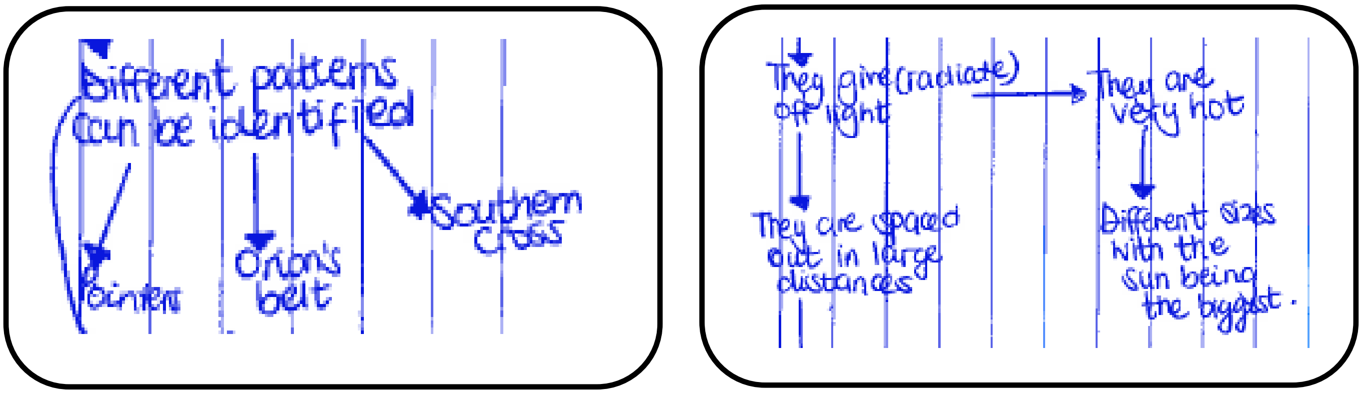


Figure 4.5: Macroscopic ideas

'Can I be a teacher with misconceptions? What does that mean about my teaching? In what ways will this affect my teaching?'- Journal entry (23/04/2016)

Misconceptions are preconceived notions that are influenced by our everyday knowledge, cultural backgrounds and from how we are taught in schools. Agan (2004) argues that students' prior knowledge about stars may be determined by the relationship between the concepts formed, everyday experience and observations. More so, Bailey et al. (2009) indicated that students' come to the class with deeply rooted conceptions that influence how well a concept is understood. The concept map has elicited the misconceptions in my ideas of stars. The one misconception which was of concern was that I thought that the sun is the biggest star amongst the other stars (Figure 4.6). This shows that I viewed stars to be objects that have the same behavioural characteristics such as the planets, which are orbiting the sun. This idea was influenced by how I have failed to conceptualise that the planet earth (which I live in) is the one moving (orbiting the sun) and not the night sky; Comins (2001) also stated this misconception.

I first went to the library to find textbooks that would help me learn about stars, it was difficult to choose a book to use that could suit me as a beginner. After looking at some books I took a few of them that I felt I could easily make sense of. I started going through the content in the books relating one idea to the other, however this was not an easy task. The textbooks were the first things that exposed my misconceptions as seen from the journal entry (12/04/2016). While going through the books I realised how many errors I have made in my concept map. One of the ideas emphasized in the textbooks was that the stars have different sizes. In my head I was aware of that but I had not yet thought of the star as one of the medium sized stars; instead I thought of it as the biggest star. I had to go back to the solar system and look at the size of the planets relative to the sun and then from there look at the sun relative to the other stars. This process enabled me rectify my misconception and to also reconceptualise the idea of sizes.

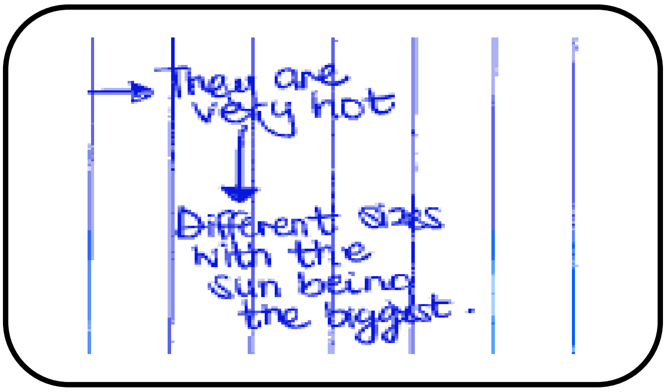


Figure 4.6: Misconception 1

Reflection

My initial plan was to create a concept map that would serve as a tool to guide me in assessing my knowledge about stars as well as to become aware of the knowledge that I lack. From the journal entry (04/03/2016) it is evident that I was uncomfortable with the idea of creating a concept map, because I had insecurities that include exposing my incorrect conceptions. I needed to cross that insecurities barrier by accepting that the process of knowledge development encompasses one's prior knowledge. The concept map revealed a lot of aspects as per my observations; these aspects included misconceptions, knowledge gaps and also missing content. For example in figure 4.7 I mentioned gravity however I failed to define and show what I mean by gravity as well as how it applies to star formation. Therefore, in order to rectify the misconceptions and fill in the missing knowledge gaps, I needed to think of ways that would enable me to move to correct scientific notions about stars. I came up with different intervention strategies which would help me in gaining the content knowledge. An intervention enables one to change their initial ideas and move towards more scientifically correct notions when it comes to astronomy (Lelliott, 2007). I started the intervention as I was at the stage of observation in the action research cycle. The first intervention was the visit to the library, the purpose of the library visit was to get textbooks that gave me an introduction to the topic of stars as well as some aspects that are important in astronomy. As seen from my observations the textbooks allowed me to question my knowledge and this enabled me to move to more correct scientific notions about stars. More so, Sharp (1996) and Agan (2004) reported similar findings to those of Lelliott (2007) in which the induction to the scientific content shifts ones' ideas and conceptions to more scientifically correct notions.

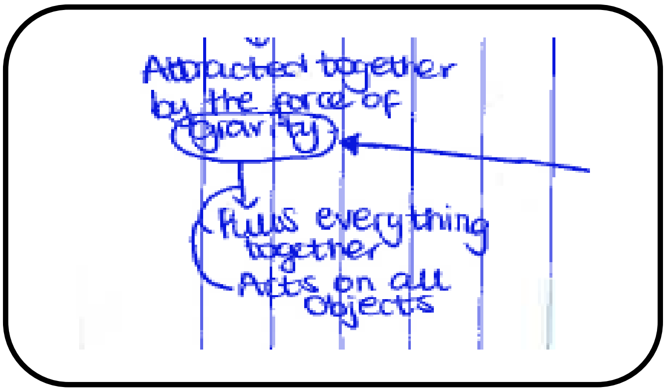


Figure 4.7: Missing content

4.5 Concept Map 2

Plan

The plan for the second concept map was to fill in the knowledge gaps which were evident in the first concept map. Filling in the knowledge gap also measured how much content knowledge I have gained and to also correct the misconceptions which arose from the first concept map. To fill in these knowledge gaps I had to go through a series of interventions to be able to shift my thinking into the scientific way of knowing. As part of the intervention I visited the library; however I visited the Bio-phy library as well as the mathematics library. The reason for visiting these two specific libraries was that they had books that are suitable for beginners and also advance science knowledge about stars. The textbooks started to be more and more complex and I could not fully understand the theories they were explaining and it was then that I realised that I cannot just rely on the textbook; I needed to do more. I then went to visit the Planetarium, my aim was to get acquainted with people who are knowledgeable in the field of astronomy to help me understand some of the terms I was not understanding and to also learn as much as I could. I also wanted to ask questions to the people who work there about stars and also enjoy astronomy shows in which I also learnt about other objects not just stars. The planetarium offered me more than just a question-answer session; I started being an active participant by attending a Friday night show which was about the wondering stars as well as collecting star charts monthly. I also used some internet sites, YouTube being one of the most effective sites. YouTube enabled me to get a better understanding of things I found difficult. YouTube unlike other sites offer verbal explanations often accompanied by visuals; I found it to be more effective for me to comprehend the content better. The journal entries below show some thoughts from the textbooks experience and one of the planetarium visits:

'These books are starting to be difficult for me to understand, where does this hydrogen come from? This is a lot of content. I need to ask my supervisor what these things are. A pulsar star?. I have realised that the more content knowledge I'm confronted with the more questions I am starting to have.' – Journal entry (23/04/2016)

'I went to the planetarium to watch the Friday show in the pursuit of learning about stars. The question remained, what is it that I would like to learn about stars? I found this visit to be one of those it was just interesting, as the idea of what about stars I wanted to learn is still fuzzy.'- Journal entry (06/05/2016)

My supervisor was also played a part in a sense that I would go and consult with him about all these concepts which I came across and he would explain the concepts and also send me to relevant internet sites to help me. In correspondence to that I joined an astronomy club on campus which served as part of the learning about stars intervention. The astronomy club consists of Bachelor of Science in Astronomy and Astrophysics students. The reason I joined this club was so that I can have people who are studying this field to help me apprehend the concepts that I do not understand and to start being comfortable when talking about stars. The astronomy club holds star gazing shows, planetarium shows presented by astronomy researchers as well as astronomy sci-fi movie nights. The journal entry below is an illustration of how I felt when I first met with the club.

'I saw people gathered around the great hall piazza on my way home this evening. I noticed that they had telescopes and I went to ask what was happening and it was a star gazing evening. I asked why they were doing it and it found that they are an astronomy club (WAC). I joined them to enjoy the stars. I finally found people who understand all these things' – Journal entry (06/05/2016)

'I think I am now ready to draw another concept map. I have learnt new concepts and I have thoroughly gone through the content. The concept map will help me to make links between what I have learnt.'- Journal entry (08/06/2016)

The day I wrote the above journal entry (08/06/2016), I felt that I needed to put down the content knowledge that I have already gained; so to see how much I have learnt as well as how much I still needed to learn. The journal entry shows that I had become comfortable and also gained confidence in the content knowledge that I had gained. The intervention from the planetarium, astronomy club, textbooks and my supervisors' comments helped me to improve my content knowledge which enabled me to be confident.

Act

I took everything that I have learnt through the interventions into a concept map (appendix F). Concept map 2 shows a change of thoughts and ideas. Figure 4.8 shows the beginning of my concept map in which my definition of stars had shifted. The reason for the shift is due to the intervention; however some ideas are influenced by my prior knowledge. Hay, Kinchin and Lygo-Baker (2008) assert that prior knowledge in concept maps is important as it forms a scaffold for new learning as well as correcting misconceptions. Figure 4.8 shows I have learnt that a star is a *'big luminous ball of gas'* which is more scientific unlike saying that a 'star is a '*heavy body in the night sky'*.

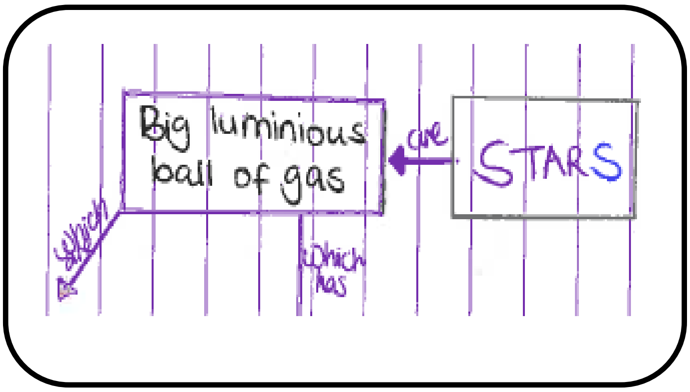


Figure 4.8: Redefining a star

To fill in the missing concept and any existing knowledge gaps from the first concept map, I needed to move from superficial ideas and start building more accurate scientific conceptions. The superficial ideas such as 'shooting stars and the big bang'; were not visible in this concept map as I could not make accurate links between them and the other concepts relating to the formation of stars..

Observation

There are certain misconceptions that came out from the previous concept map; however I did not include all of them in my second concept map. One of the misconceptions that I had which the intervention processes helped me with was that *'the stars do not orbit the sun'*. The sun is the only star that is in our solar system; life on the planet earth is provided by the sun because it provides the energy needed to support the environment (Bailey et al., 2009). All the other stars are outside of our solar system, some with masses greater than that of the sun. In concept map 2 I have included some of the stars which are brighter in the night sky. However it is important to note that just because the stars can be seen at night they are only visible at night; we cannot see the stars because the sun is up and its rays are scattered all over the atmosphere (Pasachoff, 1983).

> *'The idea of gravity is still unsettling with me, everything stays in place because of this gravity yet objects also die under this force? What is this force exactly?'- Journal entry (13/06/2016)*

My notions with regard to gravity are somehow disordered in a sense that I have come to view it as a force that creates and destroys at the same time. Although there has been a shift in how I have formulated the concept of gravity from concept map 1 to concept map 2. Figure 4.9, shows which ideas which stayed the same, the ones that changed and those that have been added.

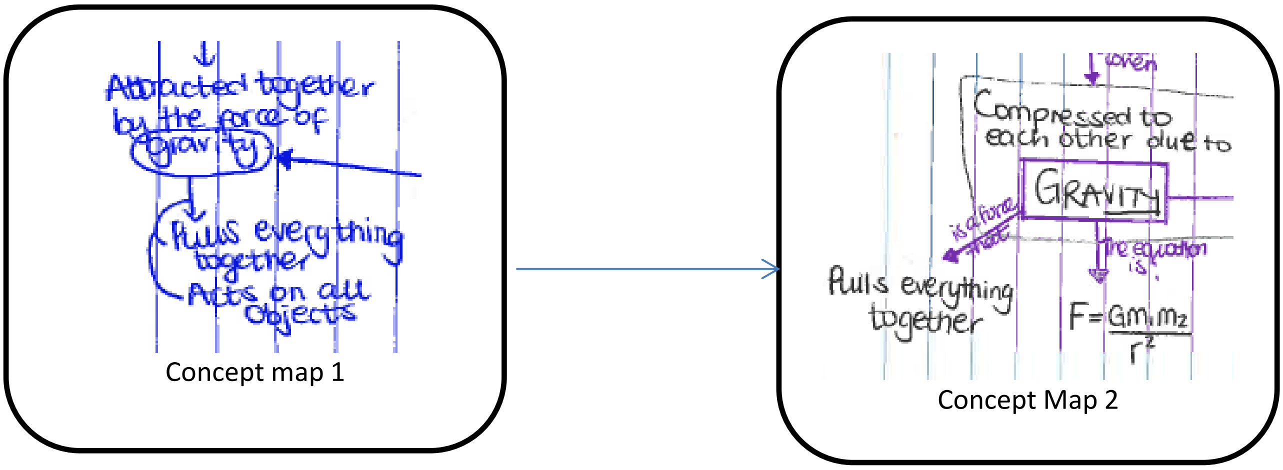


Figure 4.9: The ideas of gravity between concept map 1 and concept map 2

The concept of gravity comes in an attempt of explaining how the dust and gas comes together in forming a star. In both concept maps I have fully identified gravity as a pulling force, as I have always understood it. This prior idea of gravity as persisted in my new knowledge that I have gained and I have also added the equation in concept map 2. The reason I might have missed out on the equation in concept map 1 was because I was not thinking of other topics in science that influence the content of stars. Due to the interventions that took place, I came to realise that the Newtonian views are central to the ideas of star formation. Thus, in concept map 2 I included the equation which signifies the importance of the universal law of gravitation. In concept map 1 I used the word ‘attraction’ and the second map I used ‘compressed’; I find this twist of words interesting because when particles are attracting each other they become compressed each other.

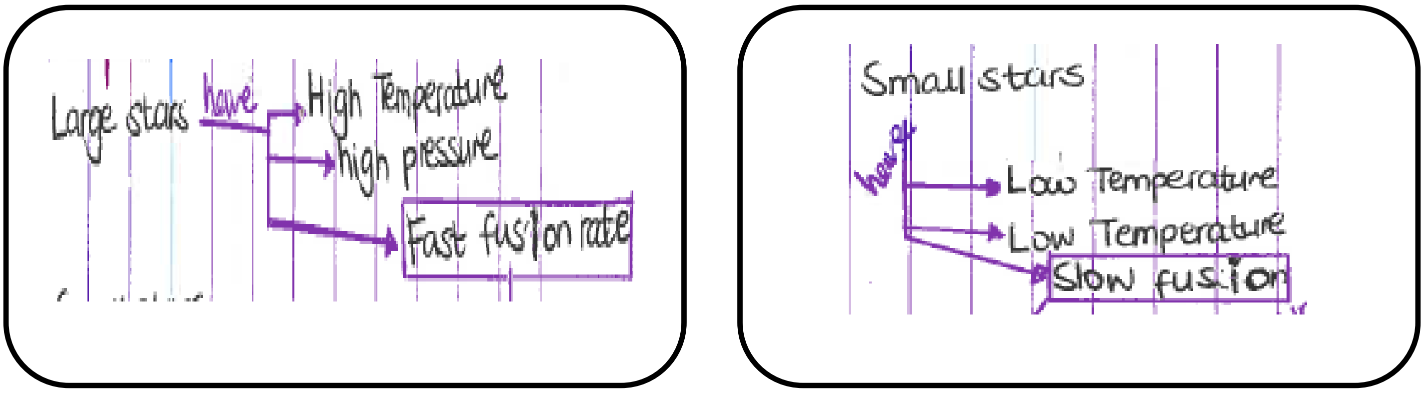


Figure 4.10: Characteristics of stars

Figure 4.10 shows that I have learnt that the mass of a star is central to understanding the future of that star. I have given characteristics of the stars showing that I am aware that the star depends on them (characteristics), in order to leave the life it lives. Bailey et al. (2009) stated that it is very seldom that students are aware of the different characteristics of the star other than they have different sizes. Being unable to identify the other characteristics that occur at the microscopic level, poses as an impediment on how one describes the stars (Bailey et al., 2009).

> *‘I remember my friends and I used to say that something is supernova instead of great, supernova to me still shows a great something, so in stars it may mean a great star?’- Journal entry (06/03/2016)*

> *‘From a lecture I once attended, I remember that a supernova is an explosion’ – Journal entry (08/04/2016)*

During the intervention I continued to think that a supernova entails something great, but the question remains a great what?. The idea of a supernova seemed to have evolved from just a superficial idea to an accurate idea in which a supernova is not an object that appears because it has to appear, but an event which indicates the death of a large star. A supernova as shown in figure 4.11; is a death of a star and a birth of a neutron star or a black hole. Therefore, yes it is an explosion of a very large star, and noting that in my journal enabled me to regain confidence in the use of this concept.

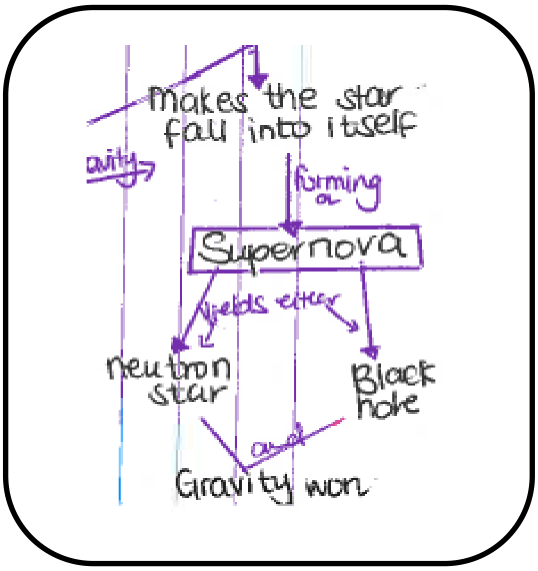


Figure 4.11: Ideas of supernova

Reflection

This concept map was an improvement from the first one; in a sense the ideas and concepts presented are all logically linked. In concept map 2 I tried to move away from macroscopic ideas and introduced some sub-microscopic ideas such as 'nuclear fusion'. This indicates that my ideas have evolved as I was able to integrate microscopic properties of stars with their macroscopic properties; showing that I am now moving in between two levels of representing knowledge. Although the shift from macroscopic ideas was not a smooth one; figure 4.12 shows that I still felt the need to mention what we see in our night sky. The journal entry (08/06/2016), illustrates why I might have felt the need to include what is in the night sky.

> *'How do I talk about stars without being able to point them out? I think I need to recognise these stars in the night sky so to think about them in relation to their characteristics from the Hertzsprung-Russel diagram' – Journal entry (08/06/2016)*

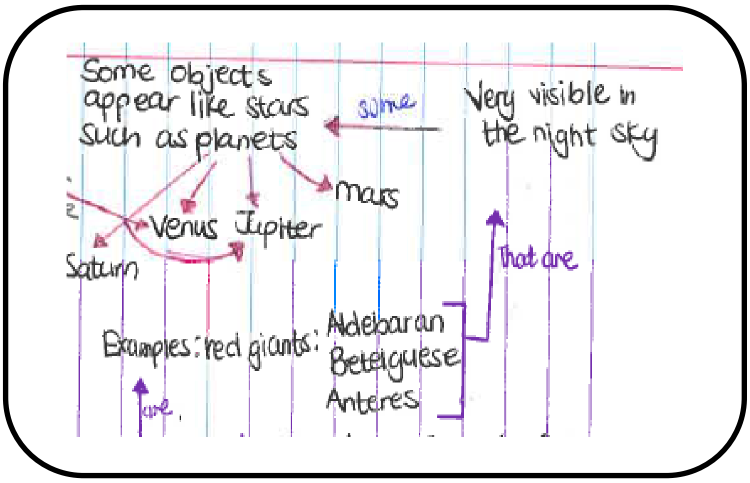


Figure 4.12: Macroscopic ideas from concept map 2

The intervention sessions which I had in place and went through helped me in gaining and understanding content. Each intervention had its own uniqueness in terms of what it offered me as well as what it helped with. For example the Planetarium visits offered me a tangible feeling of the night sky; making me to be more observant of the changes in the night sky and being able to distinguish between stars and planets. The astronomy club offered me a space in which I can have conversations about astronomy related topics with my others, which is something I have not been able to do with my peers. The conversations with my supervisor always left me curious about the past scientific or rather astronomy-stars related discoveries; one I found most fascinating was him getting a glimpse of a supernova back in the 1980's. The textbooks, YouTube and other internet sites gave me a good theoretical foundation and content knowledge of stars. These interventions enabled me to be confident in talking and thinking about stars but there were still some things which I did not completely understand.

> *'There are other concepts which I have come across in the text books and videos as I am learning about stars which I am not sure how to link with the other concepts. Electron pressure? What role do electrons play?'*-Journal entry (08/06/2016)

This entry made me to start digging deeper and start asking relevant questions in the planetarium, in the astronomy club, to my supervisor and my lecturer. At this point I was aware of the other concepts which answer the questions that are related to ideas such as 'black hole, neutron stars and white dwarf'; which come as the result of the death of star (figure 4.11). The questions raised in the journal entries display a shift in how I though generally and what I thought about stars. The role of abstract concepts in star formation was fascinating to read about although I could not make well substantiated links with them in concept map 2; which made it clear that there was a need for another intervention to take place so to strengthen my content knowledge.

4.6 Concept Map 3

Plan

The plan was to have another intervention to enable me to move to more accurate scientific conceptions. Hence, I went back to watch videos on YouTube to get a better understanding of the concepts which I did not understand. I attended a lecture with a first year studying towards a Bachelor of Science in astronomy and astrophysics; and the purpose of this was to see how other topics in physics relate to stars. This was important for me because it enabled me to move away from seeing topics as isolated from each other. I also had a session with a lecturer Dr SH, who explained most of the concepts which I was really struggling with and that session assisted me with putting related concepts together. I was also attending second year natural science astronomy lectures just to see how the lecturer teaches about the stars, and how deep in terms of content do they cover. I also started searching for learning materials and worksheets on the internet to help me build more accurate scientific notions. Doing this enabled me to have a solid scientific knowledge of stars. I then went back to the textbooks so that I can progressively move toward stronger deeper understanding of knowledge. All these interventions lead me to drawing another concept map.

> *'The session with Dr SH was quiet interesting and overwhelming, so much content but such a great view of content. I must say I feel like I can be able to tell someone else about stars, especially since the planets are also very visible in the night sky' – Journal entry (29/07/2016)*

The third concept map followed the cycle of the second concept map in the action research spiral (figure 4.1). The aim of this concept map was to fill in the missing content as well as the content that I was not able to makes links with. The intervention session with my lecturer Dr SH moved me towards creating authentic, non-superficial links between the concepts and within concepts which I was dealing with.

Act

I drew a concept map (appendix G) that reflects the content gained from more sources such as a study friend from the Wits Astronomy Club (WAC) and an Astronomy lecturer (Dr SH) from the institution. Just as in concept map 2, everything which I have gained in all the interventions I put in the concept map and created appropriate links. There was a huge shift in terms of how I chose to start my concept map. Previously in concept map 1 and 2, I was starting my concept map by defining what stars are; in this concept map I viewed stars as living objects; in a sense that they are born, they live and they die (Figure 4.13). This shift was influenced by the attempt of integrating all the concepts which I have learnt into a concept map and also the interest in what is happening at a sub-microscopic level rather than the macroscopic level. Hay et al. (2008) argues that a concept map suggests the order in which new material must be introduced if it is to be taught and understood.

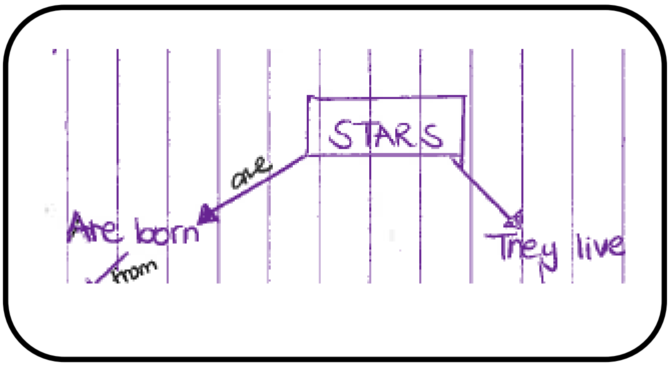


Figure 4.13: New starting point

Starting from this view in figure 4.13 enabled me to fully describe star formation microscopically. I started describing the particles found in the cloud of dust and gas; and how those particles because of the force of attraction being gravity collapse and become compressed to one another until their temperature as well as their pressure increase. With reference to gas laws; when temperature and pressure increase particles also increase their speed and they start colliding into one another (Silberberg, 2013). When this happens nuclear fusion stars, in which the hydrogen atoms collide with one another forming a heavier atom and due to this nuclear fusion a star is born (figure 4.14).

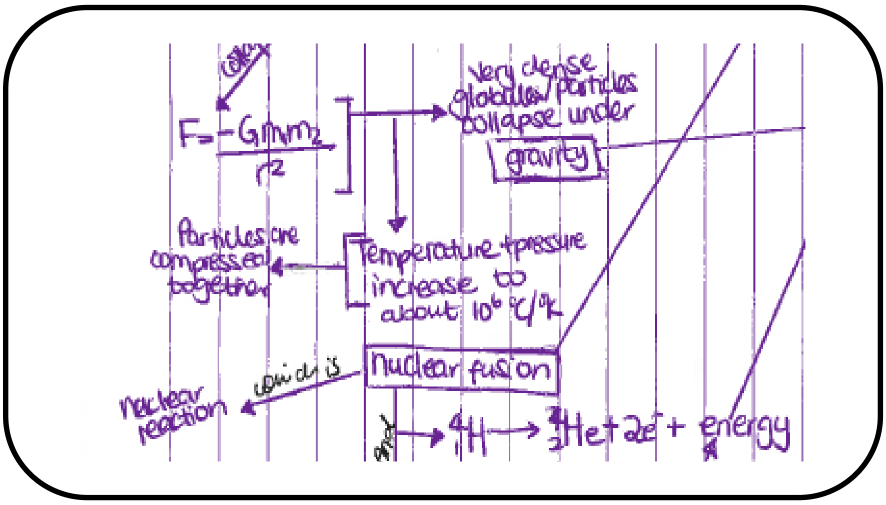


Figure 4.14: Star formation

Observation

Starting my concept map at that angle (figure 4.13 and figure 4.14) enabled me to move to more accurate conceptions about stars. The concepts that are raised from the beginning such as 'gravity' and 'nuclear fusion' are the underlying features of star formation. Such concepts can be described as big ideas which are ideas that are central in ensuring that a concept is not only well understood but also fully understood (Loughran et al, 2004). Agan (2004) contends that an emphasis on the energy production in stars is central to understanding the subject matter in astronomy; and this idea has also been integrated in this concept map (figure 4.15).

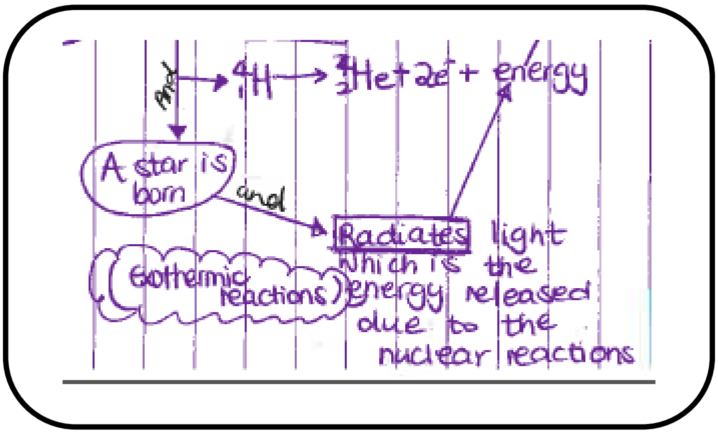


Figure 4.15: Energy production in stars

It was very essential for me to mention in my concept map that nuclear fusion does not only produce heavier atoms but it also produces energy; and this energy comes in a form of radiation. This radiation is important because it is what makes the star to be a unique object in our universe, all the other objects do not have this distinctive property. In concept map 2, I had mentioned that the star is ‘a luminous ball of gas’ however I did not expand on the luminosity idea due to my lack of knowledge.

This concept map is rich in terms of the amount of content and concepts it has. One of the most intriguing links was drawing gravity and radiation towards the same concept which was the balance of the star. Gravity and radiation are the two forces which are responsible for keeping the star in place as they are two opposite forces (figure 4.16). Hay et al. (2008) claims that a concept map allows one to recognise the new concepts which they find troublesome or difficult to acquire and gravity has been one of the main concept which I struggled to fully understand.

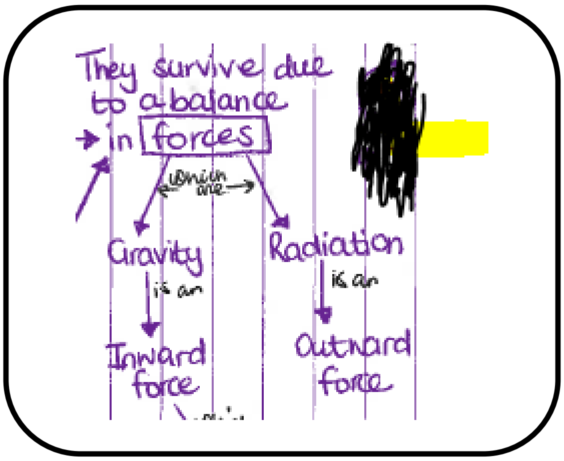


Figure 4.16: Forces

Reflection

The concept map is very detailed with links that are well substantiated by the concepts which are attached to it. This concept map shows comprehensive ideas and clearer explanations which enable me to gain confidence in this topic area. There are so many ideas which have evolved and those that have been modified due to the interventions that took place as well as my own interest and curiosity. All changes and alterations to my content knowledge were influenced by the continuous intervention plans which I took part in.

Concept map 3 is built on abstract concepts which are scientifically based; this change shows that I have gained enough content to be comfortable to explain it sufficiently and scientifically. The microscopic concepts are more salient in concept map 3 than in concept map 1 where macroscopic concepts were mostly dominant. This means that the microscopic concepts and ideas are noticeable in concept map 3 unlike in concept map 1 where all the ideas were macroscopic and based on observations.

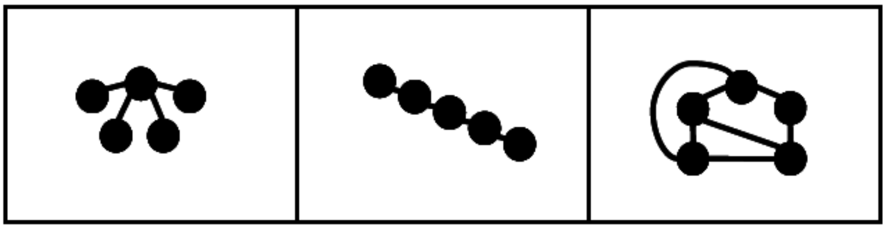
> *'I am comfortable enough to have a conversation with someone else about stars, and ask more questions, the books I read are now easier to follow and I have started criticizing how they explain things. I have taken it upon myself to learn about stars and I am at the point where they are making sense beyond the unseen'- Journal entry (01/08/2016)*

4.7 Intervention plans /sessions

Table 4.1: a table showing the intervention sessions and the activities which I did in each intervention.

Plan	Activity
Visit to the Library	Bio-phy and Maths libraries: Checking out textbooks
Internet	YouTube Astronomy sites (moon shadow, NASA)
Astronomy lecturer	Astronomy evening with a guest presenter
Planetarium	Friday night show Question and answer session with presenters Collecting monthly start charts. Sit in (High school show) PGCE show
WRAC (WestRand Astronomy Club)	Star gazing show (friends of kloofendal)
WAC (Wits Astronomy Club)	Star gazing events Astronomy lecture (careers in astronomy) Sci-fi movie day Buddy sessions with a member of WAC
Meeting with supervisor and lecturer	Asking questions about things I did not understand.
HartRAO (Hartebeesthoek Radio Astronomy Observatory)	Exposure in the field of astronomy, interactions with the astronomers.

4.8 Measuring the quality of change through concept maps



	SPOKE	CHAIN	NETWORK
Structure			
Hierarchy	single level	as many levels as concepts (but often these are unjustified)	several justified levels
Additions	additions to the central concept does not interfere with others	cannot cope with additions near the beginning of the sequence	additions and deletions have varying effects as 'other routes' are often available through the map
Deletions	generally have no effect on the overall structure unless the central (organising) concept is deleted (which leads to complete collapse)	disrupt the sequence below the deletion	
Links	often simple	often compound (making sense only when the map is read as a whole)	often rich and complex showing deep understanding
General	these structures indicate 'learning readiness' they are flexible and amenable to change in the course of learning	these structures are 'active' they are common to enterprise or to clinical practice where specific sets of actions must be carried out in sequence	these structures are 'scholarly' they often include alternative 'viewpoints' and even contradictory ideas

Figure 4.17: Prior knowledge structure of learning by Hay et al. (2008)

The spoke structure concept map is a simple single hierarchy level structure in which concepts are joined (linked) to the main idea and often disjoined from the other concepts. According to Hay et al. (2008) the spoke structure indicates learning willingness, meaning that although there is not enough content there is room for learning and accumulating more content knowledge to occur. The chain structure concept map shows ideas that are directly linked to one another in a linear form. Hay et al. (2008) contends that the chain structure is compound meaning that it makes sense only when the concept map is read as a whole. A network structure is a combination of the spoke and chain structures in which concepts can be joined (linked) to one another at any level; which shows a deep, rich understanding of content knowledge (Hay et al., 2008).

Figure 4.17 measures the quality of conceptual change through the structure of the concept map. The figure shows that some ways of organising and storing knowledge are more amenable to learning than others (Hay et al., 2008). The first concept map was definitely under 'spoke' in which the links between concepts are simple and disjointed from one another. This is because of the lack of knowledge I had at the beginning of my journey of learning about stars. The concept map 1 was very helpful in a sense that it revealed my prior knowledge and made it visible to me and others; hence enabling me to move into more accurate and acceptable scientific notions.

The second concept map was in between the chain and network structures. At that point of the second map I had gained enough content to create links between concepts although it was in a linear way. For example the concept map only makes sense when it is read from the beginning, taking a concept in the middle may throw one off the edge. Hence the second map featured both the structures because of the overlap existing between the structures.

The third concept map shows characteristic of those in the network structure with rich concepts that show deep conceptual understanding. This concept map (3) is evidence that the ideas from the first concept map can be amendable during the course of learning the content. Having gone from route knowledge, everyday knowledge to deep conceptual understanding of stars has been captured in all the three concept maps. It is however rare for one to start with a network structure when devising a concept map for the first time; through gaining more and more content knowledge and understanding it enabled the devising of a thoughtfully well scaffold body of knowledge (Hay et al., 2008).

4.9 Conclusion

The role of concept maps in this study was to make my learning process visible. This was because concept maps enhance the quality of content knowledge gained and also show that learning is a personal change and the quality of this change enables deep conceptual understanding of concepts (Hay et al., 2008). Therefore, the concepts maps have enabled me to trace my learning cycle. This chapter has discussed in full how concept maps captured my knowledge and how I preceded into gaining scientific content. The quality of conceptual change was captured using the prior knowledge structure of learning and it has proven that the act of drawing more concept maps assists one to move to a good quality of content knowledge. The next chapter goes through the process of how I gained the knowledge for teaching the content that I have learnt.

Chapter 5

Knowledge transformation (learning how to teach)

5.1 Introduction

"Those who can, do; those who can't, teach" is a famous statement which some people use to describe the role and the career of teachers. However, this vague statement is diminishing the actual role of teachers in education. Hence, Shulman (1986) criticized not only that view but also how many other researchers have neglected the role of content knowledge when speaking about teaching; thus coming up with the theory of Pedagogical Content Knowledge (PCK). This chapter discusses how I have gained the knowledge for teaching which enabled me to build and develop my own Pedagogical Content Knowledge through planning the lesson (developing the CoRe); and teaching the lesson twice.

According to Loughran et al. (2006) teaching is a complex task which develops with the experience of a teacher. However it is also essential to note that to teach is to first understand; hence the comprehension of content knowledge is the dominating part of developing PCK. In chapter 4, I have shown how concept maps have assisted me in gaining the content knowledge about stars. More so, Rollnick, Mundalamo and Booth (2008) maintain that the teachers' concept maps are likely to reveal both aspects of content knowledge and pedagogical knowledge since when they construct concept maps their knowledge of subject matter is intimately linked to how they are going to teach it. Shulman (1986) refers to subject matter knowledge (SMK) as the amount and organisation of knowledge as viewed by its domain experts and that this knowledge includes concepts, laws and theories that govern the discipline.

Accumulating content knowledge and understanding that knowledge with all its complexities and concepts does not guarantee that one can teach that content knowledge in order to promote an effective teaching and learning. Therefore, teachers are not only the bearers of content knowledge but also the bearers of content knowledge for teaching. Shulman (1986) asserts that there is a special feature that makes a teacher different from all other professions and that feature is the ability to transform content knowledge (CK) in ways that the students will be able to comprehend it. Additionally, Shulman (1987) argued that transformation of content knowledge is the process which leads to the development of a teachers' PCK. Therefore, the model of TSPCK (Figure 5.1) by Mavhunga and Rollnick (2013) enabled me to go through the components of TSPCK in which transformation is taking place in order to develop my own teachers PCK.

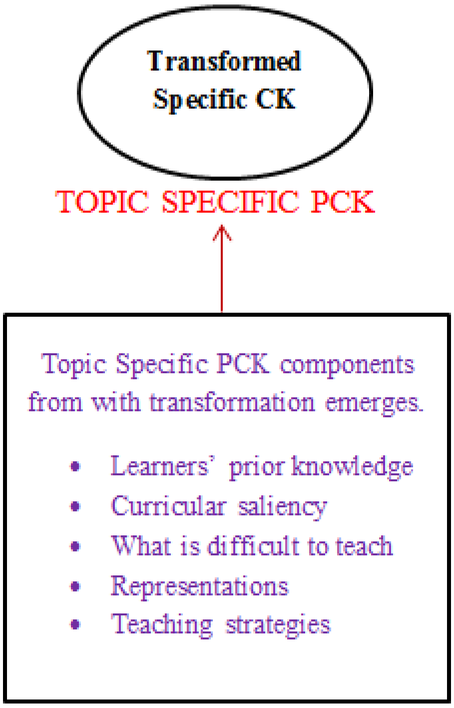


Figure 5.1: Components of knowledge transformation of TSPCK adapted from Mavhunga and Rollnick (2013)

5.2 Prior knowledge

As mentioned in chapter 4 prior knowledge refers to the knowledge and ideas which students have prior to the instruction of content. In teaching and learning prior knowledge is important as it helps the teacher to know how to go about teaching certain concepts. Learners' prior knowledge is imperative as it can either hinder or allow the development of conceptual understanding of the scientific content. More so, prior knowledge affects how learners receive new content; it affects how learners accept the information as well as how they become aware of this new information (Svinicki, 1994). The component of learners prior knowledge is very important for me as a teacher, as the views and ideas that learners come to class with are correct, incorrect or incoherent with the accepted scientific views (Geddis et al., 1993).

> *"What misconceptions do I know of with regard to stars?, are my misconceptions and prior knowledge the same as those with the students?"- Journal entry (18/07/16)*

As a teacher who has never taught this particular topic in science, my prior knowledge of learners conceptions about stars is influenced by the literature as well as the knowledge which emerged from my concept maps. My own prior knowledge was significant with regard to the fact which Lelliott and Rollnick (2010) mentioned that sometimes teachers hold the same ideas and misconceptions which are held by their students. Being aware of this, I capitalised on my own prior knowledge and the knowledge which I assumed that my participants have gained in their previous natural science courses in order to make myself familiar with the prior knowledge of stars. The prior knowledge enabled me to start thinking about the questions to ask to the students as I teach how to deal with the possible answers they will give as well as how I can go about teaching a different view than the one which students hold.

Prior knowledge played a huge role in helping me understand some of the thoughts of my students and how I can make my students say what they are thinking. Hence, I started going through the misconceptions from the heavenly errors by Comins (2001) trying to come with ways in which I can deal with them if they happen to come up as I am teaching. I also went through the misconceptions which I had that were revealed by the concept maps, trying to understand what influenced the conceptions which I had and what other ideas contradicted my thoughts to allow me to gain the correct scientific knowledge.

5.3 Curriculum Saliency

> *"I think the big decision in teaching is deciding on what to teach" – journal entry (20/07/2016)*

This journal entry lead me to the component of TSPCK which deals with the content knowledge. This component of TSPCK is important as it helps a teacher make decisions about what is suitable to teach as well as what to teach to students at a certain level. Curricular saliency is the ability of a teacher to know how and when to teach a certain topic and knowing his/her learners ability to assimilate new information (Geddis et al., 1993). Deciding on what to teach and on what is appropriate to teach is what curricula saliency addresses. As a teacher I am expected to know more than what the learners know, this is crucial for teachers because it enables the teacher to be able to deal with students' questions. This can be a big challenge when teachers are not fully informed about how the content related to everyday knowledge. This is the reason why teachers need to be aware of learners' prior knowledge even when deciding what to teach the learners.

My main source of information on what to teach was influenced by the CAPS curriculum natural science grade 9 as stated in chapter 3. This is where the topic of stars is taught, hence

I learnt the content covered in the CAPS and more which is not included in the CAPS. The reason for going beyond CAPS is that I was teaching pre-service teachers who will also going to be teaching learners, thus their content knowledge should not be limited to what the learners should know.

5.4 Representations

> *"Examples are good in teaching that I know. But each example used should be closely linked to the content which it wants to clarify. Not every example is a good example, and examples are not the reality of the situation."- Journal entry (20/07/16)*

Representations are useful in teaching as they help the learners to understand the content better. The content knowledge of stars is one of the many physical sciences topics which are made up of abstract concepts that can be only enhanced by models and concrete examples for it to be understood. When I thought about representations to be used in teaching about stars, 'examples' was the first word that came to mind. Examples are good as I have recorded in my journal; however the kind of examples to be used when teaching about stars was the most relevant question to think about. This component of TSPCK enabled me as a teacher to think about the main idea of each concept and the kind of example which will be appropriate in explaining that particular idea.

Therefore, different representations were used to communicate a certain concepts in my lesson. The three levels of representations were taken into consideration in this regards thus Figure 5.2 shows which representations were used in each level. Treagust et al. (2003) states that a teacher needs to "present new information in an appropriate level for the learner" (p. 1353). Thus, it is important to make use of different representations as some representations may work for one student and may not work for the other student. The macroscopic level representation refers to visual aids such as models, video and pictures; the sub-microscopic level representations are based on the particulate theory of matter (atoms, electrons, protons, element and nucleus) which cannot be observable with the naked eye (Treagust et al., 2003). The symbolic representations include equations, graphs and table (Treagust et al., 2003); all these representations are used to communicate the content effectively.

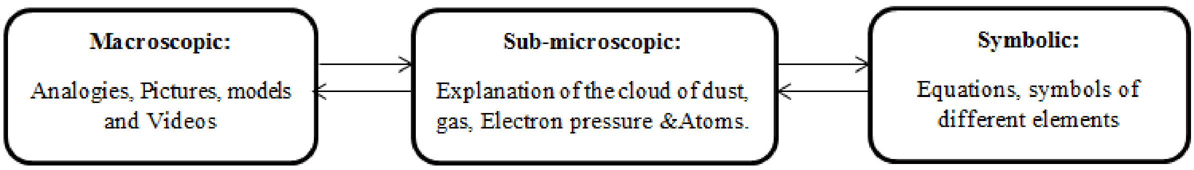


Figure 5.2: Forms of representations used in the lesson.

5.5 Conceptual teaching strategies

> *"How am I going to teach this content?, what is the main concept that I am to focus in when I teach. Maybe I will start my lesson with asking students questions about stars, but I am afraid they will give me answers which will not allow me to get into the content" – journal entry (01/08/2016)?*

Conceptual teaching strategy refers to ways in which the content can be taught. Conceptual teaching is about ensuring conceptual understanding, which and what ways of teaching a concept enforce conceptual understanding in the students. When thinking about ways to teach this content, it includes incorporating all the components of TSPCK to one another, bringing prior knowledge and curriculum saliency as well as representations together. It also included understanding the aims as well as skills that are enforced by the learning of this content; the sequencing of the lesson, when to ask questions as well as what questions to ask where; when to put up examples; all make up this component of TSPCK. The journal entry below shows how I was thinking of ideas that can be corrected and taught (Prior knowledge) and ideas that are to be learned which make up curriculum saliency. In addition, as Bishop and Denley (2007) mentioned that the sub-stages of transformation in Shulman's model of pedagogical reasoning are not discrete they are integrated in a sense that they affect one another. This is also the case with the components of TSPCK, they are not stand alones but they make up part of the whole that enables successful transformation of content knowledge.

> *"Which ideas can be taught and which ideas have to be learned?" – Journal entry (01/08/2016)*

The development of the CoRe which encompasses the components of TSPCK as seen in chapter 2; made it easy for me to breakdown the content. In addition, Mavhunga and Rollnick (2013) mention that the understanding of the component of conceptual teaching strategies can be best understood and seen in the development of the CoRe.

5.6 The CoRe

Going through all the components of TSPCK allowed me to create a Content Representation (CoRe), which is a generalized form of a teachers' PCK (Loughran et al., 2006). The CoRe is a tool that guided me and helped me in capturing and portraying the development of PCK. The CoRe as a teacher helped me in organizing my content knowledge as well as in understanding ways that I could be able to assimilate content knowledge so that students can comprehend it. Loughran et al. (2006) state that the CoRe can be created over time in order to amend it when one encounters new ideas. Hence, this alteration of the CoRe over time contributes to teachers' PCK. I started developing my CoRe before teaching, and during my teaching I would add what I thought was missing; and as I became aware of the many other students conceptions in my teaching I would add it to the CoRe.

In learning how to teach (learning how to transform knowledge); the transformation of knowledge is first planned and then enacted. The CoRe and lesson plan (appendix K) show the planning of transforming knowledge and the video recording show the plan in action. Table 5.1 shows the CoRe which I had created as I was preparing how to teach the content knowledge of stars. In addition, from the CoRe I was able to create a detailed lesson plan; which made the skills and attitudes of the lesson explicit (see appendix K). The lesson plan also helped me with sequencing and the flow of the lesson, especially on things such as what to do and when to do it (lesson steps).

Table 5.1 represents the CoRe about stars which I created to help me in planning my teaching. The big ideas which I formulated permitted me to narrow the content knowledge of stars which I taught in my lesson. The prompts of the CoRe served as guide to help me in sequencing the content in my lesson; they (prompts) also made me aware of the learners' prior knowledge and the learning difficulties that are associated with the teaching and learning of these big ideas. The prompts also deal with the important aspects of a lesson such as 'what I intent to teach to the students', 'why is it important for students to know this'; as well as teaching strategies which I employed in teaching these big ideas. Furthermore, the big ideas were central notions which my teaching aimed to get across for students to develop a deep understanding of the concept of stars.

Table 5.1: Content Representation (CoRe) about stars

Big idea / **Prompts**	**Nuclear fusion is necessary for star formation**	**Gravity is the most important force in astronomy**
1. What you expect learners to know already about this idea	Stars are heavy bodies which are part of the milky way galaxy. They shine and are mostly visible at night. Stars are far away from us, and they form different patterns which we observe at night.	Gravity is force which pulls everything toward the centre of the earth or towards each other. According to Newton's law of universal gravitation: a particle with mass attracts every other particle which also mass through a force that is directly proportional to the product of their masses and inversely proportional to the square distance between them. $$F = \frac{Gm_1m_2}{r^2}$$
2. What you intend students to learn about this idea	Stars are born or rather produced in a molecular cloud (nebula) which is filled with dust as gas. This gas is hydrogen, which when its atoms are compressed under the influence of gravity forms a star. During nuclear fusion (when the compression of hydrogen atoms occurs) a new heavier atom is formed and energy is released. $$4(^1H) \longrightarrow ^4He + 2e^+ + 2\,neutrinos + energy$$ This released energy is radiation, which makes the star to shine. This is the very unique characteristic of the star its ability to radiate their own light.	Gravity is an attractive force which is responsible for the formation of the star. It is because of gravity as per Newtown's definition that objects with mass and are a certain distance apart are attracted to each other. Gravity is constantly present and it pulls everything towards each other even in a star, in which it pulls it more and more towards itself.

	The life of a star depends on how big it is, meaning that the mass of a star tells us how the star will leave the rest of its life.	
3. Why is it important for students to know this?	It is important for students to know this because it will enable them to know about stars beyond mere identification in the sky. The conceptualisation of what happens within a star will reduce the factual knowledge of natural phenomena and enable deep conceptual understanding of star formation.	Gravity is not only present on earth as many students think, especially with reference to space. Many students think that there isn’t gravity in space (hence things are floating) and this comes from the idea that gravity only exist on the planet earth. However, gravity acts on all bodies stars, planets as well as people. A key concept of gravity is reference point, which is a hard concept to grasp (if students do not understand this they have a difficulty). Also understanding the concept of systems (sometimes gravity requires thinking in terms of systems).
4. What else do you know about this idea (which you do not intend your learners to know yet)?	Students are taught about the three states of matter; however there are 4 states of matter. Which are Solid, Liquid, Gas and Plasma. Therefore, Stars are formed in the plasma phase in which the temperature and pressure are very much higher and the collision rate is also higher. However the plasma state will not be taught as it deals with sub-microscopic particles such as the nucleus, photons, protons and the other sub-atomic particles, thus making the content to be more complex to comprehend.	Most of the recent physics conceptions are based on Einstein’s notion of gravity in terms of general relativity. General relativity describes gravity as a dent space in time and does not share the same views as Newtown.
5.Difficulties/limitations connected with teaching this idea	Generally astronomy is an abstract topic based on observations. The conceptualisation of the stars as process of nuclear reactions is complex. Distinguishing between an element and an atom in explaining how hydrogen forms helium is hard for learners to understand.	Most students believe than gravity only causes things to fall. Especially relating it to the ‘apple story’. Most textbooks usually describe gravity in that sense; while it provides scenarios in which gravity acts downwards and as consequence causing objects to fall to the ground.

<table>
<tr><td>6. Knowledge about learners' thinking which influence your teaching of this idea</td><td>Students know stars because they see them at night, however they fail to recognise that stars are unique in a sense that they are the only objects in the universe that are able to radiate their own light and actually give life to all things (especially our sun in the solar system).

Students are aware that there are billions of galaxies in the universe; however they are not aware that our own solar system contains only one star which is the sun. The other star outside of our solar system but are in the milky way galaxy.</td><td>Students are only familiar with gravity when doing calculations in kinematics and also when dealing with the concepts of energy. However, introducing the concept in a different angle will enable me to see if students understand gravity as it is meant to be. As an attractive force. A force that attracts things to themselves. A force that pulls things towards one another.</td></tr>
<tr><td>7.Teaching procedures (and particular reasons for using these to engage the idea)</td><td>Draw on learners prior knowledge:

I Put up a picture of the night sky, so to see if learners recognise any patterns or know of any stars in the night sky. After that I put up concepts which are all related to stars and astronomy, the reason for putting up the words is for students to note which words they know, don't know and recognise, then each of them share their explanations of words that they know. When students give explanations, their explanations enable me to understand where they are content wise. When I start teaching I put emphasises on their prior conceptions with content that goes along with the relevant representation.</td><td>Developing understanding:

Gravity, what is gravity and kind of force is it? $F = -\frac{Gmm}{r^2}$

Writing the equation which learners know in a different way than their normal way; will enable them to start thinking about the kind of force gravity is. Students will have a difficulty making sense of this and hence, I put emphasise on what the equation illustrates. Such as the importance of mass and the distance between two objects with mass. Discussing this equation in detail can help the students with understanding the role and the importance of gravity better. Teaching this concept starting with the representation is relevant in this case, as the students are familiar with the equation.</td></tr>
<tr><td>8. Specific ways of ascertaining learners' understanding or confusion around the idea</td><td colspan="2">Encouraging understanding:

Encourage learner questioning, ask students to elaborate on the answers which they give after I have asked a question.</td></tr>
</table>

	Show a picture of dust and gas. Explain content on the board for learners to understand better, by drawing an ideal cloud of dust and gas with dense particles (globules) and less dense particles. **Student engagement:** I will ask for students' contributions, especially since I will have taught some of the concepts. Students' contributions of how those concepts may influence other concepts which I will then teach. **Enhancing understanding:** These representations will be used to enhance understanding: • Videos • Pictures • Analogies • Balloons
9. Preferred assessment strategies or tasks to facilitate learning	A practical could be given to students because macroscopic representations enhance their understanding of the concepts which I am teaching about.

5.7 Video analysis

This section discusses the features of TSPCK which emanated from my teaching and how these features enhanced the teaching of stars for conceptual understanding. As discussed in chapter 3, I used the action research spiral (Figure 4.3) in going through the steps that allowed me to reflect on my learning and teaching. There are two videos of the lesson on "stars" which are scrutinized in this section. The first video is of the first time I taught the topic of stars and the second one is on how I attempted to improve my first lesson after I had reflected on it together with my supervisor and my critical friends; so that I could transform my content knowledge into ways that students were be able to understand effectively. The videos demonstrate moments that I termed critical incidents, which display TSPCK in action. Critical incidents are instances that capture more than one component of knowledge transformation from the TSPCK model by Mavhunga and Rollnick (2013).

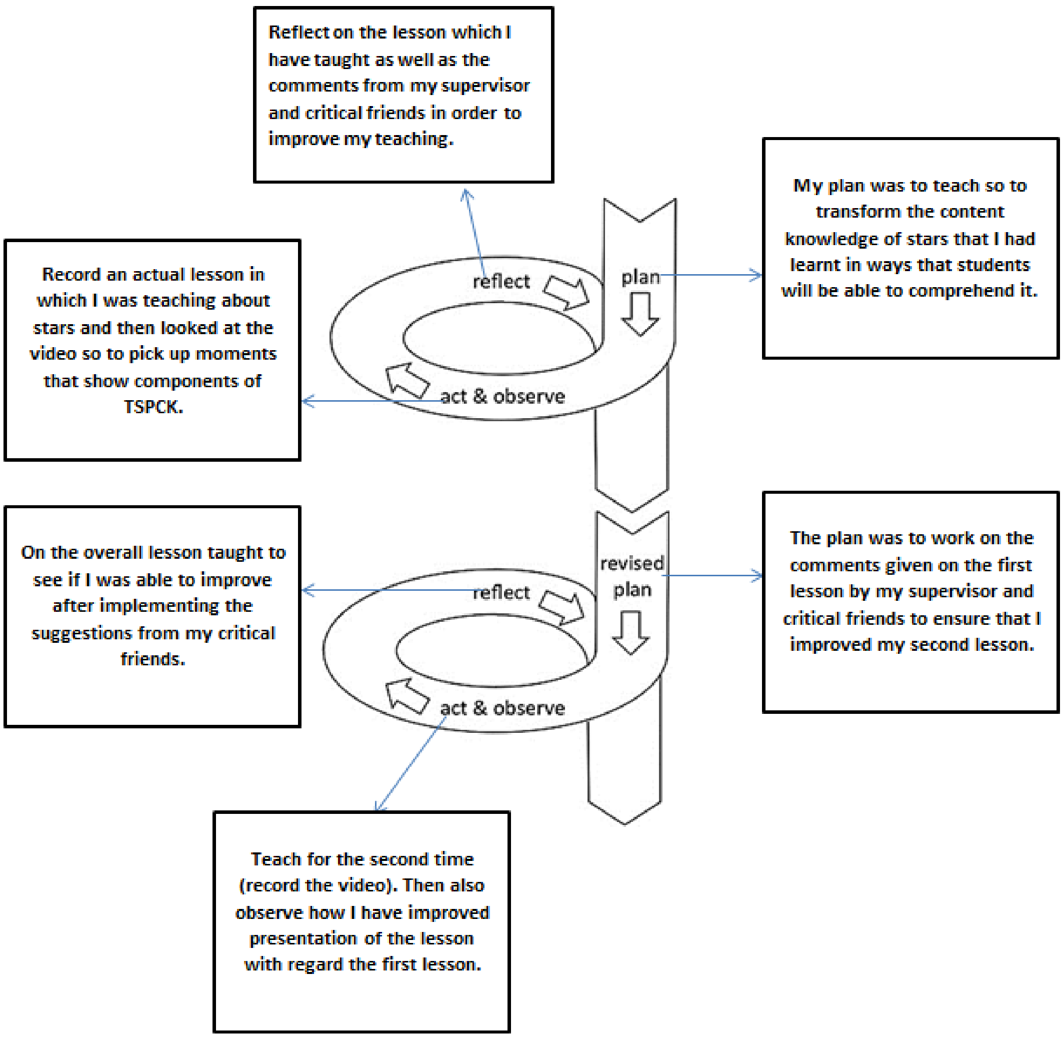


Figure 5.3: Teaching action research spiral, adapted from Kemmis and McTaggart (2000)

The critical incidents show how the components of TSPCK interact with one another in my lessons (first time teaching and second time teaching). The TSPCK Maps suggested by Park and Chen (2012) were used to show the interactions between the components. Mavhunga (2015) asserts that a TSPCK Map represents an episode (critical incident) of TSPCK in the lesson. The following acronyms were used to identify which component are visible in a critical incident; learners' prior knowledge (LP), curricular saliency (CS), what is easy or difficult to teach (WD), representations (RP) and conceptual teaching strategies (CTS) (Mavhunga, 2015). Figure 5.4 shows an example of a TSPCK Map with components of TSPCK that are interacting with one another as shown by the links. The arrows between the components illustrate the direction in which the sequence of the critical incidents appears; and the platform which is at the base of the components indicates a conceptual task which I was doing as a teacher in which the components of TSPCK transpired (Mavhunga, 2015).

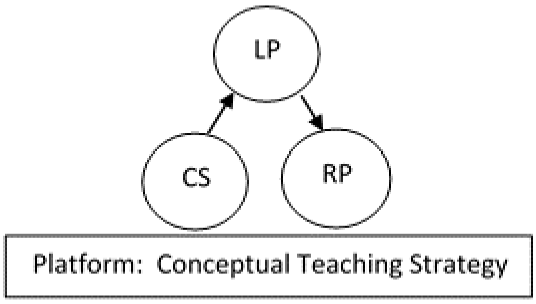


Figure 5.4: Example of a TSPCK Map (Mavhunga, 2015)

5.8 Video 1

> *I am going to teach about stars on Tuesday, after my session with Dr SH I feel more confident. I have seen how my supervisor goes about when teaching astronomy. The way he introduced his first astronomy lesson made the students to be comfortable in taking part in the lesson. Therefore, I think it was important for me to have thought of ways to ensure that I also have such an interactive lesson. But I am feeling a little scared not because I am not prepared but because I don't know if students will be able to flow with me during the lesson. I hope they aren't going to be passive students; I need to ensure that they learn and also trigger some form of interest in the field of astronomy. - Journal entry (15/08/2016)*

This video is of the first time I taught the lesson on stars. The video was critiqued by me; my supervisor and critical friends. Initially, I had given each of my critical friends including my supervisor an angle in which I wanted them to critique from. For example my supervisor was to look at Content knowledge and Curricula Saliency; my first critical friend on learners' prior knowledge and the use of analogies and my second critical friend on the general TSPCK. However, my supervisor and critical friends did not only critique the video on the one aspect of TSPCK assigned to them. This worked in my favour in a sense that it enabled me to see if we (critical friends and I) come up with similar or common instances of the lesson which capture TSPCK. Although my critical friends were not very explicit in terms of which TSPCK component is visible; the picking up the same instances in the lesson (from critical friends and I) permitted me to choose the most interesting critical incidents to evaluate.

Critical incident 1

This critical incident is right at the beginning of the lesson, in which I attempted to grasp the attention of the students as I introduced the lesson. Figure 5.5 is an image of the night sky taken from Stellarium (which is planetarium software). This image showed what we would see in the night sky if we were at the same venue in which the lesson took place. The reason for this picture was to see if students recognise any patterns such as the brightest star, the Southern Cross, Orion's belt or the Hadar pointers. Students who are able to identify these patterns show that they are aware that stars appear in the same order even though the earth orbits the sun; the patterns in the sky stay the same.

Figure 5.5: Stellarium image of the night sky

This critical incident has two components of TSPCK namely; Representation (RP) and learner prior knowledge (LP). The figure 5.5 and figure 5.6 are representations which I used in order to introduce the lesson. The purpose of these figures was to give the students visual and more 'real' experience of the night sky without any light pollution like in our normal night sky. Figure 5.6 with the astronomy concepts served as a way to get student to think about words that are familiar to them and what they mean. Getting students' to think about these words served as a way to not only capture students' attention but also to get them into thinking about stars. Figure 5.6 is the image which aimed at triggering the prior knowledge of the students as seen from the conversations which follow.

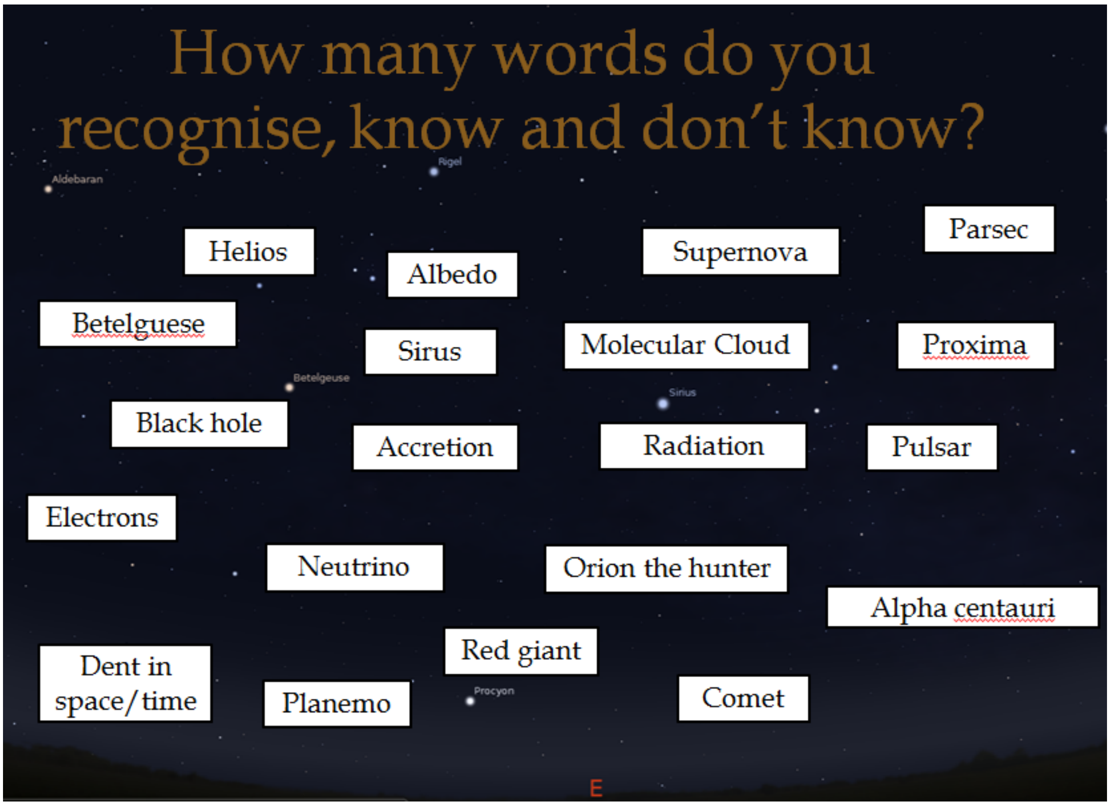


Figure 5.6: Stellarium image of the night sky with astronomy concepts

Researcher: *So I gave you a paper when you were walking in and on that paper I want you to write all the things that you know, all the words that you recognise maybe you might not know what it but you think you have seen it somewhere and all the words that you don't know. So I'll just give you about 5 minutes to do that quickly.*

Researcher: *Okay, so who recognises 20/20 of the words? (No hands)… Okay, no one? 15/20? (Still no hands) 10/20? (No hands) 5/20? (Few students raise their hands)*

Students: *More than 5 less than 10*

There are representations used in this critical incident mainly the picture of the night sky which illustrates our own night sky. The picture with the astronomy concepts also illustrates a representation, and this specific representation was used to make students' to think about concepts which are familiar and what they mean (learners prior knowledge). Thus figure 5.7, which display how the two components interact with each other.

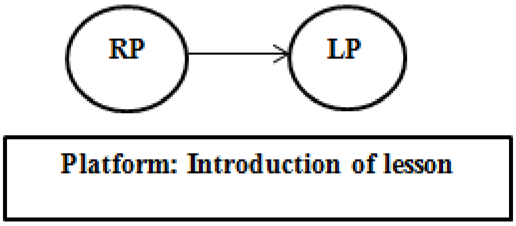


Figure 5.7: TSPCK Map of the interactions in critical incident 1

Figure 5.7, shows a TSPCK map of the critical incident. The map shows how the components interacted with each other. As seen from the TSPCK Map and the conversations between me and the researcher; the representations (RP) were the driving force in introducing the lesson and also most importantly in eliciting learners' prior knowledge (LP). However, this exercise lacked purpose in sense that I did not think about what the learners know about these words influences my teaching about the content of stars. More so, even at the end of the lesson I did not even go back to the words and give students the meaning of the words. My critical friends also mentioned that the word search might have made students to be uncomfortable, as most of them only knew about 5 words out of 20 in the word search. This has an influence in how they interact with me as the lesson continues.

Critical incident 2

In this critical incident I started the actual teaching of the content of stars. I started the lesson with saying a phrase which students' know of; 'twinkle twinkle little star' and I based my teaching on how I wonder what you are. The content here is very abstract and hence the use of drawings, pictures and videos.

> **Researcher:** *Twinkle twinkle little star, how I wonder what you are… so we sing that song because we see little things. When we look in the sky there we say twinkle twinkle little star because we really see little things. How I wonder what you are, okay so that's why we are here today…*

> **Researcher:** *Star formation, how does a star form? So stars form from a cloud of dust and gas okay, and then this dust and gas comes from cloud which is in somewhere in space which is called a nebula, so that dust and gas comes from there (showing image of a nebula cloud). Each cloud of dust and gas is made up of dense globules and less dense globules of space particles. So for example if you look over here (referring to a drawn image) if we have this cloud which is called a nebula right there in space. And*

that cloud is filled with things inside, so it's filled with all these little things here (pointing at the diagram) which are very heavy and very dense. And we also have that space there, which is not very dense, so it's less dense and less massive unlike all these heavy globules. The density of the heavy regions is about 10 to the power of 32.

Researcher: *So let's take a look at this video by Stephen Hawking that explains the star forming through an analogy of the miniature star in a stadium.*

Learner prior knowledge (LP) in this instance refers to where I based my teaching on 'how I wonder what you are'. This serves as learner prior knowledge because students are aware of stars and they do say that they twinkle; which is a misconception mentioned by Comin (2001). Curricular saliency (CS) involves the teaching of the concepts which students need to know so to understand the formation of a star. There are representations (RP) used as mentioned, such as pictures, a drawing and a video is also played, and the representations were used as the formation of stars involves a lot of abstract concepts which are difficult to teach (WD). Figure 5.8 illustrates how the components interacted.

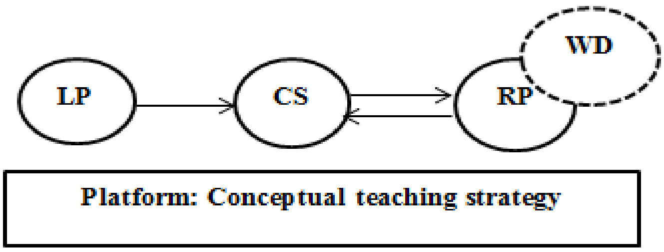


Figure 5.8: TSPCK Map of the interactions in critical incident 2

The interactions in this critical incident show four components of TSPCK. The TSPCK Map depicts how the components unfolded in this critical incident moment. The incident started off with a classic childhood song or rather a nursery rhyme "twinkle twinkle little star"; which is about stars. This song serves as learners' prior knowledge (LP) because it has an influence in what we know and think about stars. The learners' prior knowledge enabled me to introduce the content of stars (start teaching); the content knowledge was presented hand in hand with the representations, hence the double arrows. The representations that were used all included the three levels of representations. I had images (pictures) which were at a macroscopic level; the purpose of these images was for students to get tangible visual examples of the content as it is too abstract. The use of the analogy in the video about 'creating a miniature star in a stadium' was used to emphasise on the issue of mass, pressure and temperature of a star when it is born. An equation was given that illustrates what is happening at a symbolic level; this equation was used to explain how the combination of hydrogen atoms produces helium atoms. It is through this equation that we come to understand where the radiation of light from the star comes from. The use of macroscopic and symbolic shown to be effective, in a sense that it enabled me as a teacher to have a logic sequence that corresponds to the content. The microscopic level representation was done briefly at the beginning of the lesson. There was a drawing on the board that explained what a cloud of dust and gas may look like. However, this representation included elements of 'what is difficult to teach' component. This was also picked up by my critical friends in which they stated that the idea of nuclear fusion is at molecular level making it very abstract; therefore it was not easy to visualise a cloud of dust and gas with 'masses and densities of power of 10'. The explanation needed another clearer image, as suggested by my critical friends.

The platform in which this critical incident occurred was a teaching strategy, in which I was teaching the content knowledge (CS) in conjunction with the representations (RP) in order other to support the idea of meaning making and conceptual understanding of stars. The component of 'what is difficult to teach' (WD) is in dotted lines in the TSPCK map, as what was difficult to teach was included in the representations but it was not explicit in the lesson, but it was assumed due to the learning difficulties attached with abstract concepts in science. Personally I really liked how I merged representations with the content; this helped me in terms of backing up content, especially the video which explained the concepts which I mentioned in my teaching. Below are some of comments from my critical friends about this critical incident:

> *"Twinkle twinkle little star was a brilliant idea to introduce the topic. I feel that it was supposed to be your introduction so as to create a friendly learning environment. However, the organisation Position of the song might be argued to be ok. As it will calm down the tense atmosphere created by mostly unknown words as only 5 out of 20 recognise particular names."*
>
> *"'How I wonder what you are' was a good idea to introduce the content of stars. However, there are things you mentioned that are not very clear (because they are quiet abstract) such as Globules: what are these?; and the issue of Powers of 10 which you mentioned."*
>
> *"You operated on the macroscopic and very limited microscopic level and this part of TSPCK was not fully portrayed in the lesson."- Critical friend*

Critical incident 3

In this critical incident I was teaching about the idea of a supernova using multiple representations. Students often have a difficulty in understanding the idea of a supernova, especially in terms of what it is and how it comes about.

> ***Researcher****: In a large star there is a very strong gravity almost everywhere in the star. So I will be giving you these balloons. If you look at this and take it as your large star; it is very big and the gravity acts almost everywhere in the star. So the whole star collapses under gravity. So remember this, when a star forms it's all hydrogen which fuses and become helium and when it runs out of hydrogen, the helium that now fuses and forms another heavy element; for example forming carbon, after carbon we have another heavy element. So the star fuses and fuses and fuses; when it gets to iron the fusion stops. If you think about it the core of a star is now very heavy and therefore, the whole star collapses due to gravity.*
>
> ***Researcher:*** *So in a large star nuclear fusion is so fast that we get to iron. During the collapse, the star bounces in an explosion called a supernova. So if we each squeeze our balloons we are acting as gravity and push the balloon towards itself and our star (balloon) explodes.*
>
> ***Students:*** *(start pushing their balloons; until one finally bursts)*
>
> ***Researcher:*** *Okay, we have had a supernova*
>
> ***Student:*** *So is it possible that we can hear the sound?*
>
> ***Researcher:*** *No we can't hear the sound; but we can see a supernova. Well if you are lucky. I have a picture here and this is a picture of a supernova. So this is after the explosion of the star, and this specific supernova happened around I think 1058 by some Japanese or Chinese. All they saw was a very bright thing in the sky for about a month and that's when they discovered it was supernova. And when a supernova occurs it produces other elements and a supernova explosion releases more than 100 times the energy released by the sun over its whole lifetime. So that is a lot of energy released and maybe that is why we can we able to see it in the night sky, if it is going to happen while we are still alive. Let's take a look at this video*

In this extract I was teaching the concept of a supernova (CS) and I used multiple representations to enhance the understanding of this idea. The representations included a model/ analogy of a balloon, video and a picture of a supernova. Figure 5.9 demonstrates the interactions of these two components.

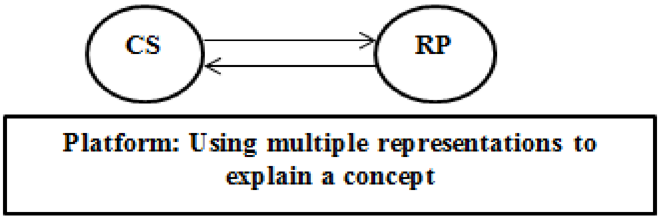


Figure 5.9: TSPCK Map of the interactions in critical incident 3

This critical incident is seen from the TSPCK map in figure 5.9. The figure 5.9 shows that there are two visible components which are depicted by the interactions in the critical incident. I was teaching about the concepts regarding the death of a massive star resulting in a supernova. I took this opportunity to explain the concept of a 'supernova'. In the beginning if my study, I could not explain or even understand the concept of supernova as seen in chapter 4, figure 4.4. It is also stated in Comins (2011) that there are a lot of misconceptions attached the idea of supernova which are mentioned in chapter 2. This is the reason I chose use multiple representations when explaining the concept of supernova, in order to ensure that misconceptions do not linger any further. Dreher et al. (2016) argues that each representation explains a certain feature of the concept which one is teaching about. Thus multiple representations complement each other, in order to help with the development and understanding of the concept. The representations used to explain the content were all at a macroscopic level. For example the picture showed what a supernova looked like in the night sky. The video which was used explained the role that a supernova plays in the creation of other elements, bringing the idea that even the human body is made up of star-dust. Another concrete example which I used was the balloons, which was a way for us to visualise how a supernova occurs. However, there was a misconception which was generated by the balloon explanation; this idea was that gravity is a pushing force instead of a pulling force. I did not recognise that there might be a misconception which might arise but it was pointed out by my critical friends. This part of the lesson made it clear that some ideas are not necessarily realised during the planning, meaning that I did not see the balloon analogy bringing in another misconception; while in the pursuit of dealing with common mistakes and ideas that are not coherent with the actual content knowledge. Hence this critical incident is made up of constant interactions between the content knowledge (CS) and representations (RP) with the platform being 'using multiple representations to explain a concept'. Additionally Plummer and Slagle (2009) assert that when verbal descriptions are joined with kinaesthetic as well as visual representations in explaining concepts, the impact of learning may be enhanced more than using a single mode of representation.

Critical incident 4

This incident demonstrates the teaching of the concept of gravity at the beginning of the lesson and at the end of the lesson. In the beginning of the lesson the concept of gravity is clarified in terms of Newton's laws and at the end of the lesson a different view of gravity is introduced. This incident aimed at displaying how new ideas can be introduced.

> ***Researcher:*** *so these dense globules and particles collapse due to gravity so that's what actually happens to an object with a lot of mass… it collapses due to gravity. And we all know that gravity is (pointing to the equation) by Newton's definition gravity is F=-GM1M2/r^2. So I have a question for you now… so you all know Newton's law… newton's universal law of gravitation and we have all seen that equation but you have seen that equation without a minus sign. Why do you think there is a minus sign there?*
>
> ***Researcher:*** *Okay I will go back to before I introduced the equation. So the dense globules collapse due to gravity, so what this means is that gravity as we all know gravity is a force of attraction. It is an attractive force. So remember that when you are using this equation most of the time you are trying to determine whether the force existing is repulsion or attraction. and if its attraction we have a negative sign 'newton' at the end of the equation like your answer will be minus whatever newton most of the time.*
>
> ***Student:*** *Tshia, but minus (laughing) a symbol of attraction. Wouldn't positive sign be attraction and negative sign repulsion?*
>
> ***Researcher:*** *okay, I am going to use an example that you guys are familiar with. So if you are working with charges and you have an electron of mass -1.666 and a proton of +1.666 (drawing on the board). So you know that a proton and an electron are going to attract. So when we multiply the masses of the proton and electron over r^2 and our answer is….*
>
> ***Students:*** *negative (ohhh)*
>
> ***Later on in the lesson***
>
> ***Researcher:*** *So all this time, I have been using gravity according to Newton, every time I've been speaking about gravity right now, we have been speaking about attraction, attractive force or the force of attraction and that is according to Newton. We all know that right?*
> ***Students:*** *yes*
>
> ***Researcher:*** *but Einstein has a different definition if gravity, do you guys know it? Please share with us?*
>
> ***Student:*** *I forgot it*

__Researcher__: anyone else who would like to try? Someone mentioned something which is aligned to this right at the beginning would like to repeat?

***Student:** I also forgot what I said, but I think Einstein definition of gravity, he spoke of space time but I'm not sure how it relates to the other concepts. But he said everything in the universe exist in the fabric of space time, so there more dense the material is the more it will bend the space time fabric.*

***Researcher:** thank you, so what he said is the definition of gravity by Einstein. According to him gravity is not a force but it something which occurs in space time. And any body with mass can bend the space. As we can see there (pointing to a picture) the sun has a mass and that's how it can bend space, So Einstein says space is a fabric in which if you were to put something it would bend the fabric and the fabric would take the shape of that.*

Since I was drawing the fact that the students' should know Newtown's law of gravitational attraction, this served as their prior knowledge (LP), also using an example of calculating the force charges (which students have done before in their course work) served as prior knowledge. The equation used when asking learners the question about the type of force gravity is, as well as the picture showing the definition of gravity according to Einstein; all served as representations. The content (CS) included explaining the type of force gravity is, as well as explaining gravity in terms of Einstein, illustrated the CS that included the component of what is difficult to teach (WD).

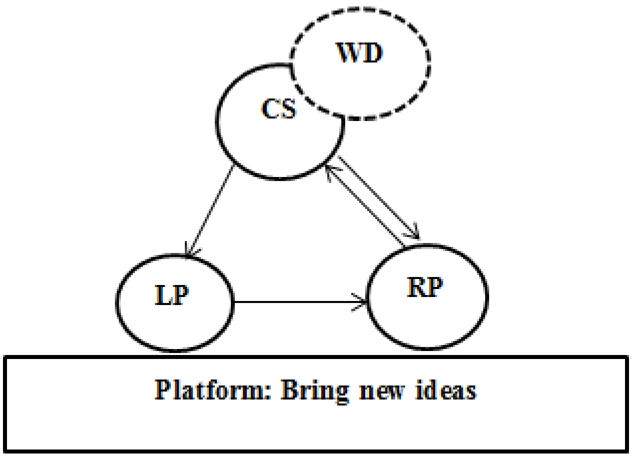


Figure 5.10: TSPCK Map of the interactions in critical incident 4

The TSPCK Map in figure 5.10 shows that there are three visible components of TSPCK and one implied component. The platform in this critical incident was to bring in new ideas that introduce the students to a new view about gravity. The content knowledge (CS) is the one guiding the teaching of the idea of gravity. I showed the learners an equation of gravitational attraction, which is a representation of the content symbolically (RP); hence the double arrows. The introduction of the equation captured learners' attention, because they have seen the equation, although now there was a minor difference between the equation that they know and the equation which I introduced. This dealt with the area of learners' prior knowledge (LP), seen from some of the responses which they gave; they would expect 'attraction to be shown with an 'addition symbol +' and repulsion with a 'subtraction symbol – '. However this is not the case in science, hence I gave an example about charges as per Coulomb's law (which is not entirely different from Newton's law of gravitational attraction; the constant is the difference in both equations and laws). The students know about this law, thus this example was a useful form of representation which works with leaners' prior knowledge, so to allow conceptual understanding. Later in the lesson I went back to the issue of gravity, in which I attempted to introduce a different view of gravity by Einstein. This idea was embedded in the CS and it falls under what is difficult to teach (WD); however it was not explicit even when I was teaching. Hence I added onto the difficulties of learning about this concept by not having enough representations as well as not showing the differences between the two views which I was referring to.

This critical incident permitted me to be more aware of the fact that just because students are expected to have done some of the content, they understand it. Some of the concepts I had to teach even though I had expected it to be their prior knowledge. My critical friends also commented on this incident by saying that abstract explanations without context are difficult for the students to make sense of. Therefore, more representations are required to allow an effective transformation of knowledge especially with new concepts. Furthermore, Treagust et al. (2003) argues that when teachers use relevant explanatory artefacts in order build on the knowledge that the learners understand and also "provide students with the information that they need to know" (p. 1353), they enable students' to comprehend the content knowledge.

This section has examined the critical incidents which emanated from the first time I taught the lesson on stars. These critical incidents demonstrated how the components of TSPCK interact with one another. This video served as a base which I can uses to look at what needs to be improved in that lesson, hence I taught it again (see video 2).

5.9 Video 2

This video attempted to improve my teaching as well as to implement the suggestions which my critical friends made from the first lesson. The critical incidents chosen here are based on what I did in lesson 1 and how I have implemented and improved the critical incidents to show a substantive development of knowledge transformation.

Critical incident 5

This critical incident is the same as critical incident 1 in which I was introducing the lesson. In this critical incident I have observed what I have improved on with reference to the first lesson. Thus, observing the components of TSPCK which emerged since the amendment of the lesson.

> ***Researcher:*** *okay there are 20 words here. How many of you know 20/20 of these words? (Anticipating a show of hands)*
>
> ***Researcher:*** *15/20, 10/20… okay 5/20 (then a few hands are raised)*
>
> ***Researcher:*** *okay, so that's good. Those who raised their hands can you please just explain one of the words which you are confidently sure that you know.*
>
> ***Student:*** *Sirius is one of the further-est stars.*
>
> ***Researcher:*** *Further-est?*
>
> ***Student:*** *Further-est that we know of.*
>
> ***Researcher:*** *okay, is it a further-est star or further-est planet?*
>
> ***Student:*** *Planet, yes planet sorry.*

The same representations were used in this critical incident; however the content knowledge (CS) was the driving force of these representations, such that the astronomy concepts in the word search are incorporated in the teaching of the content. The learners prior knowledge in this incident refers to the answers which the students gave (LP), these answers informed on how to go about when teaching certain concepts which the students do not fully understand (CS). Figure 5.11 demonstrates how these components interact.

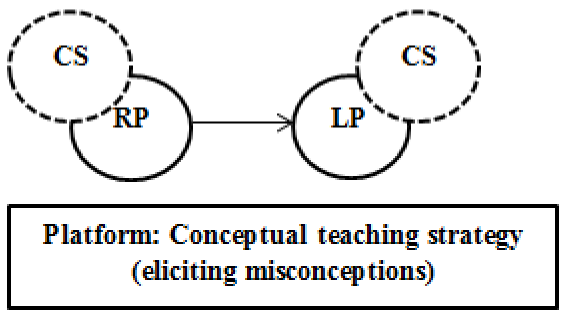


Figure 5.11: TSPCK Map of the interactions in critical incident 5

With reference to the first lesson, especially critical incident 1; I aimed at improving the TSPCK moment and having a clear purpose. Looking at figure 5.11 the platform has changed from just mere introduction, bit it was a conceptual teaching strategy in which I was eliciting misconceptions. The visible components present are still the same as in critical incident 1; however the Representations (RP) and Learners Prior Knowledge (LP) have a dotted Curricular Saliency (CS). This is because although I am not teaching about any content yet, the CS is the driving force behind the choice of representations used; and the misconceptions (LP) looks at how much CS do students have. Knowing what students know may affect my teaching as Svinivki (1993) argued that learner prior knowledge affects how learners become aware of new information. In this critical incident as seen from the conversation I am probing for learners understanding, in so doing certain misconceptions arise. As a teacher when I got the incorrect response I tried probing the student further as I am trying to understand why she was giving the answer that she gave. I used her explanation while bringing another concept to see if she herself understands what she was saying. Instead she then changed her answer to what I was saying. Therefore, it is evident that students are not always confident with the knowledge that they have. At this stage I should have went back the image of the night sky to show Sirius, in the pursuit of enabling the student to think of her answer. I then incorporated all the words in the word search in my teaching, so to show that they have a meaning in astronomy and that they relate to stars. At the end of the lesson I also give the definitions of the concepts from the word search in case the students want to know their meaning outside the context in which I was teaching from. The interactions continued as follows:

> ***Researcher:*** *yes another one…*
>
> ***Student:*** *Red giant is a planet, but it is a planet that has run out of energy, I think… and it is in a transition period to be a blue giant.*
>
> ***Researcher:*** *Red giant? Okay…*

At this point I was surprise by the students' definition of a red giant that I did not even see coming. Hence Bailey et al. (2009) states that students' come to the classroom with tenacious, deep-seated conceptions and fundamental reasoning processes that can serve to either help or hinder the incorporation of new concepts. Such conceptions had an impact in how I went about teaching the content of stars.

Critical incident 6

In this critical incident I wanted to correct a misconception which I might have taught in the first lesson. The misconception is about the influence of gravity on a supernova, or rather how gravity yields to a supernova.

> ***Researcher:*** *During the collapse the large star bounces in an explosion called supernova. So let's think about this, nuclear fusion is happening at a fast rate and the core of the star becomes very heavy and our star is also very large. And when the star is very large, gravity takes over. So if our balloon was a star, it is very large. So a large star bounces and a supernova occurs, so we going to have our own supernova, if gravity wins it mean gravity is pulling the star towards itself; so act as gravity and pull the balloon towards each other… Although you are acting as gravity and pushing the balloon, note that gravity is not a pushing force but rather a pulling force.*
>
> ***Researcher:*** *The picture here represents a supernova which happened many years ago, around 1058 if I'm not mistaken. The supernova releases more than 100 times the energy released by the sun over its whole lifetime. It also gives rise to the many other elements (Atoms) such as Gold, platinum which are a result of the fusion of the iron after the supernova. They are from a blinding flash of light (supernova explosion). Let's look at this video.*
>
> ***Student:*** *isn't it that elements cannot be created nor destroyed? And that Atoms of one element are different form the other elements?*
>
> ***Researcher****: Due to nuclear fusion which is the coming together of the nucleus of an atom; a new atom is being formed because the two have joined; but each nucleus does no longer have the same nucleus it was before it joined with the other one. And this is how the other atoms (elements) are created.*
>
> ***Researcher****: if we were to have a supernova in our galaxy, we would probably all die. However, someone I know has seen a supernova in the 1980's in the clouds of magallion (showing picture of the clouds). They did not necessarily see it happen, but they saw something very very bright in the night sky for a couple of weeks/ days.*

The teaching of the concept of a supernova serves as the curricula saliency in the lesson (CS), this concept is taught hand in hand with the representations (RP), namely the pictures, video and a model/ analogy. This model/analogy (RP) was used to correct the idea that gravity is a pulling force rather than a pushing force, as we pushed the balloon illustrating a supernova explosion. Figure 2.12 illustrates how the components are interacting.

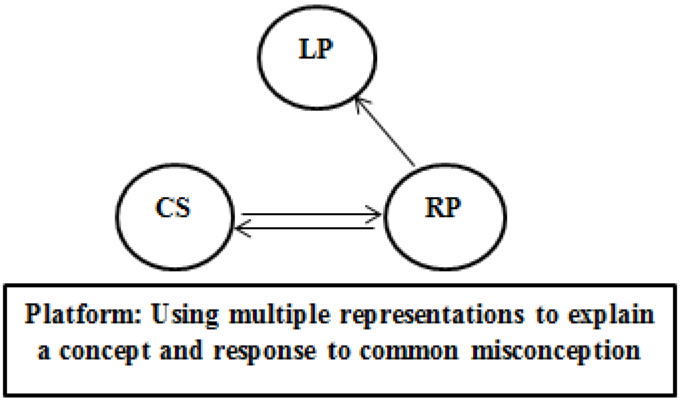


Figure 5.12: TSPCK Map of the interactions in critical incident 6

With regard to the third critical incident in video 1; in my second lesson I attempted to improve that lesson as well as my teaching of the idea of supernova. Although I used the same representations from the previous lesson, my presentation of the content versus the representations was done thoroughly in a sense that the platform was amended from ‘using multiple representations to explain a concept’ to ‘using multiple representations to explain a concept and also responding to a common misconception’. Looking at the TSPCK Map (Figure 5.12), the Content knowledge (CS) and representation (RP) are still there and interacting in the same way. However the representations (RP) are used to address the learners’ prior knowledge and misconceptions (LP); not just to avoid them and move on but deal with through the representations. The misconceptions addressed here include: gravity being viewed as a pushing force; gravity on earth and in space works differently as well as the theory of an atom (which the student here, confused with an element). As seen from the interactions, I emphasised that gravity is a pulling force even when using the analogy of the balloon. The idea of a supernova producing other elements made the students to also think about what they know about elements, this confusion was addressed by me and the video on the supernova backed up what I was saying. Therefore, the representations helped me in my attempt to address learners’ prior knowledge (LP).

Critical incident 7

In this incident I attempted to improve on how I went about teaching the concept of gravity from critical incident 4.

> ***Researcher:*** *I have an equation there (pointing to the board)* $F = -\frac{Gmm}{r^2}$*, are you all familiar with this equation?*

Students: *Yes*

Researcher: *there is something different about this equation, so I want to ask you why is there a negative sign here?*

Student: *I think it the matter of gravity, it is different from the one we have on earth and we have gravity on space. And the manner in which it acts to objects.*

Student: *I agree with what he is saying, here on earth we have a particular gravity, a certain figure for gravity, the moon has its own gravity and probably in space it is different in different zones. For example in a black hole the gravity won't be the same as here, I think it's high because it sucks in everything. So the equation will be different depending on where you are.*

Researcher: *what if I was to say that even if we are here on the planet earth that equation would still apply? So it goes back to what do you define as gravity? Gravity is a pulling force, so gravity is a force that pulls us toward the centre of the earth, it pulls everything towards something. So even if its gravity on the moon it's pulling the moon towards something, and us on earth we have the gravity that is pulling us towards the centre of the earth. We have a negative there because gravity is a force of attraction.*

Later on in the lesson

Researcher: *I have been talking about gravity and the whole time, I am referring to it in Newtonian version. me meaning that in the way Newton described gravity. Does anyone know about what Einstein said about gravity? In a nutshell (showing picture) this shows Einstein view of gravity. he said that gravity is a dent in space and time, so meaning that gravity is not necessarily a force pulling things towards each other, but gravity is like a fabric in which everything with mass even you bend it, are sort of like making a dent on it. To think about gravity in this sense, we can look at a trampoline for instance, which bends when something with mass falls on it.*

Researcher: *let us now look at Newtown Vs Einstein so that we can see how they are different.*

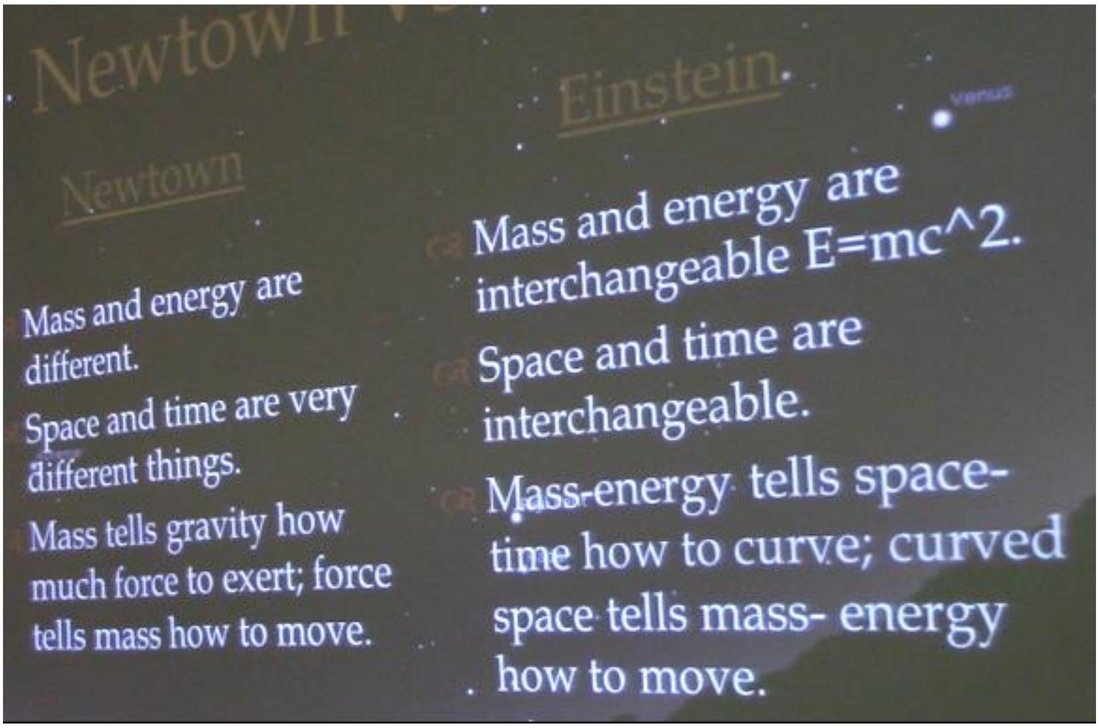


Figure 5.13: Slide from the lesson showing the difference between Newtown and Einstein views of gravity

Learner prior knowledge (LP) in this incident refers to the answers which the students gave. The representations (RP) were the equation, the picture shown as well as the tabulation between Newtown and Einstein views. The teaching of the content and also introducing the new ideas serve as circular saliency (CS) and what is difficult to teach (WD). Figure 5.14 shows the interactions that transpired.

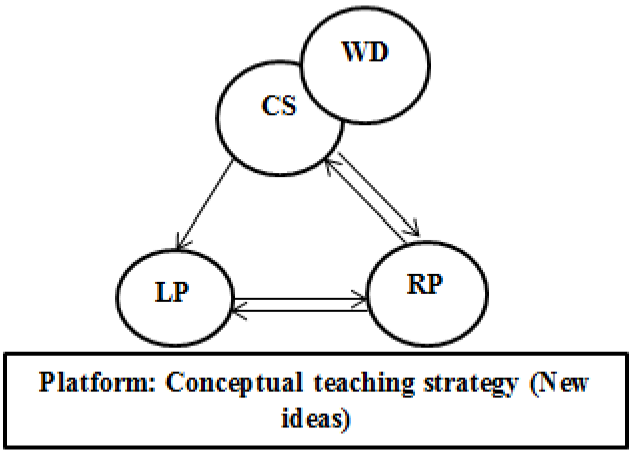


Figure 5.14: TSPCK Map of the interactions in critical incident 7

This critical incident gave evidence of four components of TSPCK in the lesson. These components are learners' prior knowledge (LP), curricula saliency (CS), what is difficult to teach (WD) and representations (RP). The two arrows between representations (RP) and curricula saliency (CS); show that the content of stars is too complex and abstract to be taught without concrete examples which students can be able to follow. Taylor et al. (2003) states that models drawn or created are useful in astronomy to promote a deep understanding of concepts. Teaching about a cloud of dust and gas and globules that are attracting each other, does not mean anything if students do not get an idea that is well aligned with the content to demonstrate which and what parts of that cloud attracted to one another due to gravity.

The arrow between curriculum saliency and learners' prior knowledge shows that some of the aspects of the content students know of and are able to identify them. The two arrows between learners' prior knowledge and representations show how students' prior knowledge is depended on the representations that they use to explain concepts. This is seen in the conversation about the equation of force and students definition of gravity. The representation helped in eliciting more misconceptions that students have with the idea of gravity and they type of force it is. As a teacher I was able to probe them and also explain the idea of gravity so that they can understand the type of force it is. In addition the idea of gravity as defined by Einstein falls under the component what is difficult to teach (WD), this is because this idea is related to the students' prior knowledge about gravity while introducing them to a new definition of gravity. Unlike in the first lesson where I simply mentioned that the two views of Newton and Einstein are different; in this lesson I gave an analogy of the definition by Einstein and also tabulated the differences between the two views (figure 5.13). Although this is a new concept it is very much aligned to the content knowledge hence, the component WD is integrated in the CS in the TSPCK Map (figure 5.14).

5.10 Summary table

Table 5.2: Summary table of the visible components of TSPCK in each critical incident

Critical incident	Number of TSPCK components	Components Present
1	2	LP, RP
2	4	LP, CS, RP, WD
3	2	CS, RP
4	4	LP, RP, CS, WD
5	3	LP, RP, CS
6	3	CS,RP, LP
7	4	LP,RP,CS,WD

Table 5.2 summaries the critical incidents, showing how many components as well as which components are visible in each incident. Most of the TSPCK components are Curricula saliency and representations and this is because I felt that I needed to communicate the content knowledge in a sense that knowledge is transformed into comprehensible ways (one of the ways being the use of representations). In addition, I have also realised that in each critical incident the conceptual teaching strategy (CTS) is not necessarily a stand-alone; instead it is included in the other TSPCK components which has also been stated by Mavhunga (2015). Therefore, most of the critical incidents incorporated a conceptual teaching strategy (CTS) or rather the main platform was a conceptual teaching strategy; as the main plan was to enable conceptual understanding. Furthermore, this section has discussed the components of TSPCK which emanated from my teaching; as the theory of TSPCK permits me to capture moments and incidents that may show the development of good teaching.

5.11 Evidence of learning

This section examines the evidence of learning if there was any, which the lesson influenced. The questionnaires where answered by the students prior to the lesson and after the lesson which I taught. The interviews took place after I had taught the second lesson, in which students were asked about their prior knowledge as well as how the lesson has influenced their new conceptions.

Questionnaire results

Table 5.3 shows the results from the questionnaire both pre and post questionnaires. Having a glance at this table it is visible that the number of participant getting correct answers increased in the post questionnaire which was answered after the lesson. It is interesting that the certainty also changed from ‘think so’ to ‘sure’. This change in certainty might have been influenced by the confidence gained through learning the content. However not all participants answered the questions correctly in the post questionnaire.

Table 5.3: Questionnaire results (N=30)

Question No	**Focus of the question**	**No of people who answered correct (Pre)**	**Certainty**	**No of people who answered correct (Post)**	**Certainty**
1	First formation of a star	18	18 (Sure)	24	28 (Sure)
2	What is a star	18	24 (Think so)	20	21 (Sure)
3	Beginning of a star	23	19 (Sure)	30	28 (Sure)
4	The light from stars	10	19 (Think so)	20	16 (Sure)
5	What causes the increase in temperature of a star during formation	16	17 (Think so)	16	14 (Think so)
6	What will the sun be in 5 billion years	23	18 (Sure)	26	22 (Sure)
7	What happens when neutron degeneracy fails	10	14 (Think so)	14	16 (Sure)
8	When does a supernova occurs	13	13/13 (Sure and Think so)	10	23 (Sure)
9	Characteristics that tell the future of a star	7	15 (Think so)	14	18 (Sure)
10	Luminosity of the star	8	17 (Think so)	15	18 (Sure)
11	Relation between lifetime and mass of a star	6	14 (Think so)	21	25 (Sure)
12	Which star appears the brightest	16	16 (Think so)	16	19 (Sure)
13	Name of star when it initially forms	14	18 (Sure)	15	23 (Sure)
14	Masses of different stars	15	19 (Think so)	20	19 (Sure)
15	Balance in forces (why a star doesn't collapse in on itself)	6	16 (Think so)	17	18 (Sure)

There are questions in which the number of people who answered correctly increased significantly; such as the questions highlighted in red in the table. These questions were poorly answered in the pre-questionnaire and in the post questionnaire they have answered correctly by the participants. In the lesson I have explained the concepts which are mentioned in these questions well. For example in the lesson, I kept on stressing that the sun survives by keeping a balance in forces, which is related to question 15. In the lesson, I explained that gravity is an attracting force which pulls things with mass to towards each other; and I also explained that the energy released during nuclear fusion is radiation; thus explaining that the star survives through a balance in forces which are gravity and radiation. Question 11 is also one of the questions which I really emphasised in the lesson, to an extent that I even explained using an analogy (see lesson plan appendix K). The question focused on the mass of star in relation to its future life events.

The questions highlighted in blue, are questions in which there is no difference between the number of students who answered correctly in the pre and post questionnaire. This suggests that the concepts were not explained adequately or that students' prior conceptions have not changed. As stated by Bailey et al. (2009) students come to the classroom with deep-seated conceptions which can either allow or hinder the incorporation of new concepts; which is what is observed in these questions. For example, question 8 focuses on the concept of a supernova which was extensively explained using multiple representations; however some students' may have held to their prior conceptions. Another factor influenced how the students answered these questions it the distractors, because students choose an answer which is close to the correct (see appendix N). Question 8 asked 'when does a supernova occur?'; most of the students chose option C which stated that 'a supernova occurs when a massive star has burnt the last of its nuclear fuel'. However the, most correct option was A which stated 'it occurs when a star reaches the end of its life'. Therefore, the distractors are also a factor in how these questions were answered.

The questions which are not highlighted are those in which most students' answered correctly in both pre and post questionnaire, this suggests that students' had a fair understanding of these concepts. Furthermore, alternative conceptions which students' hold prior to instruction and after the instruction, can be integrated with the newly learnt content information (Bailey & Slater, 2003).

Interview results

The results of the coded transcript interviews of the 4 participants is shown appendix L; where I decided to make categories which emerged from the answers from my participants. The five categories are namely prior knowledge, change in prior knowledge, enhance understanding, interest and improvement. Prior knowledge was taken from the statements such as the following, which were taken from the interviews:

> *'I have always known carbon; I thought a star is a big rock that shines' – AS 24*
>
> *'I really thought that stars only shine at night because it is dark' – AS 25*
>
> *'I know about the formation of dust and gas from the lessons we've had in NS2' –AS 5*

When students gave answers in this sense, I related them to their prior knowledge, as this was what students thought prior to the lesson. The students' prior knowledge includes some of the common misconceptions which Comins (2001), such as the one from AS 25. It was interesting to also hear from the students' what they had initially thought about stars without me making assumptions. More so, as seen from the extracts the prior knowledge of the student is also informed by having had an astronomy lesson (AS 5). Some of the students' ideas were accurate while some were not. Hence, I picked up on another category being change in prior knowledge, where students mentioned what they understand better. When I taught the second lesson as per my critical friends' advice, I was more explicit in my explanations such that I had visual representations showing the elements which are part of a life of star. I did not recognise this as a powerful way of contributing to the students' change in pre-conception, as I had implied that they know the elements. Hence the comment from AS 25 as seen below enlightened me on the impact that the representations have in learning. The comments highlighted from the interview which show the change in prior knowledge are as follows:

> *'Understanding the gravity, allowed me to see that gravity plays the biggest factor' – AS 24*
>
> *'And then when you mentioned the elements from the smallest one to the biggest one, that's when I realised' – AS 25*
>
> *'I got to understand that a nebula is not necessary a star but it is the actual cloud of dust and gas.'- AS 5*

Viennot (1979) argues that formal teaching is not always fruitful in changing students' prior conceptions. Hence, although I assume that the change in prior knowledge was influenced by the teaching of the content of stars; the driving force of was interest, as I picked out form the interviews. The more interested the students' were in learning about stars, they became more attentive. Some of the participants came to the lesson because they were just curious about stars and that enabled them to gain new understanding. Some of the excerpts of the interview are as follows:

'I have always been curious about stars' – AS 10

'I found it very interesting to find that stars are living' – AS 25

Another category was 'enhance understanding' which referred to what in the lesson helped the students to understand better. The students mentioned that the representations which I used in the lesson really helped them, to the extent that one of the participants said *'Honestly content without representation does not make sense, so representations make it easy'*. What was very appealing to me was that each student mentioned a representation which they liked and understood better. This made me realise that not every representation appeals to the student in the same way, what works for one student may not work for another. Below are some of the extracts from the interviews: The extracts from the interviews are as follows:

'I am a visual person; 'I learn from seeing and feeling.' – AS 25

'The analogy that you showed us' – AS 24

'The pictures really helped me to understand better.' – AS 10

'Honestly content without representation does not make sense, so representations make it easy' – AS 5

Another important aspect coming out of the interview was the improvement of the quality of teaching of the lesson. The students mentioned what they did not like in the lesson and what I could do as a teacher to improve it. Hence the category was labelled improvement; the comments from the students' enabled me to recognise the things that my critical friends and I did not identify. These included the amount of content knowledge presented and emphasises on certain concepts. Therefore, in my teaching I neglected the importance of concepts such as mass, size and time. From the students questionnaires I realised that there might be confusion between mass and size, which is the reason I asked the students a question related to these concepts. When Students answered the question they mentioned how the explanation of these concepts was not stressed in the lesson. More so, students also stated that they would have liked it if there was a practical or if they had gone outside; showing that the lesson lacked classroom interactions.

'It was too much information' – AS 25

'I don't think there was enough emphasis on the concept of mass and size in the lesson.' – AS 24

'Also maybe if you could do a practical in which we can model things' – AS 10

'Maybe if we had gone outside to see it' – AS 5

5.12 Reflection

The aim of the lesson was to teach in order enhance the conceptual understanding of stars. My lesson was carefully planned to be interactive, in which the students are going to be active participants instead it was not like that in both lessons. The reason I mention that is because as I was teaching and I was asking students questions it was evident that students had little knowledge about stars. Sharp (1996) mentioned that students as well as teachers rather shy away from taking about some astronomical concepts such as stars because they are not confident enough to communicate about them. This was evident in my lesson as I did most of the talking and also interacting with the materials which I had. Therefore, the conceptual teaching strategy which was used in my lesson was non-active but interactive and this is because I taught the content with a lot of supporting materials (the interaction) and a little bit of learner questioning. This change occurred of conceptual teaching strategy happened as I was teaching, and this shows an important aspect of PCK in my teaching that is pedagogy. The how I went about teaching my lesson enhanced the elements of TSPCK within my lesson. For each and every concept (content knowledge) was then supported by a representation either macro, micro or symbolic.

Being a novice teacher, my PCK can only be enhanced through more and more of practice so be aware of the different dynamics each class has and be able to cater for those students. Most of the misconceptions that I had anticipated I dealt with although not that instant in which it was raised but dealt with them as I continued to teach. This is evidence of both learner prior knowledge and what is difficult to teach.

Comments from students from the interview were as follows:

> *'You used a lot of visuals in your teaching and it really helped me, especially when you put up the atoms/elements on the board so that we can see which other heavier atoms are being formed during nuclear fusion'.*

> *'The balloons made me imagine the sound of the big bang, and when all those pebbles fell out with the other bits and pieces of the balloons, I realised that the supernova isn't just a loud bang, but it signifies the birth of other materials'.*

> *'You used a practical example of a balloon and had to compress the balloon, I couldn't stand the sound'.*

These comments made me aware that using multiple resources and representations promotes the understanding of content better. This is because students learn differently and having different representations enables each of them to understand the content. The visual representations worked well for one student, but they might not work for another student.

5.13 Conclusion

Learning to teach is a process that develops and grows as it comes with experience. In terms of this particular science topic, I have been able to think of different ways to improve how I teach the concept of stars. As seen, planning to teach a certain topic enables one to develop their PCK of that topic, thus being able to transform content knowledge for the purpose of learning and understanding. Hence, planning and execution are both important in the transformation of knowledge because they enable that deep conceptual understanding method of learning to be visible. In addition, teachers' reflection is also important in the development of PCK and this is because it allows a teacher to recognise the strengths and weaknesses that are embedded in their classroom practices, especially in how they teach, what they teach as well as the examples that they use in class. The videos of me provided; made the planning of the teaching come to life and so to show the short comings as well as the strengths of my ideas in the classroom. Some examples were good and some weren't good and this can only be revealed when the actual teaching has taken place. This chapter has highlighted the important aspects of learning how to teach which highlights how the process of knowledge transformation can be developed.

The next chapter will provide us with the answers to the research questions, and also show in what ways has my teaching has improved conceptual understanding of the concepts of stars in pre-service teacher. Furthermore, the next chapter will also provide insights which I gained in this self-study.

Chapter 6

Conclusion and Reflections

6.1 Introduction

Percy as cited in Pasachoff and Ros (2008) argues that teachers and students are capable of learning astronomy effectively by having to teach it or communicate about it. Throughout this self-study research, I have given details about how the learning of the topic of stars and learning how to teach this topic enabled me to be more reflective in improving my content knowledge as well as my teaching. This chapter begins with a brief overview of the critical reflections of the self-study followed by a discussion of the findings from chapter 4 and chapter 5. A summary of the findings with respect to the research questions is also discussed by drawing conclusions where necessary. Finally, the limitations of the self-study, the recommendations for future research are stated as well as the insights I gained are also discussed in this chapter.

6.2 Discussion of findings

Undertaking a new topic as a teacher is not easy. As seen in chapter 4, I needed to learn the content knowledge of stars, so to have a deep conceptual understanding of the topic; in order to be able to transform the content knowledge in ways that it could be accessible to students. The concept maps enabled me to trace and facilitate the growth as well as my understanding of the content knowledge. Using the concept maps in my study informed me about the state of my own prior knowledge, conceptions and ideas about stars; therefore, interrogating these ideas as I learn the correct conceptions.

Hay et al. (2008) argue that constructing concept maps can promote one's understanding. With reference to my concept maps, there is a large improvement from concept map 1, 2 and 3; this suggests that there is a great improvement in both the quality and accuracy of my own content knowledge. The observed increase in the quality of content knowledge in concept map 3 was influenced by the interventions which I went through. Learning content knowledge and being able to make sense of what you have learnt through making connections with other concepts which are related to it, shows that concepts have been comprehended. This is what was displayed by concept map 3. Furthermore, a concept map that has a net structure allows one to use various routes in a map in which more connections in concepts can occur as contended by Hay et al. (2008); concept map 3 is has developed into a net structure with the gaining of content knowledge.

The intervention plans were all in the quest of gaining content knowledge and understanding of the concepts related to stars. Without the interventions, I would have not been able to reach the level of understanding about stars and other astronomy related concepts. Percy as cited in Pasachoff and Ros (2008) mentions that learning astronomy includes a wide range of activities that includes teaching it, communicating it and developing astronomical instruments. The interventions enabled me to learn astronomy by mostly communicating it. Being in spaces, situations and events in which people are engaging in conversations about astronomy allowed me to broaden my thinking, understanding as well as my enthusiasm about astronomy; especially stars. As seen from table 4.1 (which shows the interventions), I had to involve myself with people and things that exposed me to astronomy.

The improvement in my understanding of the content helped me in developing big ideas which my lesson centred around. Big idea 1 states that 'nuclear fusion is necessary for star formation'; was informed by the ideas that I had learnt during the construction of the concept maps. This is a big idea because nuclear fusion is important in the birth and building up of a star; meaning that without the process of nuclear fusion a star cannot be born. Big idea 2 states that 'gravity is the most important force in astronomy'; was informed by the understanding that this force is responsible for the attraction that occurs between particles such as dust and gas; as well as the attraction between heavy bodies such as the planets and the sun. I used these two big ideas to facilitate the development of the CoRe; which enabled me think of ways in which I could make the content knowledge accessible to the students. Going through the prompts of the CoRe for each big idea assisted me in transforming the content knowledge which I gained into the knowledge of teaching. This made it clear that it was necessary for me to learn the content knowledge of stars to be able to teach about them; thus the content knowledge which I developed through the use of concept maps played a part in answering the prompts.

With the help of the CoRe I was able to develop a lesson plan which aimed at bringing the CoRe to life. As stated previously, there is planned TSPCK and enacted TSPCK; the CoRe and the lesson plan demonstrate the planned PCK which depicts my thinking about what to teach and how to teach it. The actual teaching of the lesson as recorded in video 1 and video 2 depicts the plan in practice thus being the enacted PCK. More so the development of TSPCK is well developed in practice, although it can be shown in writing (planning), the practice informs one in terms of what works and what does not work in a lesson and this was seen from video 1 to video 2 (Gess-Newsome et al., 2010).

The questionnaire and the interviews showed that there was improvement in learning and conceptual understanding of stars. From the questionnaire it was interesting to see the change in certainty from 'think so' to 'sure' with regard to the answers which the students' gave. Although some of the participants may have given an incorrect answer, the lesson made them to be more comfortable in talking about astronomical concepts and they were very sure of their answers. The amount of confidence shown by the participants' meant that there was/is room for conceptual change to occur. I categorised the students' responses to the interview questions in terms of 'prior knowledge, change in prior knowledge, interest, enhanced understanding and improvement'. These categories assisted in understanding the factors which contributed to the students' understanding of stars which were present in my lesson. The interview also assisted me in finding put what the students new prior to the lesson as well as how I can improve my lesson. The suggestions given by the students on improvement of the lesson permitted me to recognise things which I had neglected in my lesson as mention in chapter 5.

6.3 Answers to research questions

1. How did my content knowledge (ideas) about stars develop as I learnt about them?

My ideas on the topic of stars have developed significantly through the construction and use of concept maps. My content knowledge about the topic has improved, and this is supported by the findings in chapter 4; in which I follow my knowledge progress from before I started learning about stars to when I learnt about them. Throughout the research study, my supervisor critiqued my work such that he would recommend people who could assist me in understanding certain concepts; this support base contributed to my content knowledge progression. The comments from my critical friends and intervention plans enabled me to gain an understanding of new concepts which also contributed to my content knowledge development. The amount of exposure in astronomy activities which I immersed myself in; facilitated the learning of the content knowledge about stars. During the study I realised that just reading from the textbooks was not enough to enable me to gain the content knowledge I need, for me to be able to prepare to teach it. More so, without the concept maps I would not be able to trace how much in terms of content knowledge I have gained versus how much I did not know.

There are few ways in which I gained content knowledge; from the textbooks, You-tube as well as the internet sites; I learnt theories, laws and concepts that are important and central to the topic of stars. This added to my factual knowledge, as I needed to understand the theories and laws which guide the formation of a star for example the chemical equation that illustrated nuclear fusion. Showing my knowledge through the concept maps helped me in evaluating my own knowledge. My contact sessions with different people (WAC, Planetarium, HartRAO and lecturers) enabled me to gain a deeper understanding of the concepts. Hence, I was able to answer the questionnaire from Bailey et al.,(2012) which served as a problem solving technique that I did when I was learning about stars. In addition, being able to represent the content knowledge and also proving reasons and explanations of the concepts, displayed deep conceptual understanding (see concept map 3 appendix J).

Therefore, the development of content knowledge about stars improved greatly as documented by my concept maps. However, the development of content knowledge is not a linear process in which one reads and automatically understands the content. One needs to be able to express the content in different forms, which shows that one has fully comprehended the concepts thus being able to think about ways to teach it. Furthermore, Rollnick et al. (2008) assert that concept maps reveal aspects content knowledge, and these aspects are the important concepts which guide the understanding of stars. Gaining confidence in communicating about stars and other astronomical concepts also shows that my interest in the field of astronomy had allowed me to accept and apprehend the content knowledge.

2. In what ways can I transform my content knowledge of stars into knowledge for teaching?

The adapted CoRe by Loughran et al. (2008) assisted with the transformation of content knowledge. Looking at the components of transformation by Mavhunga and Rollnick (2013); the CoRe and its prompts are aligned with the components of transformation (see figure 2.3). Therefore, gaining the content knowledge of stars enabled me to think of ways in which this content could be taught. Knowledge transformation first entails ‘knowing what to teach’; it was important for me as a teacher to be aware of the level in which my students are at, in order to inform me about where they need to be. Secondly knowledge transformation entails ‘what students know about the topic’ that I am teaching, this aspect is important as it informs me about the conceptions which are held by students. Thirdly knowledge transformation means being able to pick ‘what is difficult to teach’ to the students; which shows that as a teacher I know more than the students and I do not plan on teaching them everything I know yet as they may not be in the appropriate level. Knowledge transformation means thinking about ways in which this abstract content knowledge of stars can be understood, thus thinking of different 'representations' that will assist the understanding of the concepts. Lastly, thinking of ways in which I was to teach falls under 'teaching strategies' which are ways in which go about teaching a certain concept which entails how I am going to transforming this content knowledge.

Going through the CoRe enabled me to think about why I chose to start the lesson with a picture or with a song; the thinking behind my teaching strategy was informed by the CoRe. The ways of knowledge transformation included the use of different representations, different methods used to elicit learner prior knowledge and different techniques of introducing concepts. These ways of knowledge transformation get better with time and constant practice. Therefore, the more I engage in the teaching of this topic and many other science topics the more I gain ways of transforming that content into the knowledge for teaching.

3. Which of my pedagogical practices can enable the development and understanding of stars in pre-service teachers?

Pedagogical practices in this study referred to how I teach the concept of stars, this involved the use of representations, questioning as well as discussions. As seen in chapter 5 while there was not much improvement in answering some of the questions in the questionnaire; the level of certainty showed that there was some confidence gained through the learning of content. Prior to the lesson, most of the students gave answers with a 'think so' certainty, thus demonstrating that they are not confident of the answer which they gave. However this was not seen in the results of the questionnaire answered after the lesson. Although some of the students got an incorrect answer, they gave a 'sure' certainty. Therefore, this illustrates that even after learning about stars, students' have continued to hold on to their prior knowledge as suggested by literature (Bailey & Slater, 2003; Bailey et al., 2009). However, it is a problem when students give incorrect answers, hence showing that as a teacher I should employ pedagogies which will enhance conceptual change. For example, doing a practical with the students, in which they are required to apply the knowledge which they learnt, engage and explore as well as explain the content knowledge in their own words; is one way of facilitating conceptual change.

The interviews enabled me to get an understanding of students' prior conceptions about stars and how they altered the way they used to think about stars. Some of the students mentioned in their interviews that were curious about what I was going to say about stars, and this curiosity is what enabled them to learn. From the interviews it is evident that my teaching was relevant because the content was explained through representations. The representations were not only limited to pictures (taken from the internet), but there were also videos, models, drawings, equations and analogies which I used in the lesson. According to the interviews the representations enabled the understanding of the concepts which I was teaching about. However, not all the representations which I used made appealed to all the students as they learn differently, and thus the combination of different representation is effective in teaching as argued by Plummer and Slagle (2009). One of my participants mentioned in the interview that '*content without representation does not make sense, so representations make it easy to understand because we get to see and visualise the content in representations'*. This statement shows that the representations were an effective pedagogical practice in transforming my content knowledge into the knowledge of teaching. There are more pedagogical practices which students mentioned that I could use in my teaching such as a practical which will enable the students to be more hands on and it involves classroom interactions.

6.4 Critical reflections of the study

My study intended to find out if I could be able to learn the content knowledge of stars as well as to transform this content knowledge (teach) sufficiently well in the pursuit of developing my PCK.

At first I had a challenge with drawing concept map 1, because I was afraid of knowing too little as a teacher (as expressed in my journal, chapter 4). Also due to my poor or rather lack of knowledge with regard to the topic of stars at that time; the construction of concept map 1 especially with respect to where to start was challenge. I found myself with ideas that were scattered about the topic; I realised that it was very difficult to link the concepts and ideas if I do not have a thorough understanding of the topic. However, the way I linked the words in concept map 1 enabled me to get a better view of my prior knowledge as well as the amount of depth of knowledge I have about the topic (which was not much). As I was learning about stars through multiple interventions (as seen in chapter 4); I was able to realise the incorrect links, misconceptions, illogical ideas, errors and superficial ideas which I had in my prior knowledge. Hence, confronting my prior knowledge permitted me to move to more correct scientific ideas and notions about stars. Developing concept map 2 was not as unsettling as developing concept map 1; rather I was starting to get comfortable in communicating my knowledge. This was influenced by the fact that my understanding and flexibility of the topic had improved. Concept map 2 was developed in the quest to rectify the mistakes of concept map 1 as well as to have a more logical flow of ideas so to improve my content knowledge. In the same way concept map 3 was constructed so that I could move to more accurate scientific conceptions about stars. The more information and content I engaged with the more confidence I gained in the topic. This enabled me to expand my understanding, thus constructing concept map 3. The use of concept maps in my study played an important role in terms of the development of my content knowledge of stars. The concept maps were analysed using the action research spiral (as seen in chapter 4); in which I was constantly reflecting on my plan, the execution of the plan (action) and making necessary observations to inform me of knowledge that may be lacking. The intervention plans helped me in criticizing my concept maps because the more I engaged with different interventions the more questions I had which enabled me to be more inquisitive and thus being able to identify illogical ideas in my thinking (concept maps). Figure 4.17 which measured the quality of conceptual change through concept maps enabled me to categorise the knowledge progression of my concept maps.

Keeping a journal in which I documented all my reflections, thoughts and other ideas that I was confronted with during the study was very crucial and helpful. I came to a realisation of what I thought was important, especially when I was planning on teaching the lesson on stars. Writing in the journal also became a comforting experience for me especially when I doubted myself, my plans, my knowledge and my ideas (will this work?, what if it doesn't work). Reflecting on the journal after every activity I took part in, made me realise the joy and pleasure I was gaining from learning and teaching about stars. There were also certain instances where I could not reflect instantly in my journal; such as the questions students asked as I was teaching and these are thoughts which could have also influenced my practice in some way. The journal entries were not analysed individually; instead the journal entries served as evidence of my thinking (processes) when I was constructing concept maps and analysing them; planning to teach the content knowledge of stars; my feelings about the interventions as well as reflecting on the inputs by my supervisor and critical friends.

During the period in which I was learning about stars (specifically after concept map 2), I also started developing the CoRe. The adapted CoRe by Loughran et al. (2004) enabled me to think about ways in which I can organise my content knowledge when teaching about stars. As I continued to learn about stars and new ideas came up, the CoRe was continuously amended. I developed a lesson plan guided by the CoRe which I had established. Loughran et al. (2004) mentions that the CoRe is a method of capturing and documenting PCK; thus there is planned PCK and enacted PCK which is why I taught the lesson to bring the CoRe into action. In addition, the CoRe was in constant revision; however the last time I made changes on the CoRe was after I had taught my second lesson after I had reflected on it and after my supervisors' and critical friends comments.

Capturing the PCK in action (which is my teaching) through videotaping was very necessary. This is because it enable me to re-play the video of my teaching as many times as I could, meaning that I could revisit the lesson and pick up on my mannerisms as a teacher as well as in identifying TSPCK critical incidents. The process of videotaping was successful although some of the questions from the participants were not audible enough due to the video recording being too far from them. The video recording assisted me, my critical friends and supervisor in such a way that we were able to critique on the events which took place in the lesson. As mentioned, the video recording was critiqued individually by my critical friends, supervisor and me; hence I took the common incidents which we all picked up on to analyse. The analysis of the video also followed the action research spiral; in which I planned, acted, observed and then reflected on my plan in order to inform me about aspects I can improve on to teach the lesson better. In both video 1 and 2, I identified the common incidents which my critical friends and supervisor acknowledged in their individual critiques to look at the emerging TSPCK components which arose from my teaching, and how these components relate to one another. For example, when I used a picture which is a representation (RP) to elicit learners' prior knowledge (LP); it showed how the components are working together in explaining a concept. More so, from the video recordings it was clear that the components of TSPCK which enable knowledge transformation do not work individually rather they work together.

The questionnaire was adapted from Bailey et al. (2012), which my critical friends and supervisor evaluated as well as reviewed before it was piloted and administered for data collection. The participants were required to answer a pre and post questionnaire; the pre questionnaire was given to the students before I taught the lesson and the post questionnaire after I taught. The reason for the questionnaires was to see whether ideas and conceptions of the students change after they have participated in a lesson such as this one (which may be seen as intervention lesson). The interviews also served as a way to find out if students were able to retain what they have learnt, also to find out students opinions about the lessons. The opinions involved what they enjoyed in the lesson as well as what aspects of the lesson that I needed to improve on. This enabled me to see if any of my pedagogical practices could promote the learning of the content of stars, thus contributing to my professional development as a teacher.

6.5 Limitations

This section examines some of the factors that may have put limitations to this self-study research. A reflection on this study is crucial as it allows me as a researcher to be critical about my work as well as the weaknesses that may be inherent in my study. Opie (2004) argues that limitations in a study are unavoidable, however admitting limitations does not pose as a shortcoming of the study, but rather illustrates that I am thinking critically about my own work.

A self-study research is focused on the researcher (me) as a person and my own experiences. Thus the generalisation of the findings of this research is compromised to a certain extent. What I mean by this is that my own experiences, challenges and difficulties which I encountered may not necessarily be experienced by another person. However, doing a similar study in the same context as in my study may reduce this limitation thus making the results of the study transferable.

The unforeseen academic circumstances during the time in which I was collecting data, constrained my participant number. I only had 30 participants taking part in my study making my sample to be very small and thus limited. Due to logistic issues and time limitations I only had one lesson which constituted a lot of content. The lesson might have had a lot of content for the students to comprehend, given that the lesson was an extra lesson from their normal schedule. More so, Opie (2004) urges that video recordings can alter the behaviour of the participants, as a consequence there was lack of participation from the students during the lesson, making my lessons to be monotone.

6.6 Recommendations

This self-study research focused on how I went about learning the content knowledge of the topic of stars as well as how I went about learning to teach this topic. From this study it is evident that content knowledge is very important in ensuring that there is growth, improvement and progression in my own professional practice as a teacher as well as in my development of TSPCK. Thus, I recommend that science teachers should constantly be reflective of their own practice, so to have a thorough content knowledge as Rollnick et al. (2008) argues that; rigorous content knowledge allows the teacher to be flexible in their teaching. Hence it is important for teachers to note that their content knowledge needs continuous improvement for effective or better performance in teaching. Additionally in order to capture students' attention and interest, continuous change in teachers' pedagogical practices leads to better learning.

Self-study research is an individual effort; however it is also a collaborative effort in which teachers can work together in the pursuit of improving their own individual classroom practices. In my self-study research, my supervisor, critical friends and other people I met during my study (through interventions) together helped me in informing my content knowledge and in teaching that knowledge. Furthermore, self-study research can be done using different approaches one of them being reflective practice in which according to Samaras and Freese (2006) teachers study their own teaching by continuously reflecting on their practice; another one is teacher inquiry in which teachers question their teaching (Nyamupangedungu, 2015) and action research which is what I used in this study. Therefore, there are many forms in which teachers can study their teaching in order to improve it for the better.

6.7 Insights

Doing this self-study was uncomfortable as I had to be critical of myself and all the things that I did and think. But mostly it was uncomfortable because it made me expose my thoughts for others to read and critique. At first I feared the criticism from my supervisor and critical friends, which was the reason I was a bit reluctant in constructing concept map 1. However, the openness and exposure of my ideas and thoughts allowed me to think deeper about what I wanted to do, what I was doing and reasons for doing it. Although some of the comments seemed strict they were very helpful in my study. I learnt studying one-self is not easy but it builds confidence in my content and in my teaching.

I enjoyed learning about stars in my study. Especially the interventions, attending the star gazing shows and being able to identify the stars and planets which were visible in the night sky was really a fulfilling experience. I enjoyed engaging in conversations about astronomy with different people I met throughout my study; they allowed me to expand my understanding about most things in astronomy. My favourite memory would be the visit to HartRAO, learning and seeing the satellites, going to the control room and engaging with an astronomer who was busy with work on star formation really got me excited about my own study.

If I could do this study again, I would have a larger group of participants. I also work together with teachers who are currently teaching and collaboratively plan an astronomy lesson that we will all teach to our students and reflect on the pros and cons of that lesson. Doing this may not only improve my individual practice but the practice of other teachers as well.

6.8 Conclusion

In this chapter I have given an overview of the study together with the discussion of the findings and the research questions. I have also stated the limitations, recommendations as well as the insights I have gained in taking part in this research study. This study was driven by the passion and interest in astronomy, however any teacher who is interested in improving their practice can engage in taking topics which they are not confident in teaching and develop ways in which they can improve their pedagogies.

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Appendices

Appendix A: Ethics

Wits School of Education

WITS UNIVERSITY

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

09 June 2016

Student Number: 481256

Protocol Number: 2016ECE029M

Dear Tshiamiso Makwela

Application for ethics clearance: Master of Science

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

Teaching about stars an action research study

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,

MMabeta

Wits School of Education

011 717-3416

cc Supervisor - Prof Tony Lelliott

Appendix B: Information sheet for Pre-service Teachers

DATE: 05 August 2016

Dear Pre Service teachers

My name is Tshiamiso Makwela and I am an MSc student here at the Wits School of Education.

I am doing research on teaching about stars (action research)

My research involves you attending a 1,5 hours session on stars, answering a questionnaire (before and after the session) and possibly a 15 minutes interview; in order to try and understand the perceptions/conceptions that you have with regards to what stars are. The sessions are scheduled to take place on the 16, 17 and 23 August 2016 and you may attend any of the session that accommodates you.

The purpose of my action research study is to develop my own pedagogical practices that enable participants to engage with their own prior conceptions about stars as well as to develop the act of knowing and understanding content through being involved in constructing my own knowledge.

I was wondering if I could use some of your time and comments to complete a questionnaire; attend the session and also be interviewed. The sessions will be in the afternoon; I will arrange it so that it does not clash with any of the classes that you need to attend as it is an extra session, an addition to the normal classes. The questions are aimed at understanding your perceptions/ conceptions regarding the stars. **Please do note** that this is not a test and it is also not for marks. It is voluntary, which means that you can withdraw at any given point and you will not be affected negatively in any way.

Furthermore, your name and identity will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study, in any case a false name will be used in order to make sure that you cannot be identified in my write up. Also, all collected information will be kept in a safe and secure place and destroyed after 3-5 years after I have completed my project.

I look forward to working with you and thank you in advance

Yours sincerely,
Tshiamiso Makwela
Ethics protocol number: **2016ECE029M**

SIGNATURE:
NAME: Tshiamiso Makwela
ADDRESS: 621 Kutlwano Street Zone 1, Diepkloof, 1864
EMAIL: 481256@students.wits.ac.za
TELEPHONE NUMBERS: +2782 8182 313

Appendix C: Pre-Service Teacher's Consent

Ethics protocol number: **2016ECE029M**

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: **Teaching about stars: an action research**

I, ________________________ give my consent for the following:

	Circle one
Permission to be interviewed	
I agree to be interviewed for this study.	YES/NO
I know that I can stop the interview at any time and don't have to answer all the questions asked.	YES/NO
Permission for questionnaire	
I agree to fill in a question and answer sheet for this study.	YES/NO
Permission to be videotaped	
I agree to be videotaped in class.	YES/NO
I know that the videotapes will be used for this project only.	YES/NO
I agree to be observed in this lesson.	YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be videotaped.
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_____________________________ Date___________________________

Phone number_____________________

Appendix D: Letter to the head of school

REQUEST FOR PERMISION TO CONDUCT RESEARCH IN THE SCIENCE DIVISION EDUCATION CAMPUS

April 2016

Dear Professor Karin Brodie

My name is Tshiamiso Makwela and I am a student here at the Wits School of Education registered for an MSc degree in Science Education.

I am carrying out an action research study on teaching about stars

My research involves attending a 1,5 hours session on stars, answering a questionnaire (before and after the session) and 15 minutes interviews with Physical Science IV and Natural Science II pre-service teachers; in order to try and understand the perceptions/ conceptions that they have with regards to what stars are. The purpose of my action research study is to develop my own pedagogical practices that enable participants to engage with their own prior conceptions about stars.

The participants will each receive a consent form in which they will be informed about what the study is about and their role in the study. The consent form stipulates that participation is voluntary and they can withdraw at any point in the study.

Upon completion of the study, I undertake to submit a copy of the full research report to my supervisor. For any further information please do not hesitate to contact me on +27828182313 or email me at 481256@student.wits.ac.za. Thank you for your time.

Kind Regards,
Tshiamiso Makwela
481256

Appendix E: An abstract from CAPS document for grades 7-9. Term 4 earth and beyond section in grade 9.

CAPS

TIME	TOPIC	CONTENT & CONCEPTS
1 week	**Birth, life and death of stars**	**The birth of a star** • stars exist for a finite period of time • stars form inside huge clouds of gas and dust called *nebulae*, far out in space • these *nebulae* (huge amounts of dust and gas) are pulled together by gravity and slowly collapse • as they contract they heat up • once the temperature is high enough a nuclear fusion reaction begins, that changes hydrogen to helium • this reaction radiates large amounts of energy into space **Life of a star** • stars change in their appearance over billions of years • stars that look blue are hotter and usually younger than stars that appear red • our Sun is about half way through its life cycle – it is a medium-sized yellow star with a lifespan of about 9 billion years • for most of their life, stars change hydrogen to helium • later, towards the end of their life, stars like the Sun will swell up to form a 'red giant' **Death of a star** • at some point the nuclear reaction runs out of fuel • for stars like the Sun, the core of the star contracts to become a 'white dwarf' • for stars like the Sun, the outer gases of the star are ejected into space, where they form an expanding cloud around the white dwarf called a *planetary nebula* • *planetary nebulae* are lit up by their central white dwarf star and are beautiful objects to observe

Appendix F: Questionnaire

Decide how confident you are about EACH OF YOUR ANSWER being correct, by placing a TICK in the relevant box

- ✓ If **<u>you are sure that your answer is correct</u>**, tick the **SURE** column
- ✓ If **<u>you think your answer is correct, but you not totally sure,</u>** tick in the **THINK SO** column
- ✓ If **<u>you guessed the answer</u>** tick **GUESSED** column

1. When a star is first formed, it is made mostly of which of the following?

a. Oxygen

b. Nitrogen

c. Carbon

d. Helium

e. Hydrogen

- How sure are you of the answer:

Sure	Think So	Guessed

2. What is a star?

a. A ball of gas that reflects light from another energy source
b. A bright point of light visible in Earth's atmosphere
c. A hot ball of gas that produces energy by burning gases
d. A hot ball of gas that produces energy by combining atoms into heavier atoms
e. A hot ball of gas that produces energy by breaking apart atoms into lighter atoms

- How sure are you of the answer:

Sure	Think So	Guessed

3. Stars begin life as

a. A protostar, from an existing star or planet.
b. A white dwarf.
c. Matter in Earth's atmosphere.
d. A black hole.
e. A cloud of gas and dust.

- How sure are you of the answer:

Sure	Think So	Guessed

4. The light from stars that we see on Earth results from

a. Reflection of sunlight.
b. Chemical reactions inside the stars.
c. Nuclear reactions inside the stars.
d. Burning of gases inside the stars.
e. Burning on the surfaces of the stars.

- How sure are you of the answer:

Sure	Think So	Guessed

5. Which of the following causes a star's interior temperature to increase during its formation?

a. Nuclear fusion causes an outward force (radiation) which generates heat.

b. Heat is generated when the star's gravity contracts.

c. Gravitational collapse involves the generation of heat from chemical reactions.

d. During collapse, gravitational potential energy decreases while its temperature increases.

- How sure are you of the answer:

Sure	Think So	Guessed

6. In about 5 billion years, the sun will become

a. Supernova.
b. Black hole
c. A red giant.
d. A neutron star.

- How sure are you of the answer:

Sure	Think So	Guessed

7. When neutron degeneracy fails in a high-mass star, it becomes a

a. White dwarf.
b. Black hole.
c. Pulsar.
d. Neutron star

- How sure are you of the answer:

Sure	Think So	Guessed

8. A supernova occurs when

a. A star reaches the end of its life.
b. A low mass star reaches the end of its life.
c. A massive star has burnt the last of its nuclear fuel.
d. Two neutron stars collide.

- How sure are you of the answer:

Sure	Think So	Guessed

9. Which of the following determines most characteristics and future events of a star's existence?

a. Surface temperature
b. Size (diameter)
c. Colour
d. Composition (type of atoms)
e. Mass

- How sure are you of the answer:

Sure	Think So	Guessed

10. Which of the following objects has the greatest luminosity: a red giant, a white dwarf, or the Sun?

a. A red giant always has the greatest luminosity.
b. A white dwarf always has the greatest luminosity.
c. The Sun always has the greatest luminosity.
d. These objects could have the same luminosity.

- How sure are you of the answer:

Sure	Think So	Guessed

11. How is the lifetime of a star related to its mass?

a. More massive stars live considerably longer lives than less massive stars.
b. More massive stars live considerably shorter lives than less massive stars.
c. More massive stars live slightly shorter lives than less massive stars.
d. More massive stars live slightly longer lives than less massive stars.
e. All stars have the same lifetimes regardless of mass.

- How sure are you of the answer:

Sure	Think So	Guessed

12. If a red star and a blue star have the same size (diameter) and are at the same distance from Earth, which one will appear brighter?

a. The red star
b. The blue star
c. Both stars will look the same.
d. There is not enough information given to answer this question.

- How sure are you of the answer:

Sure	Think So	Guessed

13. What is the name given to a star as it is initially forming?

a. Protostar
b. Nebula
c. Supernova
d. Star cluster
e. White dwarf

- How sure are you of the answer:

Sure	Think So	Guessed

14. Star C has a lifetime of 50 million years, while star D has a lifetime of only 10 million years. What can you say about the masses of these stars?

a. Star C has the greater mass.
b. Star D has the greater mass.
c. Stars C and D have about the same mass.
d. There is not enough information given to answer this question.

- How sure are you of the answer:

Sure	Think So	Guessed

15. Why is it that most stars do not collapse in on themselves under gravity's influence?

a. Material churning in and out of the centre of the star balances gravity.
b. The internal structure of the star holds the surface out and keeps it from collapsing.
c. Gravity from planets orbiting the star pulls outward on the star's material.
d. The force from particles ejected outward from the centre of the star balances gravity.
e. Radiation caused by energy created in the star pushes outward to balance gravity.

- How sure are you of the answer:

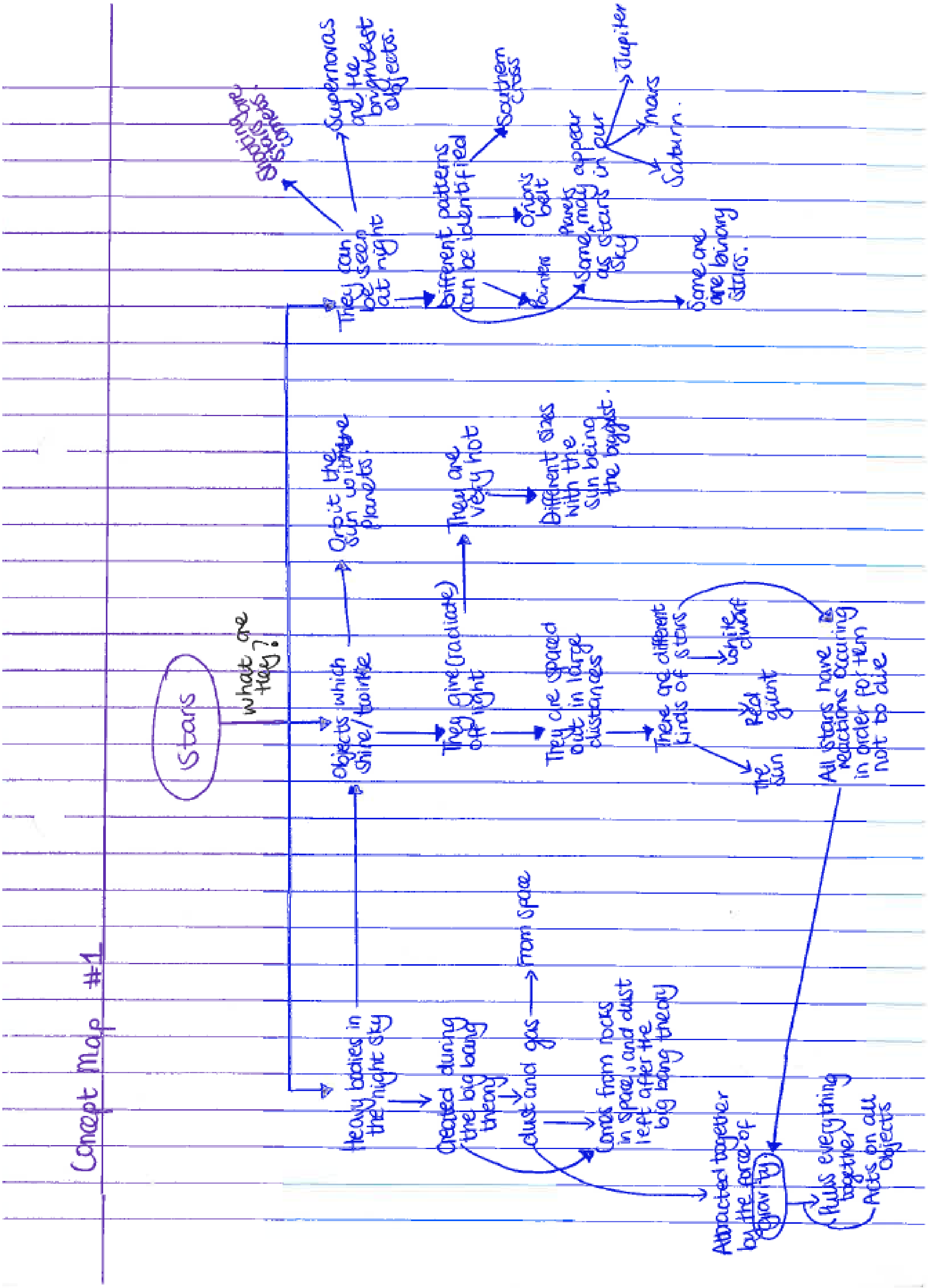
Sure	Think So	Guessed

Appendix G: Interview Questions

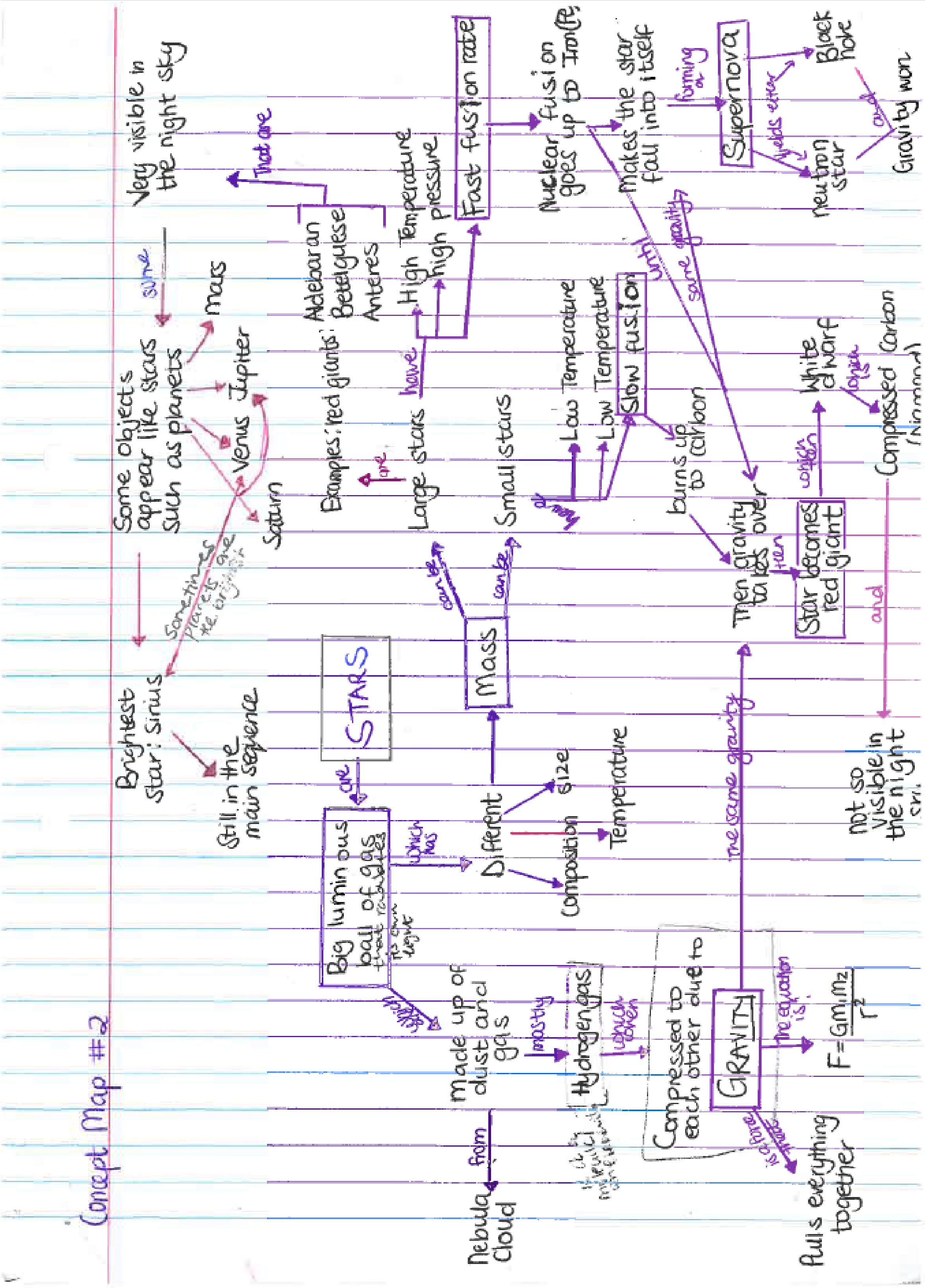
The questions aim at understanding the ideas that the participants have with regards to stars. All the questions were asked after the lesson on stars; questions differed from students based on their answers. However, the following question started the conversations:

1. What informed your initial ideas about stars, with reference to answering question1 in the questionnaire? [Have your ideas changed after the lesson?]
2. With regard to question 9, what is the difference between mass and size? [Give examples, what is emphasised in the lesson?]
3. Is the sun a star? [If yes, what makes it appear bigger and brighter than the other stars?]
4. How has the learning about stars shaped your understanding about them?
5. What and how can I improve on this lesson which I have taught, so to enhance understanding?

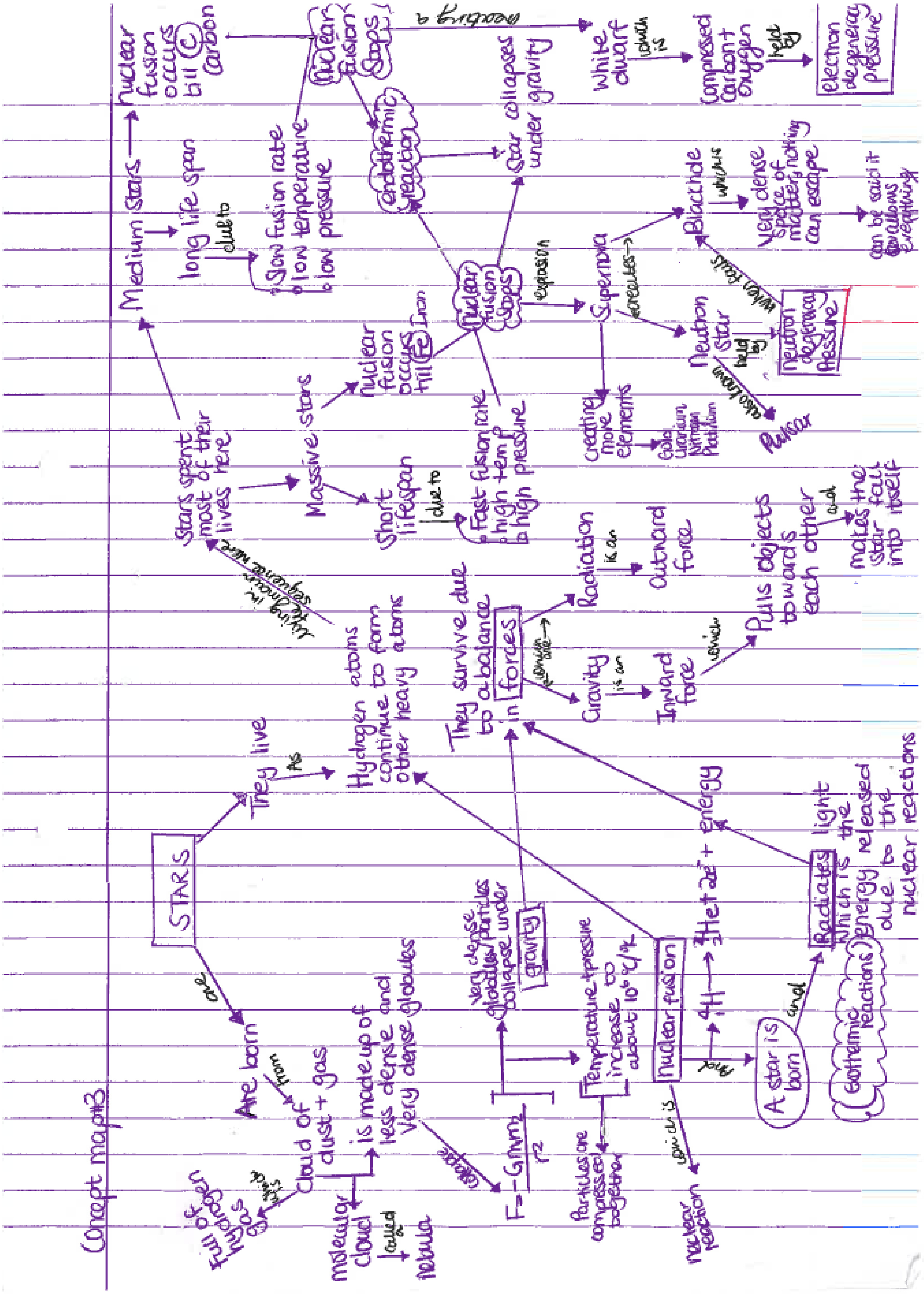
Appendix H: Concept Map 1



Appendix I: Concept Map 2



Appendix J: Concept Map 3



Appendix K: Lesson Plan

<u>Lesson plan on Stars</u>

1. What is the ***purpose*** of the lesson?

KEY QUESTIONS Write 1- 3 of the most important questions learners should be able to answer by the end of this lesson.	• How are stars born? • How are other elements created from stars? • What is the role that gravity plays in the universe?
SKILLS What should the pupils learn how to do during the lesson?	• Learning about stars will enable students to understand where heavy elements come from, as we only know from the beginning only Hydrogen and Helium. • What we learn from other stars may help us understand our own Sun, which is also a star. The Sun only seems different to us because it is so much closer to us than other stars. • We learn something about how they are born and die. This helps us understand how our own solar system was formed. • Understanding stars is also important because stars contain a large fraction of all the visible mass in galaxies.
ATTITUDES AND VALUES What does this lesson promote as being good or just or fair?	Students will appreciate the value of the unseen world of microscopic particles that contribute to the macroscopic level behaviour of materials that are seen. In a sense this means that the students will get to understand that there is a lot more than what we see with our naked eye.

2. Background of Students

What do you want pupils ***to do*** during the lesson?

Students will be expected to be fully engaged in the lesson by asking and answering questions. There will also be watching a video, drawing certain diagrams and doing tabulating tasks.

How is the content knowledge linked to the ***previous knowledge*** of pupils and/or current affairs? And what aspects of ***learner diversity*** need consideration?

The second year students have just finished a course in astronomy in which the topic of stars was taught. The fourth year students also did an astronomy course in their second year and also did a cosmology section in their fourth year. However, they still have limited knowledge when it comes to the content of stars and how to explain what stars are. This lesson will be a build up to what they have been exposed to, although it starts at the basics, it gives them more to think about with regard to the stars and the universe at large.

Students come from different backgrounds; others are from the rural areas while others come from the urban areas. However, they are all not exposed to the knowledge of stars. Some of them might have been to the planetarium in which they learnt how to recognise the stars in the night sky, but not necessarily what forms stars and what makes them shine. Students may also learn in different ways, hence videos and pictures and equations will be used to develop and encourage understanding. Examples will be given as I teach and they will also engage with those examples.

3. Lesson Materials

    - ✓ Power-point
    - ✓ Pictures
    - ✓ Video clips
    - ✓ Papers
    - ✓ Balloons

4. Some analogies that will be used:

At this point in the lesson students are aware that a star is formed through nuclear fusion which produces energy, which is known to be radiation and that is why it is different from all other object in the night sky. Students at this point know that a star survives through a balance in forces which are radiation (outward) and gravity (inward). Students at this point have also learnt about how the mass of the stars gives the other characteristics of the stars such as its temperature, pressure and fusion rate. To start of speaking about the death of the star, I will first go back to the content and then ask:

> "so we said that it will take about a 5 billion years for a medium star to die, how long do you think you can count to 1 billion or 1 million?".

The reason for doing this is to reconceptualise the idea of time and make it more realistic, because when we refer to billions of years students already zone out. Students 'answers will then make them to be more curious about this time factor and actually see how the mass really affects the future events of the star. This is a great analogy which enables learners to be comfortable to talk about what the mass of the star means for the star.

I will then give students another analogy of the gamblers which is more practical than trying to count to 1 million.

> "if there are two gamblers in a casino one with a lot money and one with just enough money, who will run out of money first?"

The answer here is a tricky one, most people think the one with little money will run of money quicker than the one with more money; some even say that it depends on the person and it is not about the money. However, the money in this scenario refers to the mass of the object, premise being that the one with more money always bets more money than the one with little money, and thus runs out of money first thinking that he still has more. This is the case with stars, the bigger you are the faster you die because nuclear fusion stops and therefore the forces are imbalance and gravity wins.

To go further with this idea of the massive star dying, I will give students big balloons with pebbles in them, and tell the students that at this point the star (being the balloon) nuclear fusion has finished and gravity takes over. When gravity takes over the star collapses more and more into itself, because gravity is pulling the star towards its own centre; the students will then be asked to compress their own balloons in the pursuit of introducing them to the concept of supernova. When their balloons burst, the pebbles and some pieces of the balloons spread out, therefore giving students an idea that the star dies and leaves out some materials. I will then play a video on the supernova which will explain that these pebbles and pieces of the balloons are other elements which are being formed by a massive star during its death. The limitation of the balloon model is that, it may give rise to the misconception that gravity is a pushing force and not a pulling force, which will be stated to the learners.

5. Sequence of lesson

- Introduction: I will welcome all participants; explain what the aims of having this session on stars. Then the participants will be asked to fill in a questionnaire on stars.
- I will teach the lesson using a power point presentation, which will have all the information and pictures that will show and explain star formation and all the concepts involved.
- Video clips will be shown in the middle of the presentations, to enable students to have a visual representation of what I am explaining.
- Students will be asked to answer questions on a paper provided for them. They will also be asked to blow balloons when illustrating one of the concepts taught.
- Examples and analogies will be used in order to ensure that students get a better understanding of the complex language involved in star formation.
- Questions from students will be accepted at any point in the lesson.
- At the end of the lesson, I will give the students a theory that may contradict or rather make them uneasy with regard to what they know. The aim of this is to give the students something to think of.

Appendix L: Interview Results (coded transcripts)

CATEGORIES	Prior Knowledge	Change in PK	Interest	Enhanced understanding	Improvement
AS 24	For me I have always known carbon to be the most found in space. I thought a star is a big rock that shines, the sun is the brightest object for me	Understanding the gravity, allowed me to see that gravity plays the biggest factor than everything else because gravity is the reason for everything existing. You gave this cool activity when you said we must right down what we recognise, so the fact that you made us explain what we were saying and you saying it back to us made us think more about what we were saying.	The balloon was the most effective representation which you used. For me to understand how big the star can become before it can collapse. It was the concept of the death of a star. You explaining the concept of a blackhole, with reference to a model you once saw, like when you roll down a ball on a circular thing with a whole like a funnel it will continue to go down, it won't come up.	I am a visual person, I like to see and touch things as I learn about them. For me the learning didn't have a lot of wording, it was word of mouth more explaining and that really engaged me because I learn from seeing and feeling. And because you drew most of the things it made it so much better to understand and remember, like when you put up the elements.	It was too much information to take in, in one lesson. There was so much to learn and I might have missed some information.
AS 25	I didn't even know that stars are born. But in the lesson I got to see that there are actually gases involved, and the gas that is forming and coming together is hydrogen. And I did not know this at all. I really thought that stars only shine at night because it is dark, whereas they don't. Secondly I didn't know that stars have lives	I really thought it was helium gas as you were teaching. And then when you mentioned the elements from the smallest one to the biggest one, that's when I realised that hydrogen comes first before helium.	I found it very interesting to find that stars are living although not leaving as in breathing but in their own way. Also I learnt about a new state of matter which is the plasma in which the formation of the star comes about that was quite interesting.	The analogy that you showed us, showing how the star is formed like the one with the stadium. I saw that a star is formed, and it is also very big and very hot. They said in the video, when its formed it could be a like a ball but as the elements fuse the temperature becomes very high we saw the seats at the	I don't think there was enough emphasis on the concept of mass and size in the lesson. I am not really sure how you can make the differences between these two concepts; maybe if you could refer to the blackhole or something. Because I can't really understand whether a blackhole presents something that is

	like us because a star is born, which is what I got from the lesson. Before I thought stars shines because maybe light, its light something that you can only see, but you cannot say I am touching the light.			stadium were melting. So it really made me realise that stars are very big and it takes a lot for it to be what it is.	big size and at the same time having a large mass. So I am not sure if it's the same thing or not. So many if you can put emphasize on the two concepts. When it came to how the star dies, you used a practical example of a balloon and had to compress the balloon, I couldn't stand the sound. Also maybe if you could do a practical in which we can model things such as the blackhole, it would really make us to be more involved.
AS 10	I have known that the Sun is a star and the sun is made up of helium. So I might have thought of hydrogen but helium is the one that I remembered or recalled.	Okay, I can say I have confusion between hydrogen and helium. So I started by saying it was helium, in my understanding the reaction that will happen, helium will convert to hydrogen gas, that's what I had in my mind. Maybe I was guessing but in the lesson I learnt that when there is a reaction when the star begins some gases are	I have always been curious about stars, why they come up in the same place every night, where I grew up is a farm and I could see the stars very clear. And when I am here (JHB) I see the stars but they are in a different form than when I am at home. so I think the direction, I have always been curious as to why I see them this side when I am at home and they are much	The pictures really helped me to understand better. even though the content on its own is abstract, different representations really helped me It was interesting to see what you were going to tell us about stars.	No, maybe let's say it was good. Thing is when you do this lesson you talked about the star will become bigger, and when it becomes bigger it loses some power. So you didn't talk much about the mass like what is happening to the mass. The mass you really talked about it when you started talking about the blackhole. So I didn't really understand the part of mass. Understanding the direction

		formed as the product of the reaction, so I thought maybe it is hydrogen there. Mass we are talking about the weight, size we talk about their out sphere. The mass is how much it weighs and the size is how big it is.	closer, and this side when I am in JHB they are far very far from where I am but in different direction. And I think there is a lot about the stars. like I didn't know about the gases		of the night sky and trying to explain what we could see at night was really hard to follow, maybe if we had gone outside to see it. More videos and us interacting with the content. The lesson should be more about us and engaging with the content, and maybe a practical for us to understand better.
AS 5	I know about the formation of dust and gas from the lessons we've had in NS2. The dust and gas come together and undergoes fusion which is what makes the star alive. It turns into helium and other heavy elements. Fusion is the interchanging of elements in the core. Whereby the inner CoRe expands and becomes a red giant. I also thought stars come in stages, like star 1 is a nebula; star 2 is a protostar just like that until we get to a star.	I got to understand that a nebula is not necessary a star but it is the actual cloud of dust and gas. And a star is born when fusion occurs. The sun is star because firstly it emits its own light. The sun is in the main sequence and as it continues to leave it will be a red giant. A white dwarf is formed at the end of the life of a star and not sure whether it is a neutron star or not. Size means how big and size means how heavy that's what I saw in the lesson although you didn't really dwell much on that.	I really never took the stars seriously, but nowadays I have more interest in stars, I look at them at night. Stars were just stars to me	Honestly content without representation does not make sense, so representations make it easy to understand because we get to see and visualise the content in representations.	In the lesson you emphasized mostly on the mass in your teaching and not much on the size. Although I don't think it is important as much as understanding the mass because of that cycle of the star they make it clear that mass is what is important. The lesson was okay, but it's just that we didn't have time. At some point we needed to interact and also maybe go outside to see the stars it would have been much better.

Appendix M: Pre-questionnaire results

PRE-Quesanalysis

Pseudony	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question	certainty	Question 1	certainty	Question 1	certainty	Question 1	certainty	Question 1	certainty	Question 1	certainty	Question 1	certainty
AS1	2	2	5	2	5	2	4	3	3	3	3	1	3	3	1	2	2	1	2	2	1	3	3	3	2	1	4	2	2	3
AS2	5	1	3	1	5	1	3	1	2	2	3	1	1	1	1	1	5	1	3	1	2	1	2	1	1	2	2	1	2	2
AS3	4	2	1	2	5	2	4	2	1	2	3	1	1	2	1	2	1	3	2	1	1	3	2	2	1	3	2	1	5	2
AS4	4	1	1	1	5	3	1	2	1	2	3	2	2	2	3	2	4	3	4	2	5	2	2	2	2	3	4	2	3	3
AS5	5	1	2	2	1	2	3	1	3	2	3	1	1	2	2	1	5	1	2	1	1	3	2	1	2	1	2	2	3	3
AS6	5	1	3	2	5	1	1	2	1	3	3	1	1	3	1	2	4	2	1	1	5	3	4	3	1	1	3	2	4	3
AS7	5	1	3	2	5	1	3	2	1	2	3	1	2	2	1	2	5	2	1	2	3	3	2	1	2	1	1	2	2	3
AS8	4	1	5	2	5	1	5	2	1	2	3	1	1	3	1	2	3	2	1	2	5	2	2	2	2	3	2	2	5	2
AS9	4	2	3	2	1	3	4	2	2	2	3	1	1	3	3	1	1	2	2	3	3	3	2	2	2	2	4	1	1	3
AS10	5	1	3	2	5	1	3	2	1	2	1	2	1	3	1	2	2	3	2	2	1	2	2	2	1	1	1	2	1	2
AS11	5	1	4	1	5	1	5	1	1	1	3	1	1	2	1	2	5	2	2	2	1	2	2	2	1	1	2	1	1	2
AS12	5	1	4	2	5	1	2	3	3	2	4	2	1	3	1	2	5	1	2	1	1	2	2	1	1	1	1	1	3	2
AS13	5	2	1	2	2	2	1	1	2	1	1	1	2	2	1	1	2	1	3	3	2	2	3	1	2	3	1	1	5	2
AS14	5	1	5	3	5	1	3	2	1	1	3	2	2	2	3	3	1	2	3	2	2	2	1	2	1	1	1	2	5	2
AS15	5	1	2	3	5	2	3	3	1	1	3	3	3	3	3	1	1	3	3	2	1	3	2	2	1	1	2	3	5	2
AS16	5	2	4	2	5	1	3	1	3	3	3	1	2	2	3	2	2	2	2	2	1	1	2	1	1	1	4	2	1	3
AS17	5	1	4	2	5	1	3	2	2	2	3	1	2	2	3	1	5	2	3	1	5	3	2	1	1	1	2	2	2	2
AS18	5	2	1	2	5	1	1	2	4	2	3	1	3	2	3	1	2	2	1	2	1	2	2	2	2	1	1	2	3	2
AS19	4	2	2	2	5	1	3	2	4	2	1	3	2	2	1	2	4	2	3	2	5	3	4	1	1	1	1	2	2	2
AS20	4	1	1	2	5	2	1	2	1	3	3	1	2	3	3	3	4	3	1	2	1	2	2	2	3	2	1	2	3	2
AS21	4	1	3	2	5	2	4	3	1	2	3	3	1	3	1	1	4	3	3	2	1	2	4	2	2	3	1	2	3	3
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AS29	5	1	4	2	1	1	1	2	1	1	3	2	3	2	4	3	4	2	3	2	3	2	2	2	5	2	4	2	1	2
AS30	4	2	1	2	5	1	4	2	2	2	1	1	4	2	2	2	2	1	3	1	4	2	3	1	1	1	2	2	4	3
Answers																														
Answer A	0	18	7	4	5	19	9	7	16	8	4	18	14	4	13	13	4	8	8	9	13	5	5	10	14	18	10	9	5	1
Answer B	2	12	7	24	1	8	1	19	6	17	1	9	10	14	3	13	10	15	9	17	6	14	16	16	11	7	13	19	7	16
Answer C	0	0	7	2	0	3	10	4	4	5	23	3	5	12	12	4	1	7	12	4	4	11	5	4	1	5	1	2	10	13
Answer D	10	0	6	0	1	0	7	0	4	0	2	0	1	0	2	0	8	0	1	0	1	0	4	0	2	0	6	0	2	0
Answer E	18	0	5	0	23	0	3	0	0	0	0	0	0	0	0	0	7	0	0	0	6	0	0	0	2	0	0	0	6	0

Appendix N: Post-questionnaire results

Pseudo	Question	Certainit	Question :	Certainit	Question	Certainit	Question	Certainit	Question	Certainit	Question	Certainit	Question	Certainit	Question	Certainit	Question	Certainit	Question 1	Certainit	Question 1'	Certainit	Question 1	Certainit	Question 1	Certainit	Question 1	Certainit	Question 1	Certainity
AS1	4	1	4	1	5	1	3	1	4	1	3	1	4	1	1	1	2	1	2	1	2	1	2	1	2	1	2	1	5	1
AS2	5	1	4	1	5	1	3	1	3	1	3	1	2	1	3	1	2	1	1	2	2	1	1	2	2	2	1	1	5	2
AS3	5	1	4	1	5	1	3	1	3	2	3	1	2	1	2	2	5	3	1	1	3	2	2	2	2	1	2	2	4	2
AS4	5	1	4	1	5	1	4	2	3	2	3	1	2	2	3	1	2	1	4	2	2	1	2	1	2	1	2	1	5	1
AS5	5	1	4	2	5	1	3	1	3	1	3	1	4	1	1	1	5	1	2	1	2	1	2	1	1	1	2	1	5	1
AS6	5	1	4	1	5	1	3	2	1	1	3	1	3	3	3	2	1	2	3	2	2	1	1	1	1	1	3	2	5	1
AS7	5	1	4	1	5	1	3	2	2	2	3	1	4	3	3	2	4	2	1	1	3	1	2	1	2	1	1	2	1	1
AS8	4	1	4	1	5	1	3	1	3	3	3	1	2	1	3	1	5	1	2	2	2	1	2	1	2	1	2	1	5	1
AS9	4	1	1	2	5	1	3	1	4	1	3	1	4	1	3	1	1	2	2	1	2	1	2	2	2	2	2	1	4	2
AS10	5	1	4	2	5	1	3	2	1	2	1	2	4	1	1	1	1	1	2	2	2	1	2	1	1	1	2	2	5	1
AS11	5	1	3	1	5	1	3	1	1	1	3	1	4	1	1	1	2	1	1	1	2	1	1	1	1	1	2	1	1	1
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AS19	5	1	2	1	5	1	3	1	1	1	1	2	2	2	1	1	5	1	4	2	2	1	4	1	1	1	2	1	5	1
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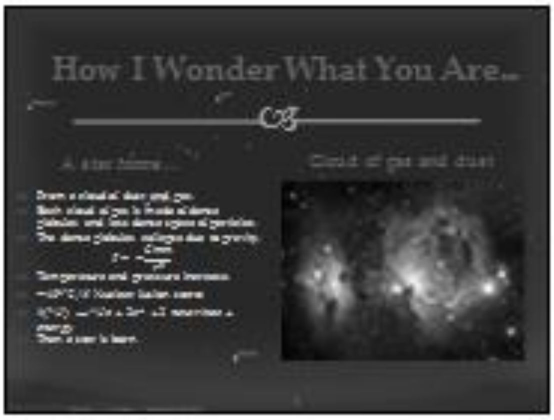
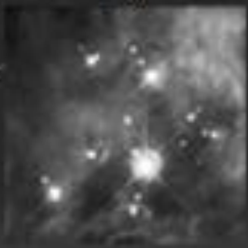
AS21	4	1	4	1	5	1	3	1	1	2	3	1	1	1	1	2	4	1	1	2	2	1	1	2	1	2	2	1	4	1
AS22	5	1	4	2	5	1	4	2	1	1	3	1	2	2	1	1	4	2	1	1	2	1	3	2	2	1	2	1	5	1
AS23	5	1	4	1	5	1	2	2	1	1	3	1	1	2	3	1	3	1	1	1	2	1	3	1	4	2	2	1	3	2
AS24	5	1	4	1	5	1	4	1	4	2	3	2	1	1	3	1	5	1	1	1	2	1	1	1	2	1	2	1	2	1
AS25	5	1	3	1	5	1	3	2	1	2	3	2	2	1	3	2	5	1	1	1	2	1	1	1	1	1	2	1	2	2
AS26	5	1	3	1	5	1	3	2	1	2	1	2	4	1	4	1	2	2	2	1	3	2	2	2	2	1	3	3	5	2
AS27	5	1	3	1	5	1	4	1	1	1	3	1	1	1	1	1	5	1	1	1	2	1	1	2	1	2	1	2	2	2
AS28	5	1	3	2	5	1	3	2	1	2	3	2	2	2	1	1	4	1	2	2	2	1	1	2	1	2	2	2	5	2
AS29	5	1	4	1	5	1	4	1	1	1	3	1	4	1	3	1	4	1	4	1	2	1	2	1	2	1	1	1	5	1
AS30	5	1	4	1	5	1	4	2	1	2	3	2	2	3	2	1	5	1	1	1	2	1	2	1	1	1	2	1	5	1
Answers																														
Answer	0	28	4	21	0	28	3	14	16	13	4	22	5	16	10	23	3	18	15	18	3	25	10	19	15	23	7	19	3	18
Answer	0	2	1	9	0	2	1	16	2	14	0	8	14	10	2	6	6	10	9	12	21	4	16	11	13	7	20	10	4	11
Answer	0	0	5	0	0	0	20	0	8	3	26	0	2	4	17	1	1	2	3	0	5	1	3	0	1	0	3	1	3	1
Answer	5	0	20	0	0	0	6	0	4	0	0	0	9	0	1	0	6	0	3	0	0	0	1	0	1	0	0	0	3	0
Answer	25	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	1	0	0	0	0	0	0	0	17	0

Appendix O: Lesson slides



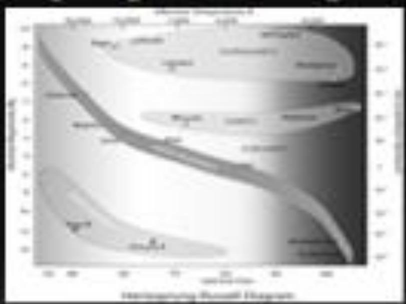
Trapezium stars ~1 000 000 years old



Main Sequence stars

- What is the nearest star?
- A star survives due to the balance in forces which keeps a star in place.
- These forces are:
  1. Gravity: which is an inward force (pulls everything towards each other, thus making the star to fall into itself)
  2. Radiation: which is an outward force (this comes in a form of the energy released during the nuclear fusion H→ He)
- Most stars live most of their lives in the main sequence, as nuclear fusion continues, Hydrogen →Helium→ to other heavy atoms; exothermic reactions continue

Hertzsprung-Russell Diagram

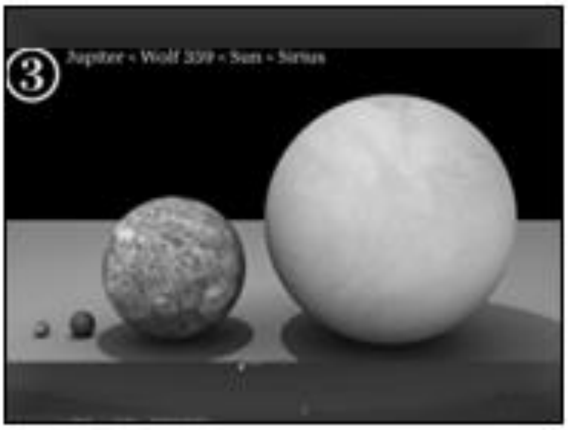


Using the HR diagram

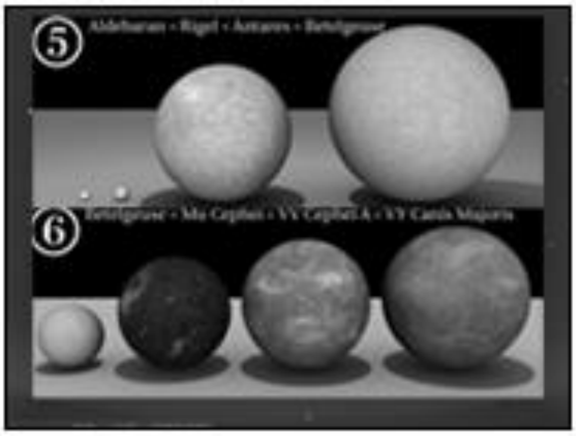
1. What colour are the hottest stars?
2. What colour are the coolest stars?
3. What category of stars is hot but not very luminous?

Stars are different

- They have different colours
- They have different temperatures
- They have different sizes
- And they have different distances (has nothing to do with the star, but it is related to us) – Parsec

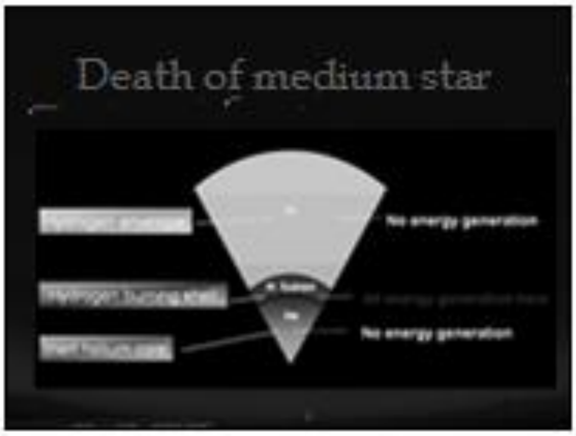



4
Sirius • Pollux • Arcturus • Aldebaran

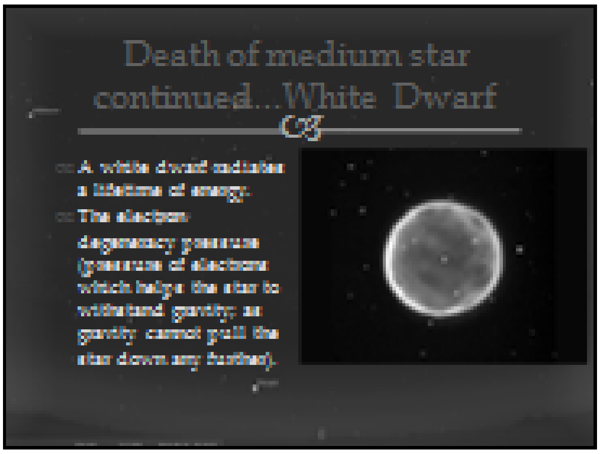

5
Aldebaran • Rigel • Antares • Betelgeuse
6


Characteristic of a Medium star
Low Temperature
Low Pressure
Slow fusion rate
Very long life (5 -50 billion years)
Medium star ~ 1 solar mass (1 times the mass of the Sun) = 1M☉
New born medium stars ~ 0.05 time the mass of the sun.

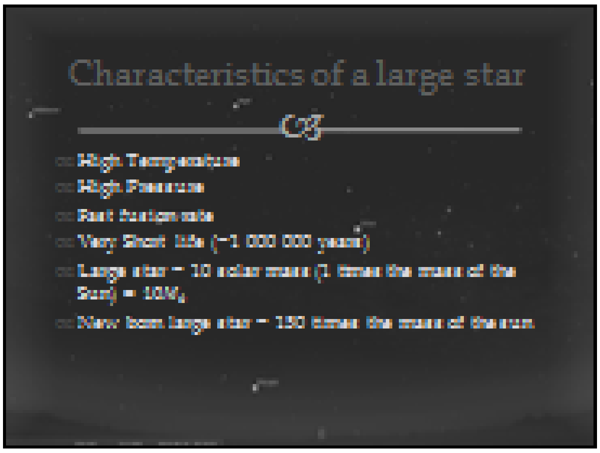

Medium star life
As nuclear fusion continues, the Hydrogen runs out; then Helium starts reacting forming heavy elements.
When the nuclear fusion converts to Carbon and then stops; when nuclear fusion stops gravity takes over.
As they age they swell up and cool down (swell up as big as Antares is; which is at about 3000°C).
Gravity holds the particles inside together.

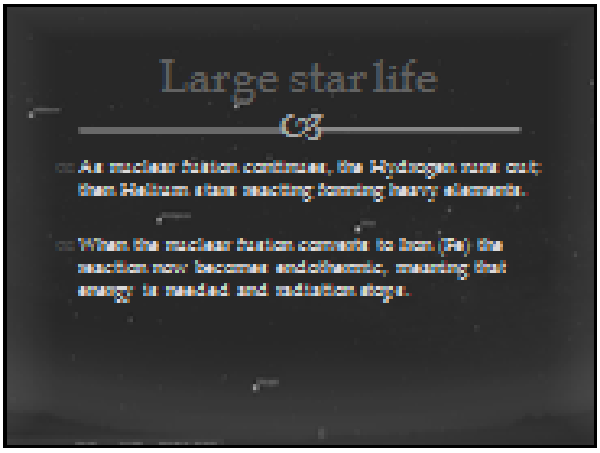

Death of medium star
No energy generation
No energy generation

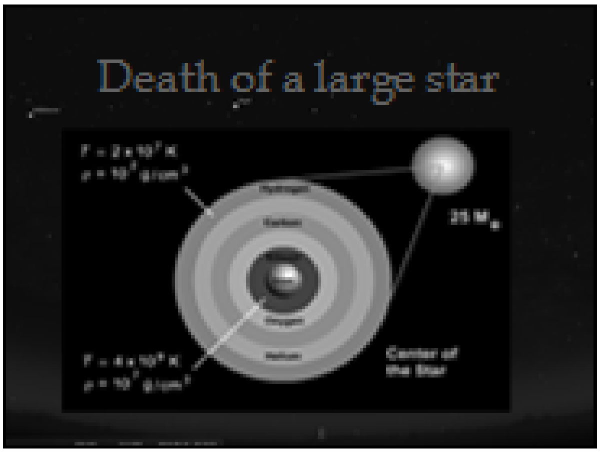

Death of medium star life
continued…

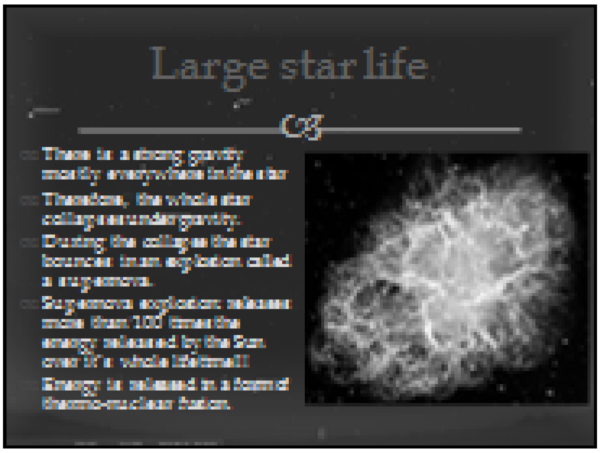

Death of medium star continued…White Dwarf
A white dwarf radiates a lifetime of energy.
The electron degeneracy pressure (pressure of electrons which helps the star to withstand gravity; as gravity cannot pull the star down any further).


Planet Neptune as seen from a telescope

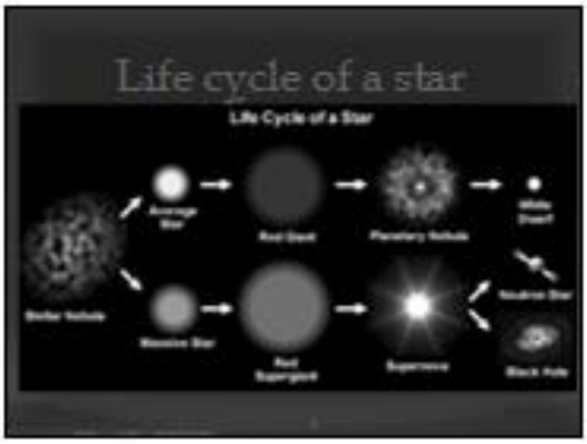

Characteristics of a large star
High Temperature
High Pressure
Fast fusion rate
Very Short life (~1 000 000 years)
Large star ~ 10 solar mass (1 times the mass of the Sun) = 10M
New born large star ~ 150 times the mass of the sun

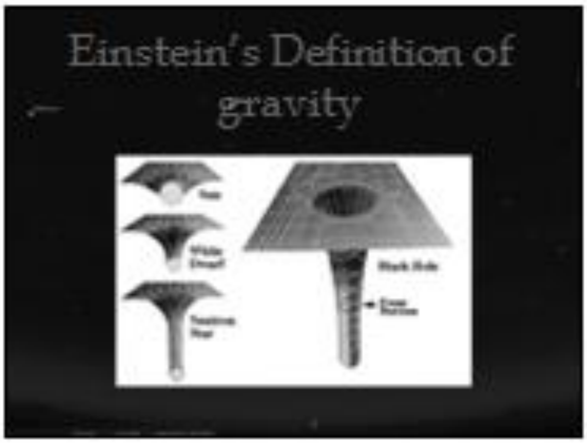

Large star life
As nuclear fusion continues, the Hydrogen runs out; then Helium stars reacting forming heavy elements.
When the nuclear fusion converts to Iron (Fe) the reaction now becomes endothermic, meaning that energy is needed and radiation stops.

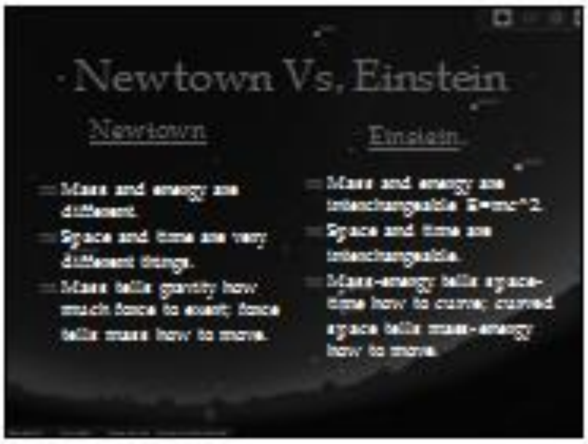

Death of a large star
Hydrogen
Carbon
Oxygen
Helium
Center of the Star


Large star life
There is a strong gravity mostly everywhere in the star
Therefore, the whole star collapses under gravity.
During the collapse the star bounces in an explosion called a supernova.
Supernova explosion releases more than 100 times the energy released by the Sun over it's whole lifetime!!!
Energy is released in a form of thermo-nuclear fusion.


Death of large star life continued….
Large
Massive
2 solar masses, 20 km wide
Neutron star (which has a high density). Think about if we can compresses Massing black into a tsp.
A neutron star is held together by the neutron degeneracy pressure.
Black hole which is very much denser.
A black hole has so much matter in it that even when you shine light in, it cannot escape it.


Life cycle of a star
Life Cycle of a Star


Einstein's Definition of gravity


Newtown Vs. Einstein
Newtown
Einstein
Mass and energy are different.
Space and time are very different things.
Mass tells gravity how much force to exert; force tells mass how to move.
Mass and energy are interchangeable E=mc^2.
Space and time are interchangeable.
Mass-energy tells space-time how to curve; curved space tells mass-energy how to move.


Stars can't shine without darkness
hydrogen and nuclear fusion