Cape Peninsula
University of Technology

The use of concept mapping to enhance the teaching of chemical equilibrium in a Grade 12 physical science tutoring classroom

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Thesis submitted in fulfilment of the requirements for the degree
Master of Education

in the Faculty of Education

at the Cape Peninsula University of Technology

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January 2014

DECLARATION

I, Deré Langford, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

24 January 2014

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ABSTRACT

There is currently a strong emphasis on the teaching of Physical Sciences in the school system. The National Department of Education has established Dinaledi schools to address this situation to increase the number of learners taking Physical Sciences as one of their school subjects and to also increase the number of passes in the subject. Furthermore, Physical Sciences learners struggle to understand certain scientific concepts and develop alternative ideas about these concepts that have a negative influence on further development of other integrated science concepts. The thesis proposes the importance of developing concept mapping to enhance the teaching of topics in a Physical Sciences classroom.

The research focused on the chemical equilibrium in a Grade 12 Physical Sciences tutoring classroom. This happened in a group setting, with learners enrolling with the specific aim of improving their marks for Physical Sciences as one of the important gateway subjects for entrance to tertiary education. The research focused on their prior knowledge of the topic and how they understood the topic. Using social constructivism as underpinning theoretical framework, and conceptual change theory, learners were taken through a process to identify and rectify their alternative ideas on chemical equilibrium. In this, perspective learning is seen as a social process in which learners actively participate and contribute with their understanding and arguments.

The research was carried out in a science tutoring classroom and focused on three groups from secondary schools in the Paarl Valley, Drakenstein area, Western Cape, South Africa. The groups were taught and observed in the science tutoring classroom with special attention to data collection in order to capture their thinking and work on the topic. Data were collected by means of concept mapping, where each learner completed a minimum of three or maximum of four concept maps. Within each concept map, learners connected key concepts of the topic with one another. Each concept map identified the learner's prior knowledge as well as any alternative ideas created by using existing frameworks.

Data were analysed using a rubric to determine each concept map's quality. Conclusions were that learners became actively involved in the process of concept mapping as well as learning. There were no definite differences between higher performing and lower performing learners. As for the enhanced teaching aspect, alternative ideas were identified quickly using the concept maps; these were centred on the individual learner, and were not general.

ACKNOWLEDGEMENTS

I wish to thank:

- My supervisor, Dr Kalvin Whittles, for all the support and academic guidance during the research.
- TriClin Educational Services and Training (TEST Learning Centre) for allowing me to work with their learners, as well as granting permission to use one of their classrooms.
- The Western Cape Educational Department (WCED) for giving me permission to conduct my research.
- The Faculty of Education and Social Sciences Ethics Committee of the Cape Peninsula University of Technology (CPUT) for granting permission to conduct this study.
- The Cape Peninsula University of Technology (CPUT) for giving me the opportunity to complete my MEd degree.
- Professor Rajendra Chetty for the Research and Methodology course and assistance.
- Dr Elizabeth van Aswegen for proofreading and editing of the thesis.

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GLOSSARY

LIST OF ACRONYMS

CMAP	Concept Map (Programme)
CM	Concept Map
CPUT	Cape Peninsula University of Technology
DBE	Department of Basic Education
DoE	Department of Education
HPB	High Performing Boy
HPG	High Performing Girl
HPL	High Performing Learner
K_c	Equilibrium constant
LPB	Low Performing Boy
LPG	Low Performing Girl
LPL	Low Performing Learner
MIT	Misconception Identification Test
NSC	National Senior Certificate
P1-HPG	Participant One – High-Performing Girl
P2-HPG	Participant Two – High-Performing Girl
P3-LPG	Participant Three – Low-Performing Girl
P4-HPB	Participant Four – High-Performing Boy
P5-LPB	Participant Five – Low-Performing Boy
TEST	TriClin Educational Services and Training
UM	University of Minnesota
VUE	Visual Understanding Environment
WCED	Western Cape Education Department

CHAPTER ONE
OVERVIEW OF THE PROPOSED STUDY

1.1 Introduction

People today live in a scientific era where science intrigues young and old; it is therefore essential to develop a set of thinking skills necessary to understand certain concepts. People, students and learners think rationally about ideas, information and knowledge, but the questions that arise are:

- Are all of the concepts gathered by people, students and learners scientifically acceptable?
- If there are some unacceptable concepts, how can we change them?

This chapter provides an introduction to the research presented in this thesis. It describes the research background and explains the rationale for pursuing this study. In addition, it provides an overview of the approach taken as well as the results obtained. Finally, it introduces the structure of the thesis.

This study addresses the use of concept mapping to enhance the teaching of chemical equilibrium to Grade 12 Physical Sciences learners in science tutoring classrooms. The study is underpinned by Piaget's theory of constructivism, which includes the principles of assimilation and accommodation, the existing knowledge of learners, conceptual change theory and the concept mapping model. This is further described in the *5-C-framework* as part of the theoretical framework.

1.2 Background to the study

The Department of Education (DoE) (Taylor & Prinsloo, 2005) and all the nine provincial departments introduced the Dinaledi project, which aims to increase the number of learners taking Physical Sciences and mathematics as school subjects. The project started in 2006 with 400 schools and is still active (500 schools in 2008), and the performance of these schools is continuously monitored. The Department of Education's (2009a) main objective related to the project is to boost learner performance in Mathematics and Physical Sciences. Yet despite of all the support from the Dinaledi project (DoE, 2009a), the results are still very poor. Of the 218 156 learners that wrote Physical Sciences, 98 060 failed. This translates into a pass rate of 54% (a pass is an achievement between 30% and 100%). The above-mentioned numbers include Dinaledi schools, where 40 379 learners wrote Physical

Sciences. Of the 40 379 learners, 11 975 failed and 28 404 passed. Most of the successful (passing) learners fell in the 30% - 49% group.

The Dinaledi project (DoE, 2009a) found that the number of schools that achieved 100 plus learners achieving a 50% pass rate increased drastically in 2008. This shows that there is an indication of some improvement. But while mathematics learners exceeded the overall outcome performance targets, this did not apply to Physical Sciences, where these results were lacking. Only five schools achieved 100 plus learners with a 50% pass rate.

The Western Cape Education Department (WCED) (2012) developed a strategy to help improve the poor results of mathematics and Physical Sciences learners. The Strategy for Mathematics and Physical Sciences has two outcomes: to increase the number of learners taking mathematics and Physical Sciences and to increase the quality of passes for the subject. This strategy falls under the Dinaledi schools. Focusing on Physical Sciences, the following table indicates the National Senior Certificate (NSC) results between 2008 and 2010. This is captured in Table 1.1 below (Western Cape Education Department, 2012).

Table 1.1: Learners that passed against target set

Year	Learners that wrote	Learners that passed	Target set (Pass rate)
2008	13 612	9 691 (71.2%)	No target set
2009	13 347	7 064 (52.9%)	9 690
2010	12 626	7 524 (59.6%)	10 000

The pass rate for 2008 was very high, with 71.2% of all the Physical Sciences learners passing. This decreased rapidly by 18.3% for 2009. Although the rate increased from 2009 to 2010, the result did not achieve the target set by the government. On a positive note, the number of learners scoring between 80% and 100% increased from 519 in 2009 to 1139 in 2010 (WCED, 2012).

Furthermore the number of learners enrolling for Physical Sciences is dropping. The results are shown in Table 1.2.

Lastly, in 2009, the WCED set some targets for the number of Grade 12 learners (for NCS) that should pass Physical Sciences. The targets were set for the next ten years, 2009 to 2019, and were aimed at increasing the number of learners enrolling for Physical Sciences as well as the improvement of the average result for the subject. The targets are identified in Table 1.3.

Table 1.2: Overall Physical Sciences enrolment (Adapted from WCED, 2012)

	2008	2009	2010	2011
Grade 12 learners enrolled	12 997	12 741	11 986	10 225

Table 1.3: Targets set for ten years (Adapted from WCED, 2012)

	2009	2010	2012 (Current)	2014	2019
Physical Sciences passes	9 690	10 000	11 500	13 500	16 000

I currently work as a tutor of Physical Sciences learners. From my experience and observations, the reasons for the low pass rate in Physical Sciences could be attributed to the way learners interpret concepts. Learners develop these Physical Sciences concepts in an informal way, which is not always scientifically acceptable. This opens an avenue for conceptual change theory as a framework and the use of concept mapping to investigate if these scientifically unacceptably developed concepts can be changed to scientifically acceptable concepts. This could help in working towards reaching the overall targets set by the WCED and the Dinaledi project. Tutoring, whether working with smaller groups or individual teaching and support, is helpful in changing concepts to enhance better understanding of certain science topics.

1.3 Purpose and research questions

The purpose of the study is to investigate how the use of concept maps could contribute to enhancing the teaching of chemical equilibrium in a Grade 12 science tutoring classroom. Enhancing, within the context of the study, refers to high-performing learner (HPL) and low-performing learners (LPL) replacing their existing unacceptable concepts on the topic with scientifically acceptable concepts under the framework of conceptual change theory.

The research questions for this study are:

- What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?
- How does concept mapping enhance Grade 12 learners' understanding of chemical equilibrium?

1.3.1 Research questions

The first research question is, “What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?” This research question forms the basis of the study, in other words, before any changes and/or rearranging can take place, the learner’s existing knowledge framework needs to be identified. Literature (Şendur *et al.,* 2010: 2*)* identifies certain concepts surrounding chemical equilibrium and provides a generalisation of alternative concepts/ideas/frameworks within this topic. Not all the information on a single alternative idea will apply to every learner, because a learner is seen as an individual creating his/her own individual framework. Therefore not every learner will have the same concepts as the next and the research concurs with this. The first constructed concept map may indicate the learner’s current framework as well as identify the existing alternative ideas.

The second research question is, “How does concept mapping enhance Grade 12 learners’ understanding of chemical equilibrium?” Concept mapping works as a natural progression from the first research question. This research question attempts to ascertain if concept mapping establishes an enhancement of learners’ understanding. This question will be studied throughout the concept mapping process.

1.4 Research outline

For the research outline, the theoretical framework, literature review, data collection methods and analysis methods come under discussion. This study uses a *5-C-framework*:

- C1: Constructivism
- C2: Conceptual change theory
- C3: Cognitive thinking
- C4: Concept mapping
- C5: Chemical equilibrium

Each “C” in this framework links with the other as seen in Figure 2.3 in Chapter Two and captures the main constructs under consideration for this study. First up under discussion is the dual nature theoretical framework.

1.4.1 Theoretical framework

The theoretical framework has a dual nature, using *C1: Constructivism* and *C2: Conceptual change theory*. Conceptual change builds upon that which constructivism has created, meaning existing knowledge, concepts or ideas. Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner; therefore each learner has to construct his or her own knowledge. In order to construct knowledge the learner uses his/her own beliefs, interpretations and ideas to interpret information conveyed by the teachers, parents or any knowledgeable person (Robottom, 2004). This study uses the constructed ideas and determines whether they are scientifically acceptable or not.

The previous view is therefore a more individual construction, thus highlighting the theory of constructivism (*C1*). Suping (2003) and Robottom (2004) argue that constructivism is a notion of the influence of learners' cultures and biographies (concepts are constructed around this), whereas science knowledge is less socially constructed. This type of knowledge is constructed by scientists and reconstructed by the learners, sometimes incorrectly. Constructivism combines very well with concept mapping, because learners construct their own understanding of certain concepts (Trowbridge & Wandersee, 1994), which can be represented on a concept map. In the next chapter constructivism is discussed, and the form of constructivism pertaining to this study will be identified as social constructivism.

According to Blok (1982), Piaget identified two concepts, assimilation and accommodation, for a developmental context. Novak (1990) and Suping (2003) further state that, according to Piaget's research, assimilation is directly linked to constructivism, because learners are reluctant to obtain new concepts and replace older concepts.

Ausubel (1968) states that the basic principles of the assimilation theory are displayed when a learner assimilates new concepts and positions them inside the learner's existing conceptual framework. The placing or positioning of the new concepts is also known as the learner's cognitive structure, which acts as the learner's knowledge framework. According to earlier Piaget research (Novak, 1990), the learners are now restricted by the quality and quantity of their existing knowledge (gathered through experiences and instructions).

> *A simple example of Piaget's assimilation and accommodation is when a child sees a zebra for the first time and calls it a horse. The child assimilates this information in the horse category. The new information is accommodated and other variables are taken into consideration (such as the horse has stripes). When the name of the horse with stripes is obtained, the child accommodates the new information in its own category. And it is classified as a zebra (adapted from Chinn & Brewer, 1993: 12)*.

Accommodation is also important within constructivism. It describes the cognitive thoughts that obstruct the explanation of new concepts (Suping, 2003).

Learners come to the science class with their own ideas, beliefs and understanding of how things work (Robottom, 2004); therefore learning is not filling the learner's head with information and data, but changing or working with their existing ideas and beliefs. This highlights the importance of conceptual change theory (*C2*) in the science classroom. Constructivism is a major theory when working with conceptual change theory. The existing concepts included in the conceptual change theory are the concepts learners shape from the world they live in, meaning their social context.

Novak (1990) argues that one of the most important single factors influencing learning is what the learner already knows; in other words the learner's existing knowledge (Robottom, 2004). Determine this and teach him accordingly. A blockade is formed when teachers want to develop new concepts (the construction process is constrained). There would be a difficult shift between existing knowledge and the new knowledge that should be assimilated.

The ability (and inability) to change one's concepts is theorised as a certain model, the conceptual change theory (*C2*). The conceptual change model also has certain implications in the classroom, and can result in a failed attempt. The size of the class and the attitude of the learner are just two examples of the implications. Suping (2003) also identifies four conditions that have to be met before accommodation can occur:

- There has to be dissatisfaction with the existing concepts.
- The new concept must be understandable.
- The new concept must be convincing and reasonable.
- The new concept must be able to sprout a research programme.

The dual nature of constructivism (*C1*) and conceptual change theory (*C2*) is an important aspect of this study. Conceptual change builds upon constructivism, using the learner's existing knowledge and changing it.

1.4.2 Literature review

This study uses conceptual change theory (*C2*) throughout the concept mapping (*C4*) process, where the learners change and/or reconstruct their existing knowledge and concepts within the topic of chemical equilibrium (*C5*).

Teo and Gay (2006: 4) describe concept mapping as a way of representing knowledge in graph form, where concept maps are the representation of knowledge based on concepts and the links between two or more concepts. Concept maps mainly consist of nodes (concepts), linkage lines (unidirectional arrow) and linkage phrases (describing the relationship between two nodes) (Mistades, 2009). The combination of these terms is called the proposition. The linkage line will link two nodes with the linkage phrase. The second most important part of a concept map is the structure, which is determined by the orientation of the nodes. This will determine if the structure is hierarchical or non-hierarchical. There are five possible structures – *Linear*, *Circular*, *Hub spokes*, *Tree* and *Network*. At the end of the study the learners' concept maps should transform from a linear structure into a network structure.

Concept mapping (Mistades, 2009) uses the learner's cognitive understanding of concepts (as well as the learner's existing knowledge framework) to create a network from which the educator can get a glimpse of the learner's qualitative aspect of learning. Mistades (2009) further elaborates that concept maps will provide a basic understanding of where the learner has certain alternative frameworks, alternative ideas and alternative concepts.

Alternative ideas (Erdemir, Geban, & Uzuntiryaki, 2000 and Şendur, Toprak, & Şahin Pekmez, 2010) are formed in the learners' minds by using the socially obtained knowledge and forming knowledge frameworks. A concept only becomes an alternative idea when the learner's existing concepts are in conflict, or are seen as incorrect, with the correct scientific view. According to Kousathana and Tsaparlis (2002), the most common alternative ideas or errors are related to dynamic characters of chemical equilibrium, the forward and backward reaction rates, the effect of a catalyst, and the reaction rate versus the extent.

Specific concepts in the field of chemical equilibrium are collision theory; rate of reactions (or reaction rate); concentration; equilibrium shift; dynamic equilibrium; equilibrium constant; Le Chatelier's Principle; and the concept within stoichiometry (Van Zyl, Craül, Meyer, Muller, Spies, & Van Harte, 2003: 290-292, 296; Long & Victor, 2009: 118-120, 124). These are just some of the concepts within the topic. Erdemir *et al.* (2000); Kousathana and Tsaparlis (2002) and Şendur *et al.* (2010) state that chemical equilibrium problems are some of the most difficult and complex problems in chemistry and are therefore also the most important, because they are related to further subjects such as solubility, electrochemistry, and acids and bases.

Asan (2007) states that in science many different concepts are linked with one another and that some concepts are built from base concepts (as seen in the last sentence in the previous paragraph). Because of the conceptual change and concept networking capabilities, concept mapping will be very helpful in the science classroom.

1.4.3 Data collection and analysis

This study, with the focus on the enhancing effect of concept mapping (*C4*), falls under a qualitative paradigm. Qualitative research attempts to describe and make sense of, rather than to explain, human behaviour. The choice of this approach is relevant as the study under discussion explores the concept problem among Grade 12 learners. This study endeavours to research whether concept maps can change existing concepts to new acceptable concepts in order to enhance Physical Sciences teaching.

An introductory lesson will be given to the participating learners (HPL and LPL) to ensure they understand the concept of concept mapping. The focus of the lessons will be the explanation and construction of concept maps, because this concept will be new to all the learners.

First data will be collected in the form of the different concept maps. Why should a concept map be used? According to Zeilik (1998), it shows how well the learner can see the big picture. Or in other words, it illustrates the learner's conceptual knowledge. Each learner will construct a minimum of three to four concept maps. Each map will show data in the form of concepts, links (with their linkage term or concept), and alternative ideas and newly formed scientifically acceptable concepts, but the first map will show the learners' existing/previous knowledge together with all the existing alternative ideas created by the learners.

Kern and Crippen (2008) use four activities in order to complete the concept mapping process. In the first activity the learner will complete the first concept map; the learner is given a set of concepts (*concept bank*) from the subject field and uses the concept words and existing knowledge to construct a concept map. This concept map will show the learner's existing knowledge in the form of the different concepts connecting one another.

The second activity (Kern & Crippen, 2008) consists of the evaluation of the first concept map. Here certain problem areas are taken into account and lessons should be given on the topics (this would create a conflict with the learner's existing knowledge framework). After the lesson, the learner completes another concept map. The third and fourth activity is a repeat of the second activity. Within these activities the learner constructs two more concept maps. If there are still problems after the second or third concept map, more lessons should be given on areas of concern. The fourth (or third) concept map is the final map and this would be evaluated. The final map should be in the form of a network rather than in linear form.

There is more than one way to score or analyse a concept map, but we mainly score the components in the concept map (focusing on the propositions [the concepts]; hierarchy levels [linkages] and examples). Asan (2007) scores the concept maps using a positive (+1), negative (-1) and neutral (0) scoring system. A positive score is given for each base concept used on the concept map, which is correctly linked to the next concept; a negative score is awarded if there is an error with the linkage between two concepts, and when one of the concepts is missing, a neutral score is awarded. In Kern and Crippen's (2008) research they found that the University of Minnesota (UM) supplies a detailed rubric for the assessment of concept maps. This rubric is specifically detailed around four different categories.

Another type of analysis is to compare the learner's maps with maps of specialists. Figures 3.1 and 5.6 are examples of a specialist's chemical equilibrium concept map. Score the following by observing the concept maps – Number of concepts present; concept linkages; branching; hierarchies; cross-linkages and examples.

The concept maps will measure the improvement from the previous map using a scoring method, which will be refined during the pilot study. The analysis of the first concept map will indicate and inform the researcher on the key concepts that are needed during the lesson time. Thereafter the analysis of the follow-up concept maps will indicate the same, as well as whether conceptual change is taking place. In order to analyse conceptual change, the concepts of a previous map would be compared with a current map.

After the final concept map, a follow-up interview will be done with each learner. Questions can be redirected to ensure that each one is answered fully; this supplies a rich form of data (Johnson & Christensen, 2004). Questions asked in the interview will follow up on whether there were any uncertainties on any of the learners' concept maps. Each interview would be conducted after the analysis of a concept map. Table 1.4 contains a summary of the data collection methods.

Table 1.4: Different data collection methods

Data collection method	Data analysis method	Description
Concept maps	*"Scoring-method"*	Scoring linkages between concepts on the concept map positively, negatively or neutrally.
	"Rubric-method"	Scoring the concept maps according to detailed descriptions in four categories.
	"Expert's map-comparison-method"	Scoring the concept map by comparing it with an expert's.
Follow-up interviews		Asking the learners questions about uncertainties on their concept maps.

Reliability in research refers to the consistency or generalisation of the research (the collection method as well as the analysis method), therefore how the concept maps are scored and whether or not the method of scoring can be repeated. Puiz-Primo and Shavelson (1996) state that to ensure the reliability of the concept map, maps could be scored using an expert's map. However Golafshani (2003) contends that to ensure reliability, the trustworthiness of the research is very important.

Wilson (1993) notes that concept mapping has been used as a research tool over the years. Concept mapping is also an excellent meta-cognitive tool (Kinchin, Hay, & Adams, 2000) which promotes understanding when the learner places newly obtained information in an existing cognitive structure. This is also known as meaningful learning.

Traditional tests do not indicate development by the learner; they only focus on existing knowledge. In traditional tests the learner can supply a ‘correct’ answer, but nothing is done to correct the learner’s alternative idea. Some interesting findings have shown that concept map scores correlate poorly with typical standardised classroom test scores, but better with transfer problem solving (Wilson, 1993). Svedkauskaite (2005) adds that concept mapping has gained popularity as an enhancement tool and continues to describe one advantage, namely that a concept map being used as an assessment method has the ability to show learners’ understanding of concepts and to identify and/or show improvement in alternative ideas. Concept maps are not confined to being used as an assessment tool but can also be used as an evaluation tool.

Kinchin, Hay and Adams (2000) state that concept mapping can enhance learning in science classrooms. Concept mapping (Svedkauskaite, 2005; Asan, 2007) has an influence on the learner’s achievements and attitudes. This was confirmed in the study, where learners showed a better understanding of concepts which in turn prepared them for future Physical Sciences classes. Overall it helped them to explain their own learning. Concept mapping teaches students to make an effort, and Asan (2007) describes the effort as an effort to understand the meaning of concepts, organise concepts in hierarchical form, and form relationships between concepts (to ultimately form a network of concepts). Research over the last ten years has focused on strategies for changing alternative conceptions for chemical equilibrium, but this research focuses on using a certain strategy to change these concepts.

1.5 Conclusion

Previous research has provided evidence that concept mapping is a powerful tool to promote meaningful learning. In science education especially, concept maps are used to see what the learner knows, to view the conceptual understanding over a period of time, and to view the learner’s cognitive process (Wilson, 1993; Svedkauskaite, 2005). Concept maps are a great asset to science education (Svedkauskaite, 2005). This study will use collected data to answer the research questions to assess the effect of concept mapping on the tutoring science classroom.

This chapter gave an outline of the proposed study. The table below captures the outline of the thesis by way of the chapter titles.

Table 1.5: Thesis outline

Chapter	**Title**
One	Overview of proposed study
Two	Literature review
Three	Methodology
Four	Pilot study
Five	Data analysis of final phase
Six	Reflection on study

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The literature review comes under discussion in this chapter. Pertinent to this discussion are the Grade 12 Physical Sciences topic of chemical equilibrium and the research questions for this study: "What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?" and "How does concept mapping enhance Grade 12 learners' understanding of chemical equilibrium?"

In the teaching of any topic, one has to consider what the learner knows and how one could affect the existing concepts. There has been a definite shift, according to Saunders (1992), in educational focus from the past to modern times. In the past the focus was placed on the external factors impacting the learners, whereas today the focus is placed on the learner's cognition. This new focus includes the learner's existing knowledge, alternative concepts and cognitive style. An equally important aspect for this study is that learners (Nakhleh, 1992), in any grade, at any school, struggle to learn chemistry. A good educator knows to start with "where the learner is" (Carey, 2000: 13).

The discussion for this chapter is informed by a *5-C-framework*. This framework will be informed by the following five main constructs for this discussion:

- C1: Constructivism
- C2: Conceptual change theory
- C3: Cognitive thinking
- C4: Concept mapping
- C5: Chemical equilibrium

The study is informed by the dual theoretical framework of constructivism (*C1*) and conceptual change (*C2*). This is important as both speak to the development of concepts. Constructivism, on the one hand, is helpful in identifying the learner's existing concepts, while conceptual change theory assists the learner in changing his/her concepts. Throughout *C1* and *C2* a high level of critical and cognitive thinking (*C3*) is expected of the learners.

Concept maps (*C4*) are useful tools to assist the conceptual change process and from here the concept-changing aspect will be assessed. It is also necessary to pin-point an area of research (field of study). For this study the topic will be in Grade 12 chemistry – chemical equilibrium (*C5*) and its surrounding concepts. Specific concepts in the field of chemical equilibrium are collision theory; rate of reactions (or reaction rate); concentration; equilibrium shift; dynamic equilibrium; equilibrium constant; Le Chatelier’s Principle; and concepts within stoichiometry (Van Zyl *et al.*, 2003; Long & Victor, 2009).

The purpose of the study is to investigate how the use of concept maps could contribute to enhance the teaching of chemical equilibrium in a Grade 12 science tutoring classroom. Enhancing, within the context of the study, refers to high- and low-performing learners changing their existing incorrect conceptions on the topic to scientifically correct concepts under the framework of conceptual change theory.

Every ‘C’ in the *5-C-framework* has an important role inside the designed research process. Every ‘C’ is linked with the other and will be discussed in the following sections. The next section under discussion is *C1: Constructivism,* which plays an intricate part in the theoretical framework of this study. We need to establish what the learner knows before we can elicit change.

2.2 Constructivism

Constructivism is the first ‘C’ within the *5-C-framework*. Constructivism is one of the pillars of the dual theoretical framework used in this study. It is important to use this ‘C’, as it will help identify the learner’s existing concepts. This section will describe the baseline of constructivism; the different types of constructivism; which type will be chosen for the study; the role that cognitive conflict plays inside constructivism; assimilation and accommodation; as well as the implications constructivism holds for the science classroom.

Piaget’s (Posner, Strike, Hewson, & Gertzog, 1982) research on how learners interpret and experience phenomena had an extraordinary impact on modern-day learning theory. Learners use their senses to help them construct meaning and understanding. This is how they understand the world (Saunders, 1992). The learner creates these structures, beliefs or understandings in his/her mind to interact with the world. In short, Saunders (1992) explains it as the necessary subjective knowledge of the world. Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner; therefore this study will use concept maps to put these constructions on paper for observation. Constructivism has an important influence in the science classroom where learners use their own beliefs, interpretations and ideas to interpret information conveyed by the teachers (Robottom, 2004; Asan, 2007). Each learner has to construct his own knowledge. This view is therefore a more individual construction, thus highlighting the theory of constructivism.

Posner *et al.* (1982) state that we need to focus more on the leaner's content (where did the alternative idea come from? & why did it form?), rather than looking at the logical structure.

From Wing-Mui's (2002) perspective, science learning is viewed from a constructivist perspective, which involves epistemological and conceptual development. In other words, when constructivism interacts with science learning, it involves epistemological and conceptual development. Ishii (2003) defines constructivism as the way people understand the world and construct their own frameworks. Constructivism is classified as a theory of knowing, rather than a theory of knowledge. In this view constructivism is described as a lens one can look through to make sense of the world. This is constructed in the individual's mind together with reality, meaning, knowledge and learning.

Learning is a rational activity (Posner *et al.,* 1982), where learners experience and observe concepts and accept them as intelligible and rational. The rational meaning of learning focuses on what learning is, and not on what it is dependent. Learning (Wing-Mui, 2002), through a constructivist's view, is seen as a dynamic social process where learners construct knowledge, meaning or concepts from their observations or experiences in conjunction with their existing experiences. This is all done inside the learner's social setting. Constructivism allows the learner to become a more active member of learning and teaching, because when the learner arrives at the science classroom he/she already has his/her own understanding of how the world works and how certain natural events occur. In the framework of constructivism, the learner does not only receive knowledge from the teacher, but also uses "out of the classroom" knowledge. The teacher should discard the idea that a teacher is only there to manage the classroom and to supply knowledge.

There is a range of different constructivism types (Julie, Angelis, & Davis, 1993), and it is very important to choose the correct type to apply to specific situations. The reason for this is that a wide gap exists between the different types. To help choose the correct type of constructivism, one should consider or look for the underlying metaphors for the mind and world.

2.2.1 Types of constructivism

The literature identifies different types of constructivism, but for the ensuing discussion the focus will be on social constructivism. It will be argued that social constructivism, as one of the types of constructivism, is more suited to this study because of its focus on learning as a social process.

Steffe and Gale (1995) focus on two different types of constructivism, namely radical constructivism and social constructivism, while Ishii (2003) states that the term ‘constructivism’ describes about fifteen different types of constructivism. This includes adding the following adjectives to the word constructivism – contextual, dialectical, empirical, humanistic, information-processing, methodological, moderate, Piagetian, post-epistemological, pragmatic, radical, realist, social, and socio-historical.

Julie *et al.* (1993) and Raskin (2002) describe information-processing constructivism in the following way. This type of constructivism is defined as knowledge which is not passively received but actively built up by the cognising subject; and the rejection of an epistemologically sceptical principle. This combination forms a very weak form of constructivism. The metaphor of mind perceives the mind as a computer, processing the data. The metaphor of the world sees it as an “absolute physical space populated by objects”. The world is seen as unproblematic and knowable. Information-processing constructivism acknowledges that the learner is busy with active processes, both individual and personal, and that everything is based on the learner’s previous knowledge.

Julie *et al.* (1993: 168) describe radical constructivism as follows: radical constructivism is based on both the principles mentioned in information-processing constructivism and they elaborate: “The function of cognition is adaption and serves the organization of the experimental world, not the discovery of ontological reality.” Ishii (2003) explains the terms ‘weak constructivism’ or ‘radical constructivism’, which differ from the definitions of Julie *et al.* (1993). Weak constructivism is described as the individual constructing his/her own knowledge and accepting the existence of objective knowledge; whereas radical constructivism is described as the individual’s knowledge being in a continuous state of re-evaluation. We can therefore say that the individual’s knowledge is continuously being adapted and evolved. To summarise this constructivism, we see it as the ability to use cognitive structure to adapt to the situation and ultimately to survive.

2.2.1.1 Social constructivism

In this section an argument is advanced to contend why social constructivism is more appropriate for this study. Social constructivism (Julie *et al.,* 1993) is one of the newer types of constructivism. We can go as far as to say that it is not a form of constructivism, but a form of social-constructivism. In this type the real world is interconnected with the social world. Kim (2001), Robottom (2004) and Treagust and Duit (2008) support this contention by stating that the focus of social constructivism is mainly on culture and context within society and that knowledge is constructed using the understanding gained through society. The underlying metaphor here is perceived as conversation, where the individual uses language to form meaningful structures.

Social constructivism is based on certain assumptions (reality, knowledge and learning) and we need to understand these assumptions in order to apply a good instructional model, as researched by Kim (2001). Here reality is constructed through social activity, but reality does not exist prior to social invention (reality can therefore not be discovered). Knowledge is also constructed within the social context where individuals create a sense of meaning by interacting with one another. Learning is viewed as a social process and meaningful learning occurs when individuals are busy with social activities.

Julie *et al.* (1993) state that the model created in this type is a socially constructed one that shares the physical and social world's experiences. This is supported by Kundi and Nawaz (2010: 32), who note that social constructivism is a collective learning process that receives information from the community, peers and parents. Table 2.1 refers to the three types of constructivism and how they are applied within the context of this study.

Table 2.1: The three types of constructivism seen as metaphors of mind and world (Adapted from Julie *et al.*, 1993)

Type of constructivism	**Mind metaphor**	**World metaphor**	**Applied to this study**
Information-processing constructivism	Computer-processing information.	Absolute space with physical objects.	Placing obtained information in a framework.
Radical constructivism	Adapting to situations.	Private domain of experiences.	Applying obtained data to a situation and changing it if the situation changes.
Social constructivism	Conversations.	Socially constructed, shared world.	Concepts gathered from teachers and/or experiences.

The socially constructed model is modified constantly to adapt to the reality of real-world situations. In social constructivism there are two aspects that affect learning (Kim, 2001). One of the aspects comprises the symbol (language and logic) and mathematical systems that the learner obtains throughout his life; and the second aspect is the nature of interaction in society. Not everyone knows everything; therefore we need to interact socially with other knowledgeable people. From them we acquire the knowledge to use the system efficiently to promote meaningful learning.

Learners arrive at the science class with their own ideas, beliefs and understanding of how things work (Robottom, 2004). Therefore learning does not take place when the teacher fills the learner's head with information and data, but when we change or work with their existing ideas and beliefs. Learning is seen by Robottom (2004) as conceptual change, constructing and reconstructing concepts; this includes existing concepts. Constructivism is therefore a major theory when working with conceptual change; and constructivism, for example, radical or/and social, influences the way research is conducted on conceptual change (Treagust & Duit, 2008).

The following are the most important aspects, according to Julie *et al.* (1993) of a constructivist approach:

- assists learners when working with new methods in the learning process;
- helps learners to expand their knowledge of the subject or topic; and
- helps learners to develop instructional methods to promote meaningful learning and scientifically acceptable concepts – to create a sense of enthusiasm to learn and to be active within their own learning.

These aspects can also be applied to the role of the teacher. When we use constructivism in mathematical or scientific situations, we say that there are only true facts, principles, theorems and laws, as described by Ishii (2003). This is how knowledge is perceived in science. To clarify this statement, we can use Newton's gravitational law as an example – "Every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them" – there is only one way this law is defined and that is the correct way.

Of constructivism (Saunders, 1992: 136) states the following: "Meaning is constructed by the cognitive apparatus of the learner." The meaning of information or knowledge can only be created and formed by the learner in the learner's mind. The teacher can only convey the information, but the learner is the one that has to make sense of it.

"Wisdom can't be told" (Saunders, 1992: 136).

Wing-Mui (2002) states that when emphasis is placed on a constructivist instruction process, it increases certain areas in a science classroom. These areas include the learner's conceptual knowledge, active engagement with scientific content, and applying knowledge gained to real-world situations.

When learners (Bergquist & Heikkinen, 1990) want to understand new material, they must use the new knowledge and combine it with their existing knowledge. The main function of constructivism is to organise knowledge by using previous experiences or understandings. Past experiences formed from observing certain processes in the world are important for learners (Saunders, 1992), because they supply the learner with the ability to make predictions and to supply reasons for these predictions. These predictions don't always seem generally acceptable to the community or to scientists. But for the learner they make sense, because they have been rationalised by past experiences. When a prediction is made and the learner's past experiences provide an incorrect prediction, the learner must be placed in a situation where he or she must compare the cognitive universe with the natural universe. In other words, the learner must be placed in a cognitive conflict.

2.2.2 Cognitive conflict's role

Cognitive conflict (Treagust & Duit, 2008) plays an important role in conceptual change, when providing an assimilation and accommodation framework. Cognitive conflict also plays an important role in learning science, and learners need to experience the conflict in any form.

Previous studies showed conflicting results. Some studies, by Treagust and Duit (2008) conclude that conceptual change is positively influenced when a cognitive conflict strategy is used, whereas other research has found that cognitive conflict does influence conceptual change, but not sufficiently for the learners to change their existing concepts.

The effectiveness of cognitive conflict is determined by its usage. The effectiveness will be of greater value if it is conducted over a period of time, where frameworks and knowledge structures are enriched (Treagust & Duit, 2008) and transformed (restructured) rather than by a sudden change.

Saunders (1992: 137) also indicates a tenet of constructivism: “If the cognitive universe supports the natural universe, stronger bonds are formed on that specific mental construction, but as soon as the two universes don't comply with each other, a conflict is created.” The learner then has three options: discard the new knowledge, deny the existence of the knowledge, or rationalise the knowledge. When the newly obtained knowledge is ‘trusted’, it replaces the past (incorrect or unacceptable) experience, bringing a harmony between the cognitive universe and the natural observed universe. This is when meaningful learning occurs (Saunders, 1992). This is illustrated in Figure 2.1.

Bergquist and Heikkinen (1990) emphasise that learners will try to find a state of equilibrium when new concepts are placed within (or replaced) the existing conceptual framework by using assimilation and accommodation.

2.2.3 Assimilation and accommodation

Currently learners will use their existing concepts to deal with new experiences. This is also known as assimilation (Posner *et al.,* 1982). Novak (1990) and Suping (2003) state that, according to Piaget's research, assimilation is directly linked to constructivism, because learners are reluctant to obtain new concepts and replace older concepts.

Ausubel (1968) observes that the basic principles of the assimilation theory are displayed when a learner assimilates new concepts and positions them inside the learner's existing conceptual framework. However, in more than one situation, the learner's existing concepts are inadequate to successfully understand the new experience. The existing concepts therefore need to be replaced or reorganised, which is known as accommodation (the radical form of conceptual change). One question that comes to mind is how accommodation would take place. To answer the question Posner *et al.* (1982) conclude that certain conditions have to be met before accommodation can take place. These conditions will be discussed in the conceptual change chapter (see *C2: Conceptual change*). Learning will take place against the background of the learner's existing knowledge; in other words, accommodation is an important aspect of constructivism (Suping, 2003). According to Teo and Gay (2006), a learner's motivation is a very important issue within the learning process, as learners will restructure or assimilate new data only when accommodation fails.

Ausubel (1968) stresses the importance of existing knowledge in the process of accepting new concepts, but according to Chiu, Chou, and Liu (2002) learners struggle to do this in chemical equilibrium. On the other hand, researchers have found that in some cases not all the existing concepts are replaced and learners will keep some of the concepts to help them through the conceptual change process.

Treagust and Duit (2008: 4) give the following advice: An intelligible concept is one that is understood by the learner and it is non-contradictory. A plausible concept is one that the learner believes in addition to the existing knowledge. A concept is seen as fruitful when it is used to solve a number of problems and not just one. It is also seen as fruitful when new research directions can be created. This is the way conceptual change is perceived and the order in which a concept needs to travel.

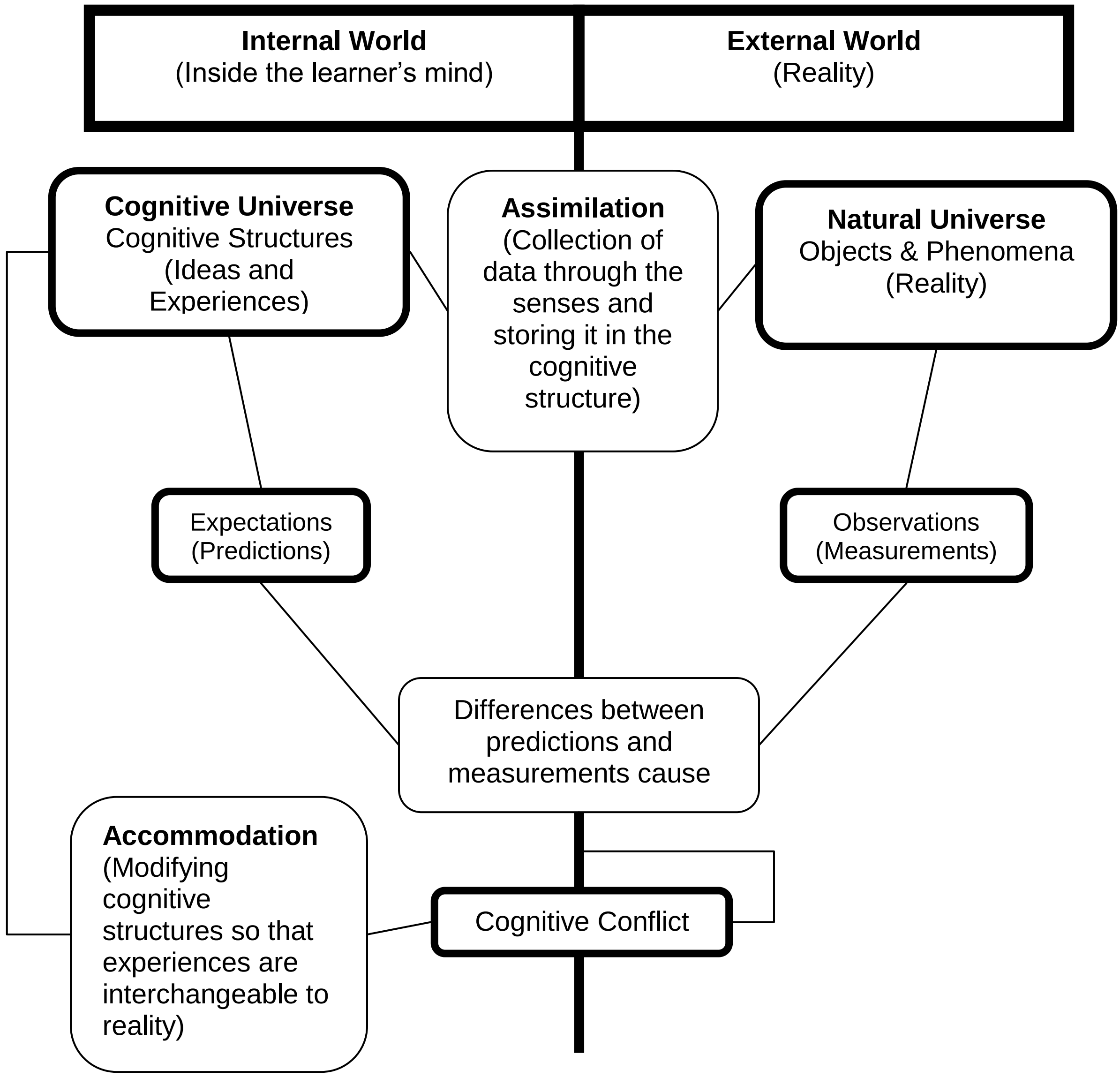

Figure 2.1: Adapted constructivism learning model
(Saunders, 1992: 139)

2.2.4 Implications

Constructivist perspectives (Saunders, 1992) form a dominant paradigm in the cognitive psychology field. It is from these perspectives that researchers have found a range of implications for the way science instructions are given and enacted.

Cognitive complexity (cognitive thinking) puts a high strain on learners when constructivists demand certain tasks be completed (Perkins, 1991), but, when engaging learners, maintain them in a constructive thinking process on the topic under discussion and the new learning method. Carefully design the instruction process in such a manner that the cognitive load is decreased, helping learners to achieve the outcome, because learners often have difficulty with the constructivist’s way. Perkins (1991) supplies the following ideas that can be used to counteract these constraints.

Use ‘scaffolding’ to ensure that there is not too much strain on learners (Perkins, 1991: 20). The job description of a constructivist teacher specifies that he/she must keep the learners in their proximity zone in which they are developing with just enough help and guidance. Too much or too little help and/or guidance and learners would not have gained anything. The proximity zone refers to Vygotsky’s *Zone of Proximal Development*, which is designed to focus on the relationship between instruction and development (Chaiklin, 2003). In theory this ‘scaffolding’ principle is outstanding, but in some instances teachers and technology could prove inadequate when working with a larger group of students.

The solution Perkins (1991) provides is to have groups limited to no more than five participants for group classes; individual classes would only have one learner per lesson. The learner’s attitude (Perkins, 1991; Saunders, 1992) also affects the extent of learning, and it is very important for learners to have a positive outlook on the learning experience. A learner with a negative outlook will not be fully engaged in the learning experience. The learner’s attitude (Saunders, 1992) acts as a wedge between the existing knowledge and the new knowledge, and it is these wedges that indicate how much of a cognitive inertia there is to overcome in order to recreate structures. We need to remember that restructuring does not come easily (Perkins, 1991; Saunders, 1992; Treagust & Duit, 2008). Read (2004) adds that learners should be active participants in the instruction process, and therefore they need to be involved in creating their own knowledge. Before learners receive schooling they are involved in this active process where they create their own understanding, but this can either be something wonderful or a problem. The worldview the learner creates has the ability to either act as the basis new experiences are built upon (desirable) or has the ability to obstruct this (undesirable).

One aspect constructivism struggles with, according to Bergquist & Heikkinen (1990), is that previous knowledge (conceptual frameworks) can interfere with constructing new conceptual frameworks. This turns into a cognitive conflict where the learner is reluctant to change the existing concepts, or in the extreme cases, rejects the new concepts.

Any theory of learning (Ishii, 2003) has implications that can affect teaching: practices in the classroom, and how learners behave in the classroom. Ishii (2003) cautions the use of constructivism in science, because it does not question the interpretation of a certain law, theorem, principle or fact, but rather focuses on each individual’s construction of concepts.

Constructivism entails that learners use their existing knowledge/ideas/concepts, obtained through a social context, to help them make sense of the world and certain problems or to solve these problems. In some cases the initially obtained knowledge is not seen as acceptable and this is when the next ‘C’ plays a role – *C2: Conceptual change theory*.

2.3 Conceptual change theory

The second ‘C’ in the *5-C-framework* is *C2: Conceptual change theory*. In this section conceptual change will be described within the study’s framework as well as the different perspectives, that is, what a concept is, the role of the teacher, and the implications of conceptual change in the science classroom. The ability and inability of changing one’s concepts are theorised as a certain model, the conceptual change theory. Conceptual change is one of the more important C’s within the *5-C-framework*; without it learners would not be able to change their existing concepts, formed during social interaction with their culture or other individuals. Learners need to change these existing concepts in order for meaningful learning to take place.

Conceptual change is largely defined, by Chi, Slotta, and De Leeuw (1994) as learning when certain existing concepts change. But it is very important to place the concepts into a specific category within this framework. Therefore an application definition is adopted where a concept’s meaning is determined from the category into which it is placed.

Conceptual change (Treagust & Duit, 2008) can be placed into different sub-categories – epistemological, ontological and affective orientation. In the epistemological view the focus of the study is placed on the learning of science concepts.

2.3.1 Epistemological perspective

This is the classic way conceptual change was seen for many years. Treagust and Duit (2008) state that the teacher makes the learners aware of the unacceptable alternative framework by creating dissatisfaction. The teacher then introduces a new acceptable framework. Introducing the new framework can limit the learners’ use of the newly obtained concepts to only a small part of the context. The best learners can come up with are a synthetic concept, where they combine only a small part of the new one with the existing one.

Treagust and Duit (2008) concur that if the learner was dissatisfied with the existing concept, there is an opportunity for conceptual change; however, the learner has to be supplied with an acceptable replacement concept. The learner then needs to find the replacement concept intelligible, plausible and fruitful for accommodation to occur.

The basic intention of conceptual change theory in science education is that it is an easy one to apply. The conceptual change model is based on the constructivist views that learners will change their prior concepts if they are deemed invalid through a scientific phenomenon (Cobern, 1995). Only then will the learner accommodate the new concepts. Chiu *et al.* (2002) confirm the previous statement with the following: conceptual change will take place when a concept is re-organised and placed within a designated category.

Cobern (1995) continues: the scientific phenomenon refers to a concept that can be used to make sense of the world. Conceptual change, as seen by Cobern (1995), will more likely occur if the new concept is seen as more intelligible (as stated in Posner's *et al.* [1982] conceptual change conditions). Therefore it can be observed as scientifically acceptable.

In the earlier stages conceptual change was developed around how the learner's concepts evolved during time (Treagust & Duit, 2008), but later constructivism influenced it by adding cognitive approaches, assimilation, accommodation, and the theory of change. This shifted the focus to how the concepts are constructed in different ways.

Constructivism (Wing-Mui, 2002) has mainly been focused on learning theories and primarily on conceptual change. The first conceptual change theory used in the classroom was Posner's (Chiu *et al.*, 2002), where four conditions of accommodation have to be met in order for it to occur.

The following are the conditions that must be fulfilled for accommodation to take place (Posner *et al.*, 1982; Saunders, 1992; Chiu *et al.*, 2002; Suping, 2003). *There must be dissatisfaction with the existing concepts*. Most learners will not easily change or replace their existing concepts; therefore a situation needs to be created in order for the learner to determine if his/her concept is invalid – cognitive conflict. *The new concept needs to be intelligible*. The learner must be able to see that the new concept is an acceptable replacement for any unacceptable concepts. *The new concept needs to be plausible*. The learner must also see the potential the newly accommodated concept holds in solving problems. The plausibility of the new concept also indicates how well it interacts with other concepts or knowledge. *The new concept also needs to have the possibility of a fruitful research programme*. The new concept must have the possibility to be extended (to open new areas where new concepts can be connected with existing or other concepts).

Chiu *et al.* (2002) implemented these conditions, which proved to promote conceptual change in a science classroom.

Posner's (Posner *et al.*, 1982; Chiu *et al.*, 2002) theory of conceptual change is seen as easy to implement and apply. Another very important step in the learning process (implementing conceptual change) is for the learners to talk about or discuss their existing or newly formed concepts (Wing-Mui, 2002), thereby becoming active members of learning in the conceptual change model (Mistades, 2009).

To determine the direction of accommodation, it is advised to use the following (Posner *et al.*, 1982) – anomalies, and analogies and metaphors. The unacceptability of an idea is an important process when a new concept is chosen (anomaly). Metaphors and analogies can place the focus on new concepts and make them more intelligible. Other knowledge also plays a role. Include other fields of knowledge when concepts are competing. When two or more concepts are competing, one of them should be more promising (intelligible) than the others.

Chiu *et al.* (2002) theorises that conceptual change will be beneficial when concepts are linked to a specific topic, therefore categorise concepts in order to make more sense of them as a group. This categorising theory is supported by research showing that it helps learners to understand the meaning of complex concepts in science. Further research shows that when learners using this theory explain their answers, it exhibits conceptual change.

When a concept is categorised we can determine the meaning of that concept according to the group. This theory (Chiu *et al.*, 2002) is also a good way to analyse the learner's conceptual change. Keep in mind that concepts are placed inside the learner's framework, which is created using the physical world as a reference. Therefore we need to take into account that the learner has certain preconceptions, already active, before we look at conceptual change.

The conceptual change process is a very important process to observers when they want to understand the process of learning (Read, 2004). Because of the learner's existing knowledge, it is inevitable that it will cause conflict with scientifically accepted concepts. It is therefore necessary to construct the instruction process around this.

In cognitive science (Carey, 2000), every learner has the potential to use conceptual change to promote learning, but Molebash (2010) determines that conceptual change is the basis on which to transform teachers in order to help learners that struggle to accommodate new concepts.

2.3.2 Concepts

Learners use information (Nakhleh, 1992) to construct their conceptual frameworks. The information is obtained via two sources – public knowledge (textbooks, libraries or classes at school) and informal existing knowledge (social experiences, parents or guardians, television and own interpretations of scientific terms). Concepts (Sisovic & Bojovic, 2000) which are used to construct conceptual frameworks are the most important form of knowledge within the thinking process; they form the mental tools to understand reality and society. Teo and Gay (2006) define a concept as a perceived regularity in a record of individual events or individual objects; or a combination of events and objects, usually labelled. Novak (2008) agrees, stating concepts are building blocks for knowledge in any field. Concepts are what surface in the cognitive process and are then used to organise activities, whereas conceptual change needs to consider the nature of these concepts (Treagust & Duit, 2008). Concepts are viewed, by Treagust and Duit (2008), as a model constructed by a learner, person or scientist according to an event or experience.

Cognitive structures are created by combining different concepts (Nakhleh, 1992), and a concept (Carey, 2000) can be placed in a network or framework for us to understand or experience context. The learner's knowledge about chemistry is based on an intricate network between different concepts and these form the cognitive structures (Nakhleh, 1992). This will help us to observe the 'bigger picture' surrounding the specific topics. Cobern (1995) argues that the strategy advanced by science education limits the scientific context of certain ideas to science only. This notion within science education fails to notice the learner's conceptions of science knowledge and thus only attempts to pursue knowledge, rather than to understand it. Keep in mind that not every learner sees it in this way (Cobern, 1995).

The content of the science curriculum determines whether the scientific concepts are intelligible, plausible and fruitful (Posner *et al.*, 1982). It is necessary to place more focus on assimilation and accommodation than to cover a vast content base. Include anomalies to help with this process. Figure 2.2 illustrates a basic flowchart of the conceptual change model.

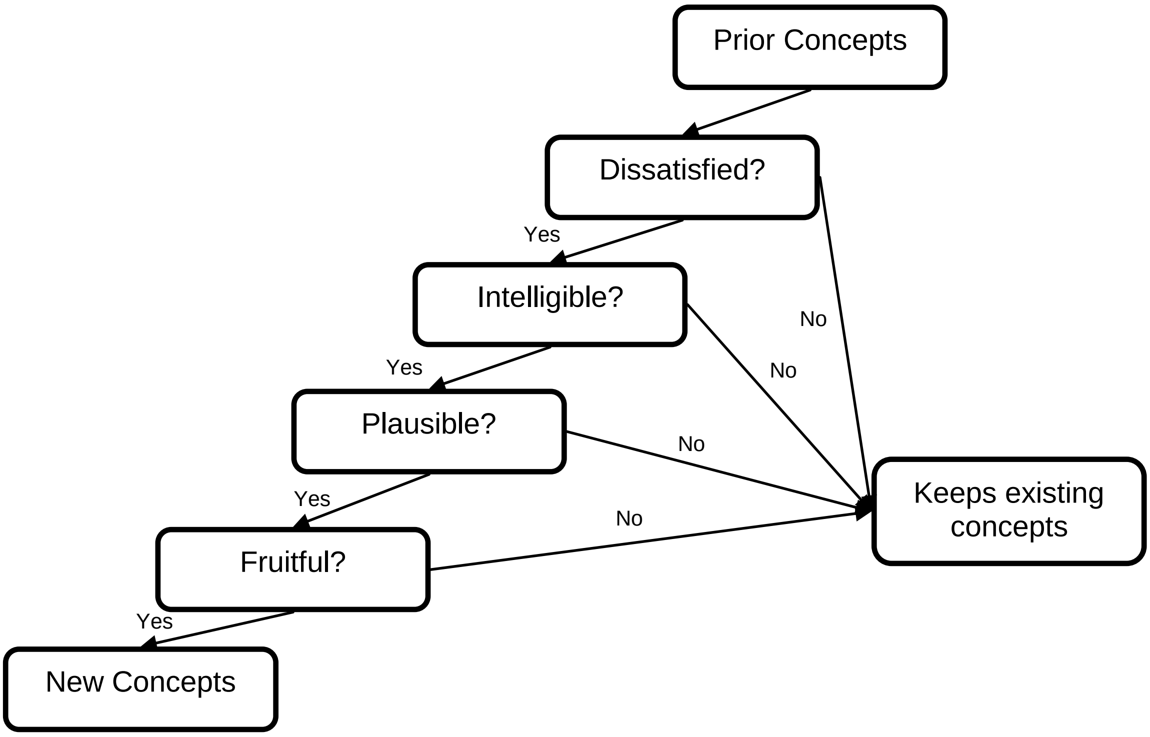

Figure 2.2: Cognitive process available within conceptual change
(Adapted from Read, George, King, & Masters, 2006)

Concepts can also change in a variety of ways (Carey, 2000). The first is differentiation, when one or more concepts is derived from a main concept (e.g. average velocity and instantaneous velocity derives from velocity). Another is integration between two concepts to form one main concept (e.g. natural motion and violent motion became motion).

Chemistry concepts become part of one's structure via thinking at three different stages (Sisovic & Bojovic, 2000) – macroscopic, microscopic and symbolic (chemical symbols, formulae and equations). When a teacher shifts from one stage (macroscopic) to another (microscopic), the learner could fail to grasp a certain concept. One way of helping learners with concepts is by means of concept maps.

According to Treagust and Duit (2008), previous research was also conducted on what conceptions the teachers hold. They found that teachers also hold their own views of certain science concepts, and most of the time their unacceptable concepts coincide with the learner's alternative ideas. Therefore the teachers are teaching their alternative concepts to learners. Not only learners need to undergo conceptual change, but teachers also.

2.3.3 Role of the teacher

Research (Posner *et al.*, 1982) has shown that it's not enough for a teacher to clarify ideas or present knowledge; he or she must also become a Socratic tutor to confront the learner's thinking and be a model of scientific thinking. The teacher therefore needs to:

- create a lecture, class, demonstration, problem that causes a cognitive conflict with learners' concepts (existing);
- organise instructions to shift the attention toward the learners' alternative thinking and identify the defensive mechanisms they use to obstruct accommodation;
- develop strategies to help with these alternative ideas and obstructions; and
- help learners to make sense of the science content.

These are some of the important roles a teacher needs to apply in the classroom, as contended by Posner *et al.* (1982).

Saunders (1992) posits that the teacher cannot change the learner's cognitive structure; only the learner can change it. But Wing-Mui (2002: 5) supplies the following teaching strategies to help learners with their conceptual reconstruction:

- Firstly identify the learner's ideas (or views).
- Create certain opportunities for learners to explore their own ideas. This is done to test the learner's ideas on events or situations.
- Provide enough stimuli for learners to further develop or modify their ideas; or change the wrong idea into the correct idea.
- Provide enough 'scaffolding' for learners to reconstruct the ideas.

If teaching methods are based on constructivism, it is a helpful way to help learners' learning; it also helps teachers that use constructivism in their science classrooms to promote meaningful learning (Wing-Mui, 2002).

Though we need to limit the cognitive perspective when teaching from a constructivist's view, we must still keep in mind the following points when teaching concepts, as noted by Wing-Mui (2002: 6). We should:

- acknowledge the learner's existing knowledge;
- teach fewer concepts at a time;
- improve abilities within key areas of progression inside concept development, since learners are exposed to scientific concepts at a very young age; and
- acknowledge the diversity of learners.

2.3.4 Educational implication

Carey (2000) argues that there are many educational implications when working with conceptual change. The following are just a few examples. The goal of education, to teach understanding, can only be achieved when we diagnose the learner's initial understanding of certain concepts in a specific context (Posner *et al.*, 1982; Carey, 2000). Incorporate recent science classroom research into teaching. It is important to know what the underlying mechanism for conceptual change is if science education research is to prosper. The classroom culture must change from passive to active. Learners must construct an understanding and be able to explain their understanding. More than one concept in science is parallel with another and learners need to be aware of this. Not all of the learners' alternative concepts, knowledge and ideas are caused by a lack of education. The learner will always construct a framework before sufficient (or scientifically accepted) information is supplied. The process of conceptual change needs to be examined and reflected upon, and during this process we would experience the current teaching style in another way.

When researching conceptual change (Treagust & Duit, 2008) in the science education field, certain challenges will arise. These challenges include conceptual change from various perspectives relating to theory; acquiring the necessary information to identify conceptual change relating to methodology; and the need to supply the classroom with successful conceptual change strategies.

The conceptual change model plays an important part in the study; if the learner's existing concept/knowledge/idea is not acceptable, it needs to be changed to the scientifically acceptable concept. It is important to change these concepts in order for effective learning to take place, and for this to happen, we need to know how the learner thinks – *C3: Cognitive thinking*.

2.4 Cognitive thinking

The third 'C' in this study's framework is *Cognitive thinking*. In this section there is a short description of the cognitive process where the learner's thinking process is explained, as well as the description of the term meaningful learning.

The most important aspect of cognitive research, stated by Chi *et al.* (1994), is to explain learning and the failures thereof. For this study, the 'learning' aspect and the failures of learning will fall under the field of Physical Sciences which includes the topic chemical equilibrium. It is important for a researcher, especially when using conceptual change as a theoretical framework, to know exactly how the learner's thinking process works during learning. Any cognitive process will place a tremendous strain on the ability to accumulate, interpret and accept knowledge, ideas and/or concepts.

Ausubel (1986), Novak (2008), and Mistades (2009) divide learning into rote learning and meaningful learning. Mistades (2009) contends that rote learning is when the learner does not accept new concepts and only uses existing concepts. Meaningful learning is when the learner accepts new concepts and positions them inside the existing cognitive structure. Most learners have trouble relating the new concepts to their existing concepts, and therefore fall back on rote learning. Meaningful learning can only occur when the following three conditions are met:

- The subject or concept must be conceptually clear; this includes a language and example presentation, within the learner's existing knowledge. Concept maps serve as an excellent base for this; they can be used to anchor knowledge in the learner's conceptual framework.
- The learner must have relative existing knowledge of the subject. The first and second condition are in relation to each other.
- Meaningful learning is the learner's choice. The teacher can only motivate the learner towards meaningful learning by incorporating new knowledge with the learner's existing knowledge.

In some cases research (Collins, Brown, & Holum, 1991) has shown that when learners are required to use cognitive thinking to solve mathematical science problems, they rely on the textbook samples and examples for guidance. And in more extreme cases, when the parameter of the problem falls outside what the textbook provides, the learners are unable to solve the problem. Saunders (1992) further posits that most of the educational science programmes are focused around a textbook and fail to utilise the full focus of the enhancing teaching methods. This is confirmed by research that has shown that education is very textbook-centred (Wing-Mui, 2002).

Wing-Mui (2002: 7) continues: the teacher is also dependent on the textbook, not just the learner, and everything in the science classroom is done using it. Besides the textbook, there is also a teacher's guide that helps the teacher with all the concepts and how to explain them to the learners. All these helpful materials come with certain problems, such as a decrease in critical thinking and learners not understanding the context.

"The result of an active learner ensures cognitive processes" (Wing-Mui, 2002: 4).

As stated in the above quote, the learner needs to play an active role in the cognitive process to ensure a meaningful outcome.

2.4.1 Cognitive process

There are specific cognitive functions that are identified within the cognitive process, namely, the 'in-process', 'rationalising' and 'out-process' (Schur, Skuy, Zietsman, & Fridjhon, 2002: 41). In most cases the functions are related directly to deficiencies. These distinct functions are described in the following paragraphs.

Perceptual stability depends on the learner's capacity to conserve constancy within the diversity of objects with their characteristics and dimensions. This is known, according to Schur *et al.* (2002), as conservation of constancies. There is a great lack when it comes to learners using two or more sources for information. This causes problems at the entry level (in-process) that in turn lowers the learner's performance level in academic and everyday life. If the learner only uses one source, he/she limits the cognitive functionality. This function encompasses use of two or more sources of information.

Another function is called projecting virtual relationships. Projecting virtual relationships is linked with the learner's relationships that have already been developed and implemented, but not yet used to handle real-life situations. These relationships exist in the learner's mind (hence the virtual) and the learner still needs to use these relationships in real-world situations and problems. The next function is called continuous versus episodic grasp of reality (Schur *et al.*, 2002). What this function entails is that the learner must observe the world as whole and not as individual parts. Each event or problem has a link to another event or problem. If the learner sees reality episodically, then each event is seen in isolation, whereas in continuous reality the learner links more than one event with another. When a learner sees reality as individual events, he/she misses the opportunity to place the experience within a meaningful context, thus limiting his abilities to re-use this data in another event.

Observation plays a large role in the learner's performance of tasks. It is hypothesised by Collins *et al.* (1991), that when the learner observes, he/she forms or develops a conceptual model prior to performing the task. Nakhleh (1992) avers that learners will build their own understanding from their own experiences and observations. This is done within the world they live in, which provides the learners with a mental advantage.

Cognitive apprenticeship cannot be observed easily and therefore needs to be brought to the surface with some type of model. This is a very important point made by Collins *et al.* (1991). In this study such a model is essential; therefore concept mapping (Novak & Cannas, 2006) is an ideal tool.

The combination of *C1: Constructivism*, *C2: Conceptual change* and *C3: Cognitive thinking* is a powerful combination to help promote meaningful learning. The next section, *C4: Concept mapping,* will use all three of the previous C's in one research tool – the concept map.

2.5 Concept Maps

Concept mapping is the fourth 'C' in the literature study's *5-C-framework*. This section will describe concept maps (definitions, examples, and guidelines for use which include the instructional process), the critical disposition of concept mapping, and concept mapping as a tool in the science classroom.

To better understand the conceptual change theory, researchers have developed models which include concept mapping. Concept maps (Zeilik, 1998) supply the 'big picture' of how learners see things and are a visual illustration of a learner's conceptual knowledge. Concept maps, as determined by Sisovic and Bojovic (2000), are used as a teaching aid to show the link between concepts as seen by the constructor. Teo and Gay (2006) describe concept mapping as a way of representing knowledge in graph form. Concept mapping (Asan, 2007; Mistades, 2009) is also called systematic mapping and is similar to long-term memory.

Concept maps must consist of an *n*-dimensional network, where *n* is the number of dimensions (but has to be greater than two) (McAleese, 1998). Otherwise we are just working with a Cartesian plain. We can also refer to some of the linkages as three-dimensional, where one of the three can go into the page or out of the page. Zeilik (1998) and Novak (2008) describe concept maps as a two-dimensional diagram where concepts are linked with each other and the learner's knowledge structure of a specific topic is visualised. Mistades (2009) describes concept maps as follows: Concept maps consist of nodes (concepts), linkage lines (unidirectional arrow) and linkage phrases (describing the relationship between two nodes). When we combine the two concepts with a linkage word or phrase, the combined structure is called a proposition. The linkage line will link two nodes with the linkage phrase.

McAleese (1998: 16) suggests the following guidelines when creating a concept map:

- Choose a main concept. Every other concept will sprout from this concept.
- Choose or use supplied additional concepts. If not given, determine which concepts will apply to the main concept.
- Create relationships between two concepts using a linkage arrow and a linkage phrase. When linking concepts, try to use a sufficient linkage phrase to sprout more potential matches with other concepts.

- Add more concepts to existing concept clusters.
- Delete inappropriate concept clusters.
- Edit existing concept clusters (can be cluster, linkages, linkage phrases or single concepts).

Zeilik (1998) also supplies a more detailed instructional process when creating concept maps, using a simple concept such as plants:

- Introduce a simple example of a concept topic (Plants).
- Write down ten more concepts, e.g. Flower(s), Roots and Food.
- Write the more important concept at the top of the paper (Plants).
- Explain that the next step is to link one of the concepts with another and then repeat with the rest of the concepts (remember to link the concepts with a directional arrow and using a linkage phrase); (Plants --> Food = linkage word produce).
- Supply the learners with enough time (20 – 30 minutes). Encourage networking (cross linking).
- Give assistance to all the participating learners. Make sure to tell them that there is more than one correct answer.
- Collect the concept maps, analyse them and then hand them back to the learners.
- A missing step that can be applied is by taking the concept maps, handing them back, but to a different learner. This way no learner has his/her own map and he/she can see different ways of linking concepts.

'*Selected terms*'-concept mapping will be used in this study. Here the learner will use the provided concepts (in the form of a concept bank) to construct his/her own map. The main focus (Zeilik, 1998) of these concept maps is placed on the linkages (the relationships) between concepts and the progression of the structural complexity. Mistades (2009) adds: The structure of the concept map is determined by the orientation of the concepts. This will determine if the structure is hierarchical or non-hierarchical. There are five possibilities of structures – Linear, Circular, Hub spokes, Tree and Network. The network structure is the one this study aims to achieve with the learners.

The following, extrapolated from Mistades' (2009: 177) research, is an example of a linkage between two concepts using a linkage word:

"Potential energy (concept or node) consists of (linkage phrase) either gravitational potential energy (concept or node) or elastic potential energy (concept or node)."

In the beginning of the instructional period learners will try to memorise the concept maps rather than use them as thinking tools (Zeilik, 1998), but concept maps do not value the learner's memorisation skills within learning, rather his/her understanding of the system of concepts (Sisovic & Bojovic, 2000). Novak (2008) contends that if concept maps are implemented during the instructional period, the learners will form a greater understanding of science.

The purpose, as stated by Novak (1990), Zeilik (1998), and Mistades (2009), of the concept maps, is to assess the learner's understanding of specific concepts within a topic (making links between concepts) or to determine the frequency of an alternative idea or a group of alternative ideas over a period of time. The best use of concept maps is for answering certain questions or understanding a certain event (or situation) by organising knowledge. The following bullets indicate that concept maps are used in this study to:

- determine the prior knowledge, concepts and ideas the learners hold;
- determine if learners can connect concepts with other concepts in a predetermined field in chemistry (which is *C5: Chemical equilibrium*);
- connect specific concepts in the topic field, thereby helping the learner to see the 'bigger picture';
- pin-point problem concepts; and
- observe and test the change in concepts over a period of time, in other words *C2: Conceptual change*.

When the researcher reads the map he/she can observe the following: the specific way a learner views a scientific topic; valid understandings of learners as well as of their alternative ideas; and the learner's cognitive structure and its complexity (Zeilik, 1998). When analysing the learner's concept map, the focus needs to be on the quality of the map and the validity of the representation of his/her knowledge. When analysing the concept map, the following questions can emerge (Zeilik, 1998):

- Is the most important concept on the map?
- Do the linkages and linkage phrases make sense?
- Is the map showing a network?
- Did the learner's maps change over the period of time?

Concept maps do not have to contain all of the topic's concepts at once. "We do not want to teach the learners all of the concepts at once," according to Cullen (1990: 1068). Concept maps are a great way to help the learners make a connection between concepts in chemistry.

2.5.1 Critical disposition

According to Cliff (2010), there are certain advantages when using concept mapping for assessing learners' learning. These advantages include making visible the complex structure of the learner's knowledge (Asan, 2007; Cliff, 2010); uncovering learners' misunderstandings; and revealing learners' conceptual change.

McAleese, Grabinger, and Fisher (1999) go further by supplying more concept map attributes. The first one is the recalling of specific concepts and concept labels. It continues with organising concepts into specific categories; creating systematic cognitive structures which include hierarchies and databases; creating multiple routes to a single concept, thereby developing a better understanding of linkages between concepts; creating a neat and comprehensive template by ignoring the complexity of the concepts; revising existing concepts and refining them; debating alternative concepts of a specific topic amongst one another in order to consider the strengths and weaknesses; creating a cognitive flexibility; and gaining more knowledge to solve a wider range of problems.

There are two aspects (Novak, 2008) that are very important in promoting creative thinking in concept mapping. Firstly, the hierarchical structure (important concept or concepts at the top of the page and the less important concepts thereafter), and secondly, the ability to cross-link concepts (this is very important and one of the main characteristics of a concept map).

Concept maps are useful in order to show learners the network of links between concepts (Zoller, 1990) and furthermore proving where there are inconsistencies in the learner's alternative concepts (Zoller, 1990; Zeilik, 1998). All of the learners taking part in previous research improved their learning skills and ability to integrate knowledge and concepts.

Zeilik (1998) lists a few disadvantages when working with concept maps. Progression over a period of time can become time consuming when working with large classes or larger groups. You are obliged to use a consistent scoring method during the whole study. Concept maps are a demanding cognitive process and learners tend to struggle with them. To counteract this problem, sufficient information, time and practice need to be supplied to the participating learners.

Zoller's (1990) research showed that concept maps promote the learners' meaningful learning, when they show links between different concepts, while adequately guided through the process by their science teachers. Meaningful learning (Zeilik, 1998) has occurred when a learner changes how he/she experiences the world. The basis of the theory is linking meaningful learning with an existing framework of prior knowledge. Concept mapping is directly linked to Ausubel's Assimilation Theory (Zeilik, 1998), where emphasis is placed on meaningful learning. Concept mapping (Teo & Gay, 2006) is a way to focus the learner's activity for effective learning. Mistades (2009) argues that it uses the learner's cognitive understanding of concepts. From the cognitive understanding teachers can get a glimpse of the learner's qualitative aspect of learning.

Zoller (1990) further states that concept maps are not suitable for abstract, non-intuitive and non-interrelated concepts, but Cullen (1990), who is a chemistry professor, uses concept mapping extensively in his science classroom. He also states that he has no problem using these maps in order to teach abstract, intuitive or indirectly related concepts.

2.5.2 Concept maps as a tool

Concept maps are used as remedial tools and research has shown that these remedial tools will influence the learner's learning skills (Zoller, 1990). In order for the learner to gain meaningful information, the learning process is highly dependent on the ability to reason and to build relationships between information gained. Novak (2008) argues that the main use of concept mapping is as a tool for organising and visualising information, data and knowledge.

Concept maps are seen as a tool to help the learners to 'learn how to learn' in chemistry (Cullen, 1990: 1068). Four studies were conducted (Asan, 2007) to determine the effect of concept mapping as a tool for the learner's problem solving. The study of concept mapping's effects reached the following conclusions: concept mapping was a helping factor in the learner's selecting, organising and recall operations. The studies further showed that learners could use thinking and learning skills more effectively in certain situations and contexts. Novak (2008) asserts that concept mapping is a very powerful tool. It can be used as a learning tool, but can also be used as an evaluation tool. This will also lead learners to the meaningful side of learning. Concept maps are also used to identify valid and invalid ideas among learners.

Other studies showed an improvement in the learner's problem-solving skills and higher order of thinking. This was measured by chapter quizzes, tests and projects.

Green (2003) states that concept maps are used to identify certain gaps between concepts and if any alternative concepts have been formed. Green's (2003) contention is supported by Mistades (2009); concept maps are an important tool for this study, because they will provide a basic understanding of where the learner has developed certain alternative frameworks, alternative ideas and alternative concepts. This is because learners structure their concepts according to their existing knowledge or concepts (Mistades, 2009).

Concept maps (*C4*) will play an important role in this study as seen in this section, but nothing can take place without a specific topic. The topic chosen for this study falls under the field of chemistry and the topic is chemical equilibrium (*C5*). The next section will explain why this topic was chosen.

2.6 Chemical equilibrium

The last 'C' in the *5-C-framework* is chemical equilibrium (*C5*). This section will highlight why this study chose to select chemical equilibrium as a field of interest. It will also describe some of the frequent alternative ideas found within this topic.

The Department of Education (Department of Education, 2009b) provides a set of guidelines for schools that shows all the main concepts (including definitions, examples, and possible type questions) for the Grade 12 Physical Sciences curriculum. The focus is placed mainly on the end-of-year examination. Table 2.2 shows these guidelines.

Table 2.2: Guidelines for rate and extent of reactions Grade 12 (Adapted from DoE, 2009b)

Rate and extent of reactions	What the learner must know
Reaction rates and the factors affecting the rate: - *Nature of reactants* - *Concentration* - *Pressure* - *Temperature* - *Catalyst*	• Define reaction rate. • List the affecting factors (surface area, concentration, pressure, temperature and catalyst). • Use the collision theory to explain the affecting factors.
Measuring reaction rate	Create experiments for measuring reaction rate as well as gas volumes, turbidity, change of colour and the change of mass.
Mechanism of reaction and of catalyst	• Define activation energy. • Identify and interpret the Boltzmann graph as well as explain how adding a catalyst or changing the temperature affects the rate. • Explain what happens when we add a catalyst. Refer to the lowering of activation energy.
Chemical equilibrium and affecting factors	• Define the following terms: - Open/Closed system - Reversible reaction - Dynamic equilibrium • List the affecting factors (temperature, concentration, pressure and catalyst).
Equilibrium constant	• List the factors that influence the K_c value. • Write down a K_c expression. • Do K_c calculations. • Interpret and explain high and low K_c values.
Application of equilibrium principles	• State Le Chatelier's Principle. • Apply Le Chatelier's Principle. • Interpret chemical equilibrium graphs. • Apply the chemical equilibrium principles in the industry.

The mentally constructed information or knowledge a learner has isn't always scientifically acceptable (Saunders, 1992). This is when alternative ideas, alternative knowledge or alternative frameworks are formed in the learner's mind. In the Physical Sciences field learners adopt these alternative, naïve, existing misconceptions (Chi *et al.*, 1994) very quickly. Erdemir *et al.* (2000) also refer to them as naïve concepts. Chiu *et al.* (2002) contend that it is therefore very important to create an effective learning environment, especially with chemistry concepts such as chemical equilibrium, because as Asan (2007) states, in science many different concepts are linked with one another, and some concepts are built from base concepts. Because of the conceptual change and concept networking capabilities, concept mapping will be very helpful in the science classroom.

Chemical equilibrium is a topic within the main topic of chemical change. Both the main and the selected topic use another topic, chemical reaction, to describe certain elements, for example, Le Chatelier's Principle (Sisovic & Bojovic, 2000). Therefore chemical change and chemical reactions are directly linked, with overlapping concepts such as particle mobility as a condition for chemical reactions; energy changes (endothermic and exothermic reactions); rate of chemical reaction; and influences on the reaction rate if there is a change in temperature, volume, pressure, catalyst or nature of the reactants.

Chemical equilibrium is one of the most difficult topics in the science classroom (Bergquist & Heikkinen, 1990); it doesn't matter in which grade (Erdemir *et al.*, 2000; Şendur *et al.*, 2010); and therefore this topic gives rise to more alternative ideas than other topics. Chi *et al.* (1994) underscore this statement: learning science concepts requires comprehending concepts across different categories, and that is why science concepts are so difficult to learn. It is very important to eradicate these alternative ideas within this topic because they act as a base topic for others, for example, acids and bases.

Research has found diverse reasons why science concepts are so difficult to study – they are represented by mathematical expressions, and they are abstract (Erdemir *et al.,* 2000; Şendur *et al.,* 2010); amongst others.

Nakhleh (1992) maintains that chemical equilibrium concepts are abstract, therefore learners fail to understand the relationship between symbols and what the symbols represent, and will then be resistant to observe the dynamic function of the system (Nakhleh, 1992; Kousathana & Tsaparlis, 2002). Research, according to Erdemir *et al.* (2000), shows that stoichiometry and its reactions, as well as oxidation and reduction reaction concepts, are included as abstract concepts within this topic. Şendur *et al.* (2010) adds that alternative ideas in science include mole concept, the molecule, chemical equilibrium, chemical bonding, electrochemical cells and phase changes.

The research has shown that alternative ideas in chemistry are wide spread and that each topic within chemistry will be linked with another. The abstract characteristic of chemistry concepts will cause alternative ideas, but Chi *et al.* (1994) argue that it originates from the learner's mismatching and incompatibility between categories. The category linkages are between chemical equilibrium concepts.

2.6.1 Alternative ideas

Research (Zoller, 1990) that focuses on learners' understanding, conceptual understanding and alternative ideas, has increased throughout the years and is still expanding. Different researchers refer to different terms when working with conceptual change, according to Read (2004). In this study the terms 'alternative idea', 'alternative knowledge' or 'alternative concept' refer to any concept that differs from the scientifically accepted concept.

Often research refers to alternative ideas as misconceptions; Zoller (1990) classifies misconceptions as more susceptible to change because they are less firmly placed within the learner's conceptual framework. When the learner tries to construct his/her own concepts, it often happens that his/her perception of the concept differs from the acceptable versions (Nakhleh, 1992). These unacceptable concepts are called alternative concepts or alternative ideas. Nakhleh (1992) and Erdemir *et al.* (2000) indicate that an alternative idea will interfere with the learner's learning.

Learners often assimilate misunderstandings and form an alternative idea, as claimed by Bergquist and Heikkinen (1990). Many of the learners assume certain ideas about the concepts, for example, when equilibrium is established the concentration of the chemicals shifts around and adding more reactants to the mixture will only cause the product's concentration to increase. Nakhleh (1992) argues that one cause of alternative conceptual frameworks is that learners do not construct acceptable understandings from the beginning of their chemistry studies. They therefore miss the complex concept that derived from the basic chemical concepts.

Bergquist and Heikkinen's (1990), Nakhleh's (1992), and Kousathana and Tsaparlis' (2002) research found that learners become confused with the rate of reaction; whether the forward or backwards (reverse) reaction, learners fail to see chemical equilibrium as a whole. Learners see these two reactions as two separate things, according to the reaction, and both reactions (forward and reverse) alternated when equilibrium was achieved. Nakhleh (1992) counteracts the equilibrium alternative idea by using Le Chatelier's Principle correctly, which will cancel the alternative viewpoint of the forward and reverse reactions being seen as two separate reactions. Nakhleh (1992) concludes that learners would find it hard to use their existing knowledge to solve Le Chatelier problems. There are a great many different alternative ideas inside chemical equilibrium, therefore researchers (Chiu *et al.*, 2002) developed the misconception identification test (MIT) to determine which alternative ideas frequently occur in a Grade 12 science classroom.

Both Bergquist and Heikkinen's (1990) research and that of Chiu *et al*. (2002), surrounding the MIT, found that Le Chatelier's Principle also causes great confusion regarding the forward and reverse reactions. This is confirmed by Kousathana and Tsaparlis (2002), who identify Le Chatelier's Principle as one of the central problem areas in chemical equilibrium. Learners assume that when the conditions are changed, the favoured reaction's rate is increased and the opposing reaction's rate is decreased. Again the learners see the two reactions as separate things.

Şendur *et al.* (2010: 2) name the following as more common alternative ideas in the field of chemical equilibrium: the rate of the forward reaction is greater than the reverse one at equilibrium; no reaction occurs at equilibrium; a catalyst affects the rate of the forward and reverse reactions differently; the concentration of the products or reactants changes when adding a catalyst; equilibrium always shifts to the product's side; when we increase the pressure, only the rate of the favoured reaction is increased; when we increase the pressure, the concentration of the products and reactants stays the same; and Le Chatelier's Principle can be applied before the reaction reaches equilibrium.

Many learners believe that equilibrium reactions stop after a period of time and do not see the process as ongoing (Bergquist & Heikkinen, 1990; Nakhleh, 1992). In other words, the learners fail to view equilibrium as a dynamic system; instead they determine that when the reaction reaches equilibrium a balance is achieved, therefore the reaction has stopped. There is therefore a misunderstanding between the rate of the reaction and the extent of the reaction. Erdemir *et al.* (2000) contend that in chemistry, at a macroscopic level, it seems that the reaction is stable (static) at equilibrium, but at a microscopic level the reaction is actually dynamic. This means that there is an ongoing process where bonds are being broken and created (with the net result being zero). Furthermore the MIT determined that learners struggle with mass and concentration, reaction rate and degree thereof, and constancy of chemical equilibrium.

Another study, conducted by Chiu *et al.* (2002) was based on the relatedness coefficients for every pair of main concepts. It found that high-performance learners could connect to additional concepts very easily, but lower-performing learners would associate concepts, rather than including them with others.

An even deeper investigation into the problem-solving skills of high- and low-performing learners exhibited two distinctive results, demonstrated by Chiu *et al.* (2002). High-performing learners were able to solve the problems easily by translating words into scientific symbols and applying different principles (Avogadro's Principle and/or Le Chatelier's Principle). This indicated no lack in understanding concepts, but showed the development stage of the learners. Lower-performing learners struggled with translating the words to symbols, and therefore showed a lack of comprehension of concepts.

Erdemir *et al.* (2000), Kousathana and Tsaparlis (2002), and Şendur *et al.* (2010) state that chemical equilibrium problems are some of the most difficult and complex problems in chemistry and are therefore also the most important, because they are related to further topics such as solubility, electrochemistry and acids and bases. Studies concluded that lack of knowledge is not the only reason why learners struggle with chemical equilibrium (Chiu *et al.*, 2002). Other reasons include the inability to organise concepts when concepts are created, and the basic creation of conceptual frameworks.

2.7 Conclusion

What this discussion highlights is the importance of each 'C' within the *5-C-framework*. It highlights that existing knowledge (*C1: Constructivism*) plays an important role when conceptual change (*C2*) is being used to change the learner's scientifically unacceptable concept to an acceptable one; in other words, changing the learner's conceptual framework and conceptual thinking (*C3: Cognitive thinking*). An excellent way to apply conceptual change is through concept mapping (*C4*) within chemical equilibrium (*C5*), which is a building block of chemistry and harbours some of the most difficult concepts. Figure 2.3 shows the outline of the study. A concept map will indicate the following main aspects to the teacher, researcher or any chemistry observer, namely:

- Learner's existing knowledge (the first concept map).
- How the learner's conceptual framework is designed.
- Where the learner's alternative ideas are.
- How the learner is progressing (when comparing two or more concept maps).

The most challenging aspect of the Physical Sciences classroom is to help teachers and developing teachers to see science as an evolving framework of concepts (spider's web of concepts) and to understand that there is a relationship between concepts (Novak, 1990). Teachers should also realise that there is a methodology for constructing new concepts.

Mistades (2009) supplies an example where concept maps were used as a methodology to teach chemistry learners an understanding of chemical concepts. The concept mapping scores improved and the learners were able to construct the maps.

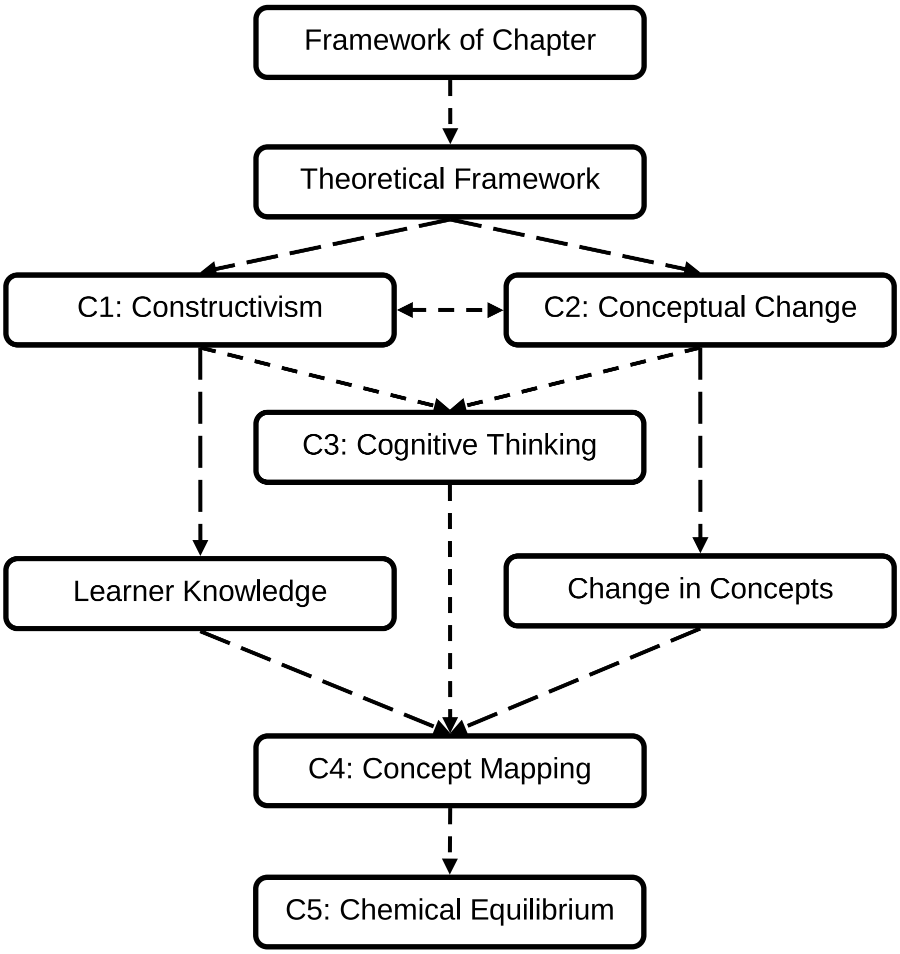

Figure 2.3: Framework for literature study

It is very important to not only correct the learner's alternative conceptions (Zoller, 1990), but to make the new concepts 'stick'. The learner therefore has to make sense of the new concepts and be able to re-use the information in another situation.

Concept mapping has made such a big impact that it is now being used as an educational learning tool in different countries such as the United States of America (USA), United Kingdom (UK), and Japan. Concept mapping acts as basis to promote improvement. Furthermore, concept mapping is a good method to use when we want to improve the retention and recall of learners and it is also a helpful tool when working with learners with learning disabilities (Asan, 2007).

This chapter concludes the *5-C-framework*, but to ensure that meaningful learning is taking place, the concept mapping process has to be managed effectively. Therefore the methodology is an intricate part of this study and comes under scrutiny in the next chapter.

CHAPTER THREE
METHODOLOGY

3.1 Introduction

In this chapter the methodology comes under discussion. This chapter discusses the qualitative paradigm, sampling procedure, data collection and analysis and the ethical considerations. Of importance for the methodology is the research design, which in this study is a qualitative paradigm. This study will therefore discuss and report on the quality of data collected and analyse the data to answers the research questions.

The baseline for research includes the following – identifying the study's research questions; researching the literature and collecting data to answer the research questions; analysing the gathered information and supplying an interpretation; and sharing the conclusions and results. Berg (2004) argues the importance of data collection to answer the research questions.

There are certain factors (Burns & Grove, 2007: 38) that can influence the desirable outcomes of the study, therefore a research design is needed to act as a blueprint. The design approach determines the nature of participants, sampling method, data collection, and analysis method. This study, with the focus on the enhancing effect of concept mapping, falls under the qualitative research paradigm.

Discussion in this chapter is done under the following headings:

- Qualitative paradigm
- Sampling procedure
- Data collection and analysis
- Ethical consideration

3.2 Qualitative paradigm

There are two different types of research designs to choose from: quantitative and qualitative. For this study a qualitative research paradigm is more suitable. Qualitative research provides an understanding of issues and tries to answer the 'why?' and 'how?' questions (Marshall, 1996: 522). The research questions are: "What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?" and "How does concept mapping enhance Grade 12 learners' understanding of chemical equilibrium?" The choice of this approach is relevant as the study under discussion aims to explore the concept problem for the topic of chemical equilibrium among Grade 12 learners.

The aim of this study is to research if concept maps can change existing concepts to new acceptable concepts in order to enhance Physical Sciences teaching. The qualitative approach will include an interactive but flexible study plan and the researcher will play an integral part in the study. To assess the quality of the outcomes, we use indirect quality assurance methods of trustworthiness. The measure of the results' utility is transferable.

Qualitative research (Hoepfl, 1997) is a phenomenological inquiry where the researcher seeks the understanding of the phenomena inside a specific topic. Qualitative research is not statistically based and therefore there is no quantification. Creswell (1998) concurs by referring to qualitative research as an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. In some studies, referred to by Bless, Higson-Smith, and Kagee (2006), it is more important to focus on languages, which provides sensitive and meaningful experience. In these cases words and sentences are used to provide the researcher with quality data. This is known as qualitative research.

Qualitative research focuses to focus on the quality of the data rather than scoring it, which quantitative research does. Concept maps, together with qualitative research, provide a link to answer the research questions. Wilson's (1993) research shows that concepts maps can reveal the qualitative information inside the specific topic. This is one of the main reasons why concept maps are chosen for this type of research.

3.3 Sampling procedure

There is a range of different sampling methods to use in research studies, but for this study the focus is on convenience sampling. It coincides with the availability of the participants, high-performing learners (HPL) and low-performing learners (LPL), at the data collection site. This section discusses the sampling process as well as the data collection site.

Marshall (1996) states that the sample size for a qualitative research project is determined by how adequately it answers the research question, whereas Bless *et al.* (2006: 107) note that the size of the sample group depends on the study itself. According to Bless *et al.* (2006: 107) large groups supply more accurate results, but are more costly and time consuming, whereas smaller groups are less accurate but more convenient to work with. Large groups often don't guarantee the desirable results, especially when the incorrect sampling method is chosen. Therefore a balance between the two groups is the best option, but the choice is still dependent on the study itself.

According to Marshall (1996: 523), there are three sampling strategies: convenience sampling, judgement sampling and theoretical sampling. Convenience sampling is a less strict strategy and the selection takes place according to convenience (how accessible the samples are). This strategy is less costly in terms of time, effort and money, and is designed to take all the possible samples at hand (Bless *et al.*, 2006).

This study's selection process fell in the category of convenience sampling, because the participants are all conveniently located in the appropriated classes at the site of data collection. This type of sampling is a non-probability technique where the participants are selected by their convenience, with respect to accessibility and proximity to the researcher (Castillo, 2009). The convenience was greater, in the sense that the learners are self-selecting, because they choose to come to the classes. Participating learners are all Grade 12 learners of mixed gender. Because of the convenient sampling, a maximum number of five learners participated; this is the maximum number of learners available at the data collection site. All the learners are from the surrounding Drakenstein area, which is located in the Boland, Western Cape, South Africa.

Data was taken in two different classes – group classes and individual classes. The group classes consist of five to eight learners, while the individual classes are focused on one learner per session. The data was taken from two different categories of learners, including low- and high-performing learners. Low-performance learners (LPL) are those who struggle with the topic and want to improve their marks and high-performance learners (HPL) are those who are not struggling but who also want to improve their marks. High- and low-performing learners are used in this study because of their different performing abilities; Nihalani, Wilson, Thomas, and Robinson (2010) include learners' learning strategies, existing knowledge, the construction of conceptual frameworks, and teacher-learner interactions. Research indicates that results between the two groups would be different in terms of the first concept map's quality. The performance percentage region for HPL is between 70% - 100% and LPL 40%-69%.

This study combined convenience sampling with HPL and LPL to establish if concept mapping will have the same effect on both.

The study took place at a private training and educational centre (TriClin Educational Services and Training: TEST Learning Centre) catering for learners who want and need tutoring in Physical Sciences, Mathematics and Accounting. The educational centre was established in 2004, and offered services in business training, education and corporate and government training. In 2009 the centre was expanded and rebranded, and its main aim is to equip staff from private and government sector, as well as learners at school, with the necessary skills, education and knowledge required to complete in a demanding global economy. The educational centre is situated in Paarl and is located in close proximity to a number of high schools in the Drakenstein District.

3.4 Data collection and analysis

This section discusses the data collection and data analysis methods for this study, as well as the reliability and validity. The data will be collected in two forms:

- Concept maps (main collection method)
- Follow-up interviews (to be used if necessary)

Constructivism's role is to make the learners more active in their learning environment, or in terms of this study, the data collection process. Markow and Lonning (1998) agree that constructivism influences learners to be actively involved in the process, and concept mapping ensures that this happens. The learners are constantly constructing their own concept maps, which use a combination of different theoretical ideas, such those of Piaget, Ausubel and Von Glaserfeld, and implementing them.

3.4.1 Data collection

The data collection occurred in two different phases. Phase one of the data collection, called the pilot study has the sole aim of refining the research instrument (Bless *et al.*, 2006; Burns & Grove, 2007). This is very useful when the researcher wants to determine the difficulty of the proposed programme (methods and materials). A more detailed discussion of the pilot phase of the study is captured in the chapter titled 'Pilot Study'. Using the pilot study, the data collection and data analysis methods were refined for the final data collection and analysis. The second phase of the data collection phase of the data collection was captured in Chapter Five. The feature of the participants is given in the table below.

Table 3.1: Participants in pilot study

	HPL	LPL	Total
Boys	-	-	-
Girls	1	1	2

In the pilot study a total number of two participants participated, which includes one HPL girl and one LPL girl (represented in Table 3.1); whereas the final data collection has a total number of five participants, which includes one HPL boy, one LPL boy, two HPL girls and one LPL girl (represented in Table 3.2).

Table 3.2: Participants in final data collection

	HPL	LPL	Total
Boys	1	1	2
Girls	2	1	3

All data collected were used in the analysis. Berg (2004) contends that any of the data collected can potentially be helpful to answer the research questions. The research questions that need to be answered are: “What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?” and “How does concept mapping enhance Grade 12 learners’ understanding of chemical equilibrium?”

The data collection process was discussed in the following section. The collection started with an introductory lesson to the participating learners to ensure they understand the concept concerning concept mapping. The focus of the lessons was the explanation and construction of concept maps.

Data was first be collected in the form of the different concept maps. Concept mapping is described as a six-step process (Trochim, 1993).

The first step is *Preparation*. Preparation includes operational planning, selecting the participants and developing a schedule. This study selects participants by their availability over a period of four months, when they would complete a total of four concept maps.

The second step is *Generation*. This step entails a brainstorming session to discuss the selected topic. Chemical equilibrium is the selected topic for this study and is discussed in Chapter Two.

Step three is *Structuring*. In this step the participant starts with an instructed sorting of the data surrounding the topic. Here the multi-dimensional views already start to develop.

In step four, *Representation*, the participant analyses the given data and places it in a structured formation. This is where the participant creates the concept map.

The fifth step in the process is *Interpretation*. In this step the participant is guided by the teacher/tutor/facilitator to interpret the meaning of the concept map, and whether there are acceptable or unacceptable connections made between concepts.

The sixth step is *Utilisation*. Here the participant develops ways to change specific areas on the map. The teacher/tutor/facilitator develops cognitive conflict situations in order for this to occur.

All the steps are important for the concept map process and will be included in the data collection process. Each learner will construct a minimum of three concept maps. The reason for this is that concept maps (Kinchin *et al.*, 2000) should be monitored through a sequence (not just one map) in order to illustrate the development of the learner's mental thinking. This will also monitor the understanding accumulated by the learner. Each map will show data in the form of concepts, links (with their linkage term or concept), misconceptions, and newly formed scientifically acceptable concepts, but the first map will show the learner's existing/previous knowledge (Trochim, 1993; Kinchin *et al.*, 2000).

Kern and Crippen (2008) use four activities to complete the concept-mapping process. In the first activity the learner will complete the first concept map. The learner is given a set of concepts from the subject field and uses the concept words (for e.g. Table 3.3) and existing knowledge to construct a concept map. The supplied concepts will come in the form of a concept bank, which contains predetermined concepts from the selected chemistry field. The first concept map will show the learner's existing knowledge in the form of the different concepts connecting to each other.

Table 3.3: An example of a concept bank

Concepts	**Concepts**	**Concepts**
Dynamic (System)	Le Chatelier (Principle)	Changes
Products	Temperature	Chemical (State)
Pressure	Reverse (Reaction)	Volume
Concentration	Rate of reaction	Forward (Reaction)
Chemical equilibrium	Reactants	Shift
Closed system	Equilibrium constant (K_c)	Physical (State)

When following the data collection steps, the following should be noted:

- Each map is unique to its creator (Kinchin *et al.*, 2000), because the learner uses his/her own existing knowledge.
- Not every learner, whether they are in the same class as others or not, would have the same alternative idea.
- The previous bullet can also be seen to point to an alternative idea on its own, especially when teachers assume this.

- Each learner would have his/her own alternative idea regarding a certain topic or subject.
- Each learner is seen as an individual and not a minority. Therefore all the developed material surrounding alternative ideas is generalised and not focused on one area alone.

The second activity (Kern & Crippen, 2008) consists of the evaluation of the first concept map. Here certain problem areas are taken into account and lessons should be prepared and given on the topics. After the lesson the learner completes another concept map. The third and fourth activity is a repeat of the second activity. During these activities the learner constructs two more concepts maps. If there are still problems after the second or third concept map, more lessons should be given on the areas of concern. The fourth concept map is the final map and this would be evaluated. The final map should be more of a network than in linear form.

All the above mentioned information should be remembered when working with concept maps. The construction of concept maps is helpful in organising information and therefore in helping the learner to understand. Wandersee (as described in Kinchin *et al.*, 2000: 44) contends that "to map is to know".

3.4.2 Data analysis

In this study each concept map will be analysed, which may supply the teacher with a great tool to select certain problem areas where the most common alternative ideas are formed. In most cases these alternative ideas would never have been identified by the teacher (Kinchin *et al.*, 2000). The results of the data analysis may provide sufficient data to answer the research questions.

Glenaffric Ltd (2007) identifies a six-step approach to an evaluation system. The six steps are designed to help with the implementation of an evaluation system.

Step 1: Identify the participants and concepts.

Why are the following participants chosen for the research and which concept will be used to complete the concept maps? These are the two main questions that need to be answered. In answer to these questions for this study: the participants are chosen because of their availability and convenience at the tutoring centre, and the list of concepts includes the main concepts in chemical equilibrium. Some of them include *Le Chatelier*, *temperature*, *equilibrium constant*, *concentration*, *catalyst*, *rate of reactions* and *dynamic system*.

Literature also provides insight into some of the major concepts of concern, for example, *Le Chatelier's Principle*.

Step 2: Describe and understand the project programme.

Supply the logic model of the project plan with a background, an approach and outcomes. This will help to create a flow throughout the research programme. Participants will create a total number of four concept maps during data collection. The analysis part of the study will identify possible answers for the research questions – "What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?" and "How does concept mapping enhance Grade 12 learners' understanding of chemical equilibrium?"

Step 3: Design evaluation.

Design an evaluation model with evaluation questions to help with the evaluation plan. Supply the plan with evaluation criteria which indicate specific areas. The evaluation model occurs in the form of a pilot study; here the data collection and analysis methods are tested and refined for the final data collection and analysis.

Step 4: Collect data.

Choose the correct data collection method, followed by whether it is primary data (new data) or secondary data (existing data). This study uses concept mapping as the data collection method, which gathers new data from each participant. This, then, is primary data.

Step 5: Analyse data.

Check the data. Put the data in a table to make it more convenient. Analyse results, compare them and present the results and findings. After the concept maps have been completed, they are analysed using the data assessment rubric. They are analysed overall on the quality they represent.

Step 6: Report findings.

Complete a report with the result findings and reach a conclusion. Include recommendations and limitations. This will occur in Chapter Six.

Over the years the analysis of concept maps was accomplished by a qualitative approach based on a scoring system, but some researchers made some modifications (Kinchin *et al.*, 2000). Assessing concept maps (Svedkauskaite, 2005) should be conducted on two different levels. The first level of assessment will focus on how the learners apply (link) the concepts on the maps and the second level will focus on the learners' understanding – current and emerging. The scoring methods all have the same scoring factors:

- Number of valid links
- Degree of cross-linkages
- Amount of branching
- The hierarchical structure

Assessing a concept map includes selecting the concepts supplied and the resultant demands. It also includes scoring the concept map for content, organisation of the structure, and correctly linked concepts (Svedkauskaite, 2005). But there is more than one way to score or analyse a concept map. Mistades (2009) claims that there are overall six different ways to score concept maps, but the following is an outline for the scoring: score (Mistades, 2009) the components in the concept map (focus on the propositions [the linkage between two concepts with its linkage word], hierarchy levels [linkages], and examples). Also compare the learner's maps with maps of specialists (Kinchin *et al.*, 2000; Svedkauskaite, 2005; Mistades, 2009). The figure below is an example of a specialist's chemical equilibrium concept map. Score the following by observing the concept maps – number of concepts present, concept linkages, branching, hierarchies, cross-linkages, and examples.

Asan (2007) gives a positive score (+1) for each base concept used on the concept map, which is correctly linked to the next concept. A negative score (-1) is awarded if there is an error with the linkage between two concepts. When one of the concepts is missing, a neutral score (0) is awarded. Scoring a 'valid' link can be problematic in terms of its definition (Kinchin *et al.*, 2000). How can we define a link as valid and invalid when learners use their existing knowledge to construct concept maps? To them the link seems 'valid' as is stated in a constructivist's view. The link illustrates the learner's basic understanding of the relationship between two concepts. To rely on a number scoring method is to miss valuable information.

Kinchin *et al.* (2000) conclude that scoring concept maps has limitations and therefore needs to be consistent. To improve on the last statement, a more qualitative assessment tool needs to be designed in order to maintain consistency and benefit the learner's learning experience. In Kern and Crippen's (2008) research, they note that the University of Minnesota (UM) supplies a detailed rubric for the assessment of concept maps. Table 3.4

shows such an assessment rubric that will be used to assess the learner's concept maps during the research process.

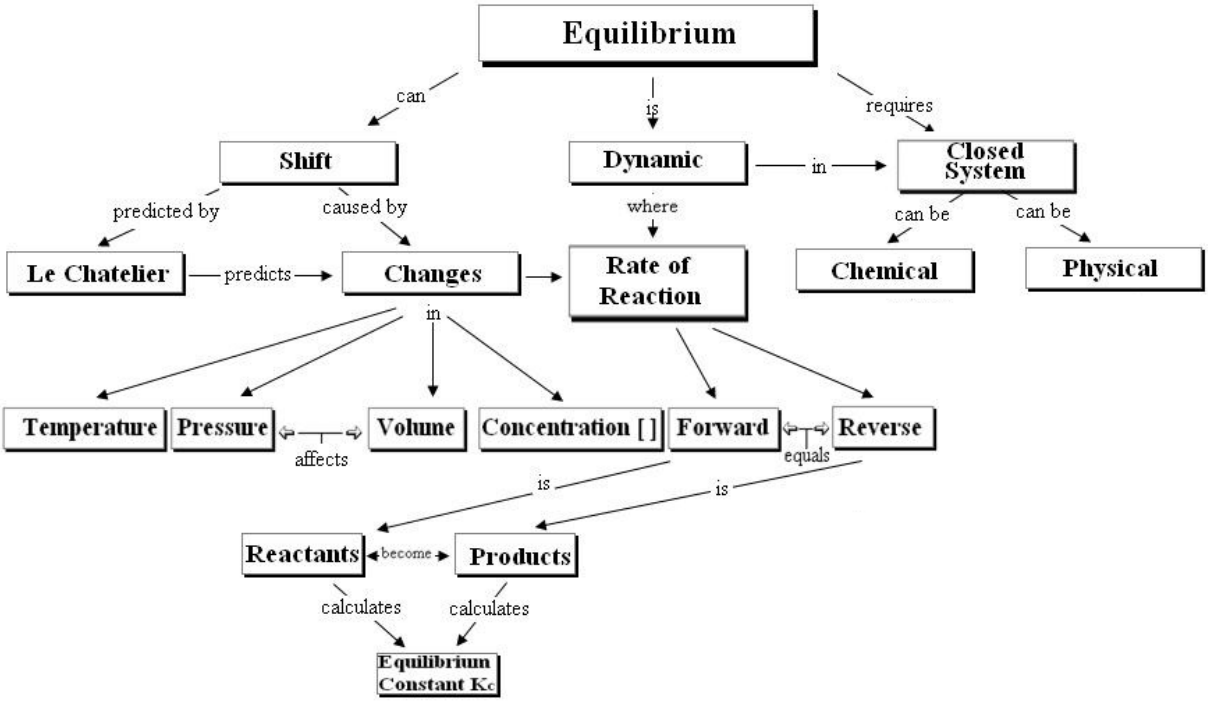

Figure 3.1: Expert's concept map

The concept maps will measure the improvement from the previous map using the scoring method. The analysis of the first concept map will indicate and inform the researcher of the key concepts that need the lesson time. Thereafter the analysis of the follow-up concept maps will indicate the same as well as whether conceptual change is taking place. In order to analyse conceptual change, the concepts of a previous map will be compared with a current map.

The following section takes a look at the follow-up interviews and how to approach them.

After the final concept map, a follow-up interview will take place with some of the learners. Interviews are a useful way of collecting large amounts of data in a short time. Questions can be redirected to ensure that each one is answered fully; this supplies a rich form of data (Johnson & Christensen, 2004). The most important aspect in an interview is to listen. Listening should commence on three different levels. The first is listening to what the participant is saying; the second is listening 'between the lines' (do not just listen to the outside voice); and on a third level, listening and awareness should commence at the same time (Seidman, 2005: 63).

Table 3.4: Data analysis rubric (adapted from Kern & Crippen, 2008)

Criteria	**Excellent**	**Good**	**Adequate**	**Marginal**	**No credit (It is unacceptable to review)**
Structure	Non-linear structure providing a very complete picture of ideas.	Non-linear structure providing a complete picture of ideas.	Non-linear structure providing a picture of ideas.	Non-linear structure that illustrates a relationship between ideas.	Inappropriate structure.
Relationships	Relative importance of ideas is shown. Simple and complex relationships are very effectively mapped.	Relative importance of ideas is shown. Relationships are very effectively mapped.	Relative importance of ideas is shown. Relationships mapped.	Importance is evident, but not very distinctive. Relationships are unclear or lacking.	No differentiation between ideas. No evidence of meaningful relationships.
Exploratory	Map indicates complex thinking about meaningful relationships between ideas, themes, and frameworks.	Map indicates effective thinking about meaningful relationships between ideas, themes, and frameworks.	Map indicates definite thinking about relationships between ideas, themes, and frameworks.	Map indicates some thinking about relationships between ideas, themes, and frameworks.	Thinking process is not clear.
Communication	Concepts are presented clearly. High level of understanding.	Concepts are presented clearly. Good level of understanding.	Concepts are presented clearly. Basic level of understanding.	Concepts are presented clearly. Some level of understanding.	Information is not clear and is very difficult to understand.

The researcher will follow up on questions asked in the interview if there were any uncertainties on any of the learners' concept maps (Johnson & Christensen, 2004; Seidman, 2005). Seidman (2005) adds that the basic structure of an interview is to begin with a set of predetermined questions, but a follow-up interview will develop question(s) from what the learners said or did. The following is an example, and an answer from the study from Participant One (P1-HPG):

<u>Question:</u> "*What was your intention with the linkage word between chemical equilibrium and forward reaction and reverse reaction?*"

<u>Answer:</u> "*Chemical equilibrium always consists of a forward reaction and reverse reaction.*"

In the question-and-answer example, the linkage word determines the question asked of the participant. The way the participant perceives the link may differ from what the researcher perceives; this is why it is important to get clarity from a participant when such an uncertainty arises. Each interview should not take more than fifteen minutes.

3.4.3 Reliability and Validity

In this section, the reliability and validity of the instrument, concept maps, are discussed. Concept maps have a growing popularity and they have been used in a variety of places, including social services, mental health, health care, education, educational administration and theory development (Trochim, 1993). The questions then would be: Why would we use a concept map? Or is a concept map reliable and valid? According to Zeilik (1998) concept maps shows how well the learner can see the ‘big picture’, which is what this study aims to accomplish. Or in other words, it illustrates the learner’s conceptual knowledge.

The standard way to determine the reliability is to assess the instrument in two ways. The first is that for every question there is a correct answer (Trochim, 1993), and the second is that the instrument is stable, as well as supplying consistent scores over time (Miller, 2012). According to Puiz-Primo and Shavelson (1996), reliability is a term used in research which refers to the consistency or generalisation (replicability) of the research. In other words, how the concept maps are scored and whether or not it can be done again. To ensure reliability (Golafshani, 2003), the trustworthiness of the research is very important. Reliability is defined, by Bless *et al.* (2006), as the consistency of a study, whether or not the measurement can be performed repeatedly with the same results.

Trochim (1993) shows that the reliability of concept maps shifts towards consistency or change over a period of time. Whereas Puiz-Primo and Shavelson (1996) assert that to ensure the reliability of the concept map scoring, the maps could be scored using an expert’s map. Each learner’s map can be cross-referenced with the expert’s map. Bless *et al.* (2006) state that in social science ‘regularities’ of alternative ideas and opinions are most often observed. If such an observation is made, meaningful information is being measured.

Concept mapping, according to Kinchin *et al.* (2000), will provide the teacher with a valuable insight into the learner’s mind and therefore help to promote meaningful learning. Validity is linked with reliability, neither one can take place without the other (Bless *et al.*, 2006). Validity is defined in one question: “Is the instrument measuring what is needed?” For this study, the instrument, concept maps, needs to measure the effect on the learner’s understanding of chemical equilibrium concepts and the links between them. Concept maps provide the researcher with a precise focus on how the learner’s concepts change over a period of time, meaning that validity of the instrument is ensured.

3.5 Ethical considerations

Ethical consideration is an important part in any study. First and foremost permission is needed from the Western Cape Education Department (WCED) (Appendix A), the ethics committee of the Faculty of Education and Social Sciences at the Cape Peninsula University of Technology (CPUT) (Appendix B), and from the data collection site TriClin Educational Services and Training (TEST Learning Centre) (Appendix C). The employer should supply permission for the use of classrooms, as well as the participation of any staff members (if applicable). Permission is also needed from the participants (Appendix E) and their parents or guardians (Appendix D). All the participating learners and their parents need to give their permission, in order to participate in the study. The participating learners and parents need to complete a consent form and the form must be signed by both parties.

Bless *et al.* (2006: 141) summarise the ethical considerations under the following headings:

3.5.1 Non-maleficence

This is better known as the ‘no harm principal’, where no harm will come to the participants. In this study there will be no harm, mental or physical, to any of the participating learners.

3.5.2 Beneficence

This is known as the ‘beneficial principle’. Not only will no harm come to the participants, but the study will contribute to the participants’ well being, in the sense of contributing to the participants’ academic work. The technique the learners would be using will increase certain aspects of the academic work, such as organisational skills and deeper understanding of links between concepts.

3.5.3 Autonomy

This is also known as the ‘freedom principle’. The participants have the freedom to make their own choices and perform their own actions. The participants also have the choice to participate in the study, and can also withdraw from the study at any time.

3.5.4 Justice

This is known as the 'justice principle'. In this study all participants are treated as equals and therefore no discrimination of any kind is tolerated (bias, race, gender, disability or financial history).

Confidentiality ensures that participants, parents or guardians, and places are kept anonymous and a high level of autonomy is sustained. Furthermore, any names, surnames and identities are kept secret. This is to not implicate any of the learners or their parents in the study. Publication of the research results will only be made available to the researcher, supervisor, TEST Learning Centre, and the Cape Peninsula University of Technology, and not to any other source.

A strictly professional relationship will be maintained with the organisation where the study is taking place. This study will not be biased towards any of the participants.

3.6 Conclusion

This chapter discussed the importance of the methodology of this study. The participants are conveniently selected owing to their availability at the data collection site. The main data collection method is focused on concept mapping, where the participant constructs a network between concepts using existing knowledge as well as new knowledge. This provides the primary data form for this study. An additional data collection method, follow-up interviews, will be added should any uncertainties be captured on a participant's concept map.

The data analysis part of the study uses three different methods. The '*scoring-method*', where each link on the concept map is scored positively or negatively; the '*rubric-method*', where the quality of the concept map is rated in four different categories (*structure*, *relationship*, *exploratory* and *communication*); and the '*expert's map-comparison-method*', where the participant's map is compared with an expert's to establish a baseline.

In the next chapter – Pilot Study – the data collection and analysis methods will be refined for the final data collection and analysis.

CHAPTER FOUR
PILOT STUDY

4.1 Introduction

This chapter reports on the data analysis of the pilot study. The first section consists of a description and analysis of the data collection and participants, and the final section reflects on the design of the instruments for the main collection.

This study made use of a pilot study to develop, assess and refine the methodology, instructional process, research tool and data analysis. A pilot study (Burns & Grove, 2007: 549) is a smaller version of the actual study. The pilot study is used to collect data to develop and refine the methodology of the study, which includes the instrument, data collection and analysis to be used in the main study (Bless *et al.*, 2006; Burns & Grove, 2007). Bless *et al.* (2006: 60) define the pilot study as a technique to evaluate and improve certain methods and materials of a study.

The pilot study is conducted exactly the same way as the actual study, except for its being on a smaller scale (Bless *et al.*, 2006; Burns & Grove, 2007; De Vos, Strydom, Fouché, & Delport, 2011), which includes setting, subjects, treatment and data collection and analysis. De Vos *et al.* (2011: 73) state that the pilot study is mainly used to determine any shortcomings in the instrument, process or material. If the pilot study is not done correctly and in the same manner as the main study, it will lose its value. This is very useful when the researcher wants to determine the difficulty of the proposed programme (methods and materials). It can also determine the response of the participants for the main study.

The pilot study was used to refine any step inside the research process or change the whole study design.

The reasons for conducting a pilot study are listed in the following bullets (Burns & Grove, 2007: 38):

- Is the proposed study feasible?
- Develop/refine research treatment.
- Develop a system to implement the treatment.
- Identify any problems in the design.
- Determine if the sampling method is effective enough to use in the main study.
- Check the reliability and validity.
- Develop/refine data collection method.
- The pilot study supplies the researcher with experience (sampling, data collection and data analysis).

- Implement data analysis technique.

If it is found that the pilot study has uncovered numerous difficulties, the method and materials should be redesigned and a new pilot study should commence (Bless *et al.*, 2006).

Two learners were selected to participate in this pilot study. Each learner completed the data collection process (four concept maps each), and the data analysis was done for each map the learners complete. From here certain refinements was made to anyone of the methodologies, instruments, materials and/or data analysis.

The pilot study was conducted in the same manner as the actual study to maintain effectiveness and applicability (Bless *et al.*, 2006; Burns & Grove, 2007). The effectiveness relates to whether every part of the process is completed with ease and by the book (De Vos *et al.,* 2011) and applicability relates to whether everything done in the pilot study will be conducted in the actual study (Bless *et al.*, 2006: 60). The learners chosen for the pilot study came from either an individual class, group class or a rewriting Grade 12 class (a learner who is rewriting his/her Grade 12 examinations). The class setup looks exactly the same as the actual study where each learner has his/her own desk to work at. There is a maximum of ten desks in the classroom, excluding the teacher's desk. A whiteboard, which is situated in front of the class, was used to explain examples or any other information (this includes the classes given to the learners). The setup is shown in Figure 4.1.

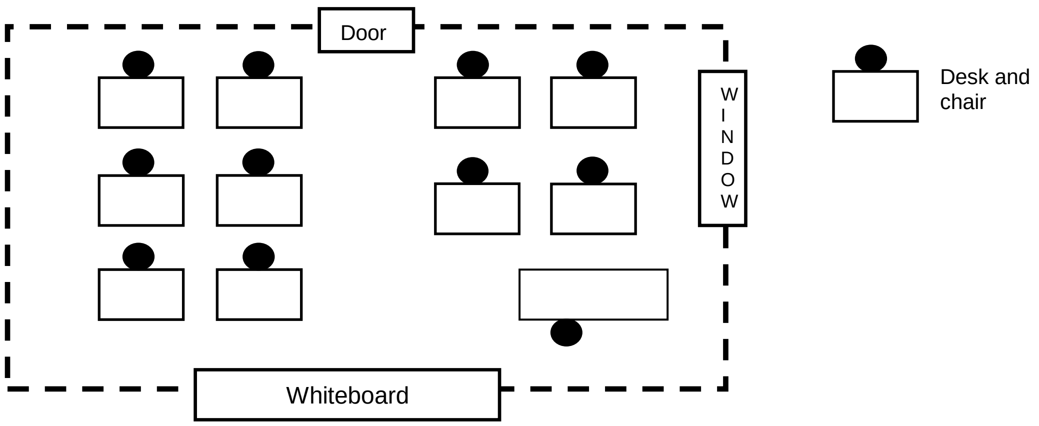

Figure 4.1: Classroom setup

Two learners were selected to participate in the pilot study. One learner completed four concept maps, whereas the other only completed one, throughout the determined period of time. Furthermore, each of the maps was collected and analysed.

4.2 Introductory class

The introductory class was held to help learners understand the purpose of the study, what it entails, and to explain the way concept maps work. Some of the basic questions explained to the learners are shown below:

Question 1: What are concept maps?

A concept map is a useful tool to visualise concepts on a certain topic. The map indicated the links between these concepts and therefore showed the 'bigger picture' (Zeilik, 1998). The understanding is therefore illustrated on the concept map and it also shows whether or not any alternative ideas are present.

This tool is also very useful when studying, because it acts as a long-term memory.

Question 2: How does it work?

Concept maps contain concepts (supplied using a concept bank), linkage arrows and linkage phrases (supplied or learners have to obtain them on their own). For the purpose of this study, the learners had to supply their own linkage phrases. The concepts are about the specific topic chosen by the researcher (in this study it will be chemical equilibrium); the linkage arrows connect two concepts with each other (the arrows can be multi-directional), but the arrow is inconsequential without the linkage phrase. The linkage phrase is the important word or phrase that connects the two concepts with each other. The linkage word or phrase showed the understanding of the two concepts, in other words, the relationship.

Question 3: What will happen?

After the introduction, questions were answered and uncertainties explained. The learner or learners will complete an example map with the researcher. The concept bank (Table 4.1), together with a topic, is supplied to the participating learners.

Table 4.1: Concept bank for class example

Concept	Concept	Concept	Concept
Plants	Petals	Colour	Fruit
Green	Flowers	Roots	Stems
Leaves	Seeds	Food	

Each example map constructed during the initial classes was different, which indicates that there is more than one way to link two concepts with each other. Figure 4.2 is one such example. This map shows the network like links between concepts and appropriate linkage words or phrases.

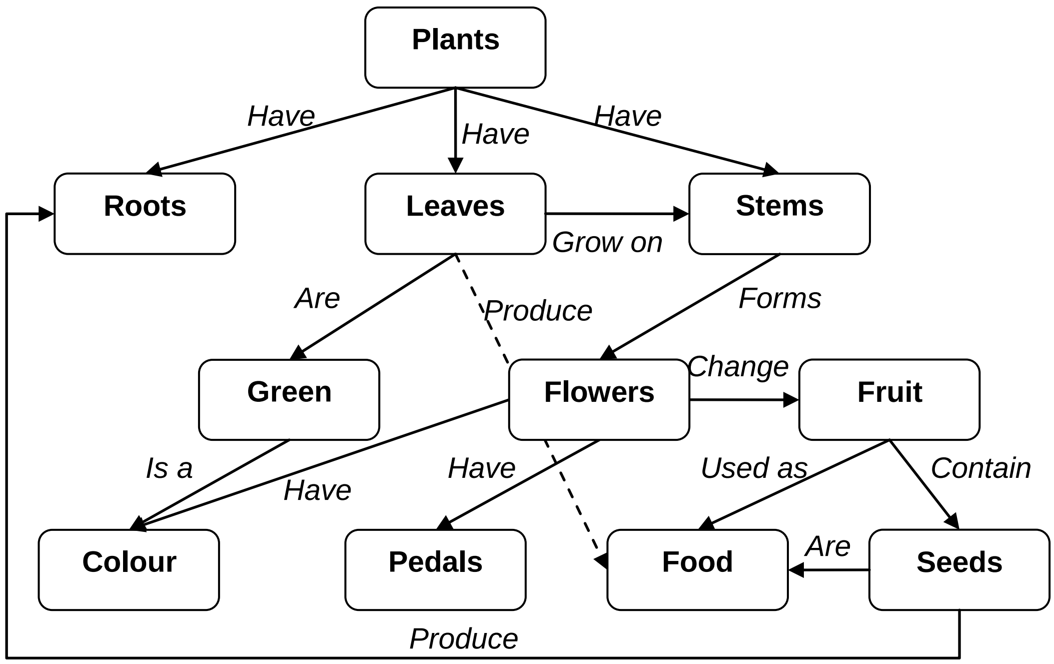

Figure 4.2: Concept map class example

After the example concept map, the learners will begin with the study – completing their concept maps.

4.3 Data collection and analysis

The pilot study used two participants to participate in the refining process. Participant One is a high-performing girl (HPG) and Participant Two is a low-performing girl (LPG). After the initial introductory class was given to Participants One and Two, each completed her first concept map using only her existing knowledge. Participant One did not have any previous experience with concept maps or the topic chemical equilibrium; whereas Participant Two had already gone through the topic at Grade 12 level the previous year. Participants One and Two completed their first concept map using the supplied concepts in the concept bank (example in Table 3.3).

After the completion of the first concept map, two methods were used to analyse them. The first analysis method was the '*scoring-method*', which proved not to be useful. The method relies on the researcher to give a positive mark (+1) for each 'correct' linkage between concepts, but the classification of a 'correct' linkage is unclear. The learner sees each link as 'correct' using his own knowledge. Furthermore, if the maps are given a score, it will fall under quantitative research and not qualitative (Kinchin *et al.*, 2000). For the purpose of this study, the research will fall under qualitative research.

The second analysis method is the '*rubric-method*' (Kern & Crippen, 2008). This method will not be scoring the maps with marks, but analyse the quality (qualitative research) of each map. The rubric consists of four categories – structure, relationship, exploratory and communication. Each concept map the learner completes is analysed according to these categories. An example of the data analysis rubric can found in Table 3.4.

The third analysis method is the '*expert's map-comparison-method*' (Kinchin *et al.*, 2000; Svedkauskaite, 2005; Mistades, 2009). Each map the learner completes is compared with an expert's concept map. Here the structure and linkages of the learner's concept maps were compared with those of an expert's. An example of an expert's concept map can be found in Figure 3.1.

The analysis of each map indicated where the problem areas were, which would indicate the main objective for the upcoming classes. The classes given to the learners featured concepts that were linked invalidly, concepts not used (usually written on the side of the concept map), or missing concepts. Hereafter Participant One and Two both would complete a maximum of three more maps, depending on the progress and quality of their upcoming maps. Participant One completed a total of four concept maps, but Participant Two only completed one concept map.

4.4 Results and conclusion

What was found during the collection process?

Overall the collection process had no problems with collecting the data itself. The participants completed the maps and the data was collected and analysed.

The only real problem with collecting the data was that Participant Two showed up irregularly for classes, therefore the pilot study was mostly conducted on Participant One's four concept maps. Nevertheless valid and reliable data was collected from Participant One's concept maps.

Although the construction of concept maps was a new concept for the participants, they handled it well and understood it easily. In some cases certain concepts were missing and not written down on the side of the paper, which was not a problem, but more work was needed in determining which concepts were problem areas. Participants also forgot to use linkage words and/or arrowheads in some of the linkages between two concepts. Furthermore the pilot study found that the participants struggled not to use the word 'AND'. This word does not describe a connection between two concepts.

The concept map as a data collection tool was excellent. It captured the raw data of each participant and showed what needed to be shown. Alternative ideas were easily discernible and other concepts not used showed what needed to be focused upon.

What was found during the analysis process?

All three types of analysis methods were used with the analysis of the first concept map, thereafter only the '*rubric-method*' and '*expert's map-comparison-method*' were used. The reason for this was (as stated in a previous paragraph), that scoring a linkage as 'correct' is debatable. Another reason was that when scoring is used, the research is perceived as quantitative.

The rubric was a good choice with which to analyse each concept map, although it was slightly adapted from the one by Kern and Crippen (2008). Tables 4.2 – 4.4 show the application of the data analysis rubric.

Table 4.2: HPG's map one results

Structure	Marginal
Relationship	Adequate
Exploratory	Marginal
Communication	Adequate

Table 4.3: HPG's map four results

Structure	Good
Relationship	Good
Exploratory	Excellent
Communication	Excellent

Table 4.4: LPG's map one results

Structure	Marginal
Relationship	Marginal
Exploratory	Marginal
Communication	Marginal

Table 4.2 and 4.3 are two examples of the results achieved by Participant One using the '*rubric-method*'. As shown in these two tables, there was a definite progress/improvement in the quality and understanding of the participant's maps. Comparing the participant's maps

with those of an expert also showed his/her level of understanding. Overall it is a very good analysis process.

4.4.1 Conclusion

To analyse the participants' concept maps the study used a combination of '*rubric-method*' and '*expert's map-comparison-method*'. The main analysis method for this study was the '*rubric-method*' and the secondary was the '*expert's map-comparison-method*'. The collection method remained the same.

The following needs to be considered for the final data collection phase:

- Learners need to try and use all of the concepts.
- Any concepts omitted should be indicated on the side of the concept map.
- Use directional arrows if you link two concepts.
- Don't use a linkage word such as 'AND'. Rather link two concepts to another.
- Rather use a multi-functional linkage word that can describe more than one link between two concepts. For example use 'changes' or 'influences' instead of only 'increase' or 'decrease'.
- Examples for clarification are captured in Figures 4.3 and 4.4:

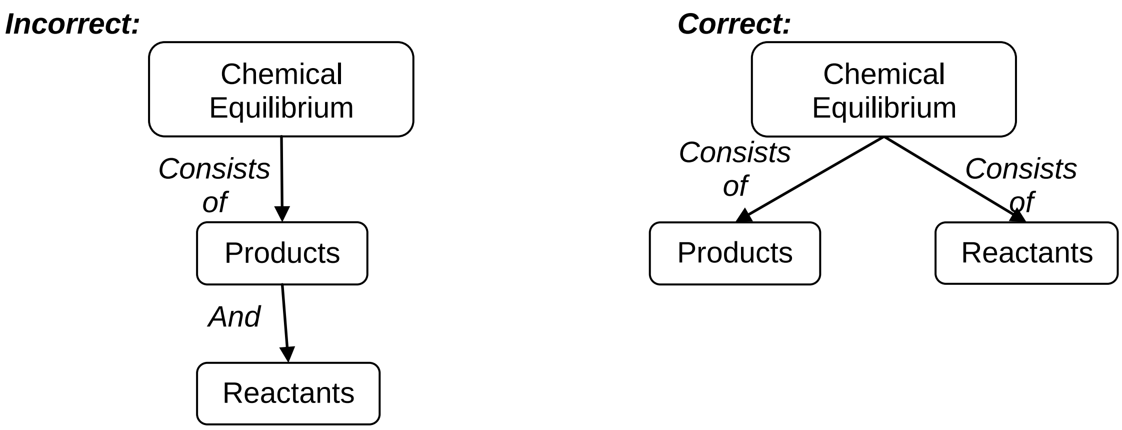

Figure 4.3: Getting rid of the linkage word "AND"

The information gathered in the pilot study will be used in the final data collection and analysis. The next chapter will discuss and report on the final data collection and analysis.

Incorrect: ***Correct:***

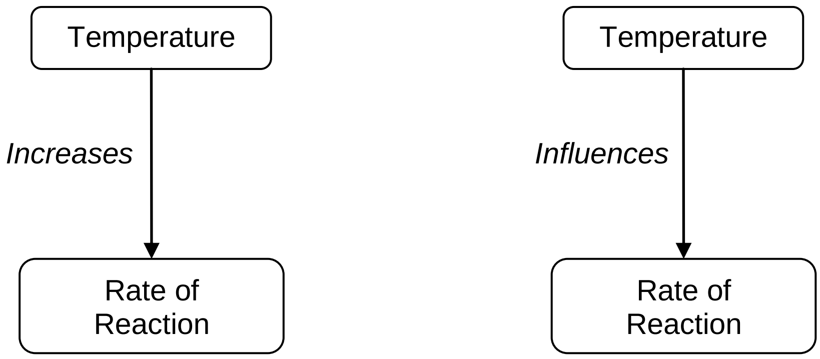

Figure 4.4: Multi-functional linkage words

CHAPTER FIVE

DATA ANALYSIS OF FINAL PHASE

5.1 Introduction

This chapter discusses and reports on the data analysis of the final data collection. The first section will explain and report on the data collection process, followed by the second section that explains and reports on the data analysis process. The final section will discuss the findings from the main collection and analysis.

The study has two main research questions, which are important and need to be taken into account for the duration of the study. The first research question is, “What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?” and the second is, “How does concept mapping enhance Grade 12 learners’ understanding of chemical equilibrium?” At the end of the study these research questions need to be answered. To strengthen this statement Zhang and Wildemuth (2009: 2) state that the analysis phase of qualitative research should begin in the early stages of data collection. This will help with the back and forth movement between concept development which aims to answer the research questions in the best way possible.

Therefore the key areas to answer the research questions are data collection, data analysis, and the findings. The main focus will be on the data analysis part of the study.

5.2 Data collection process

A total of six learners in Grade 12 participated in the data collection process – two participants participated in the pilot study and five in the final data collection. The data was collected through concept maps, but as a secondary collection method follow-up interviews were held to diminish any uncertainties about the concept maps. The five participants that participated in the actual study completed a total of three to four concept maps.

Of the five learners participating in the final data collection there were one high-performing boy (HPB), one low-performing boy (LPB), two high-performing girls (HPG) and one low-performing girl (LPG). The following indicate the HPL and LPL allocations of the participants:

- Participant One – High-performing girl (P1-HPG)
- Participant Two – High-performing girl (P2-HPG)
- Participant Three – Low-performing girl (P3-LPG)
- Participant Four – High-performing boy (P4-HPB)

- Participant Five – Low-performing boy (P5-LPB)

The expectation for the HPL and LPL should reflect on the type of concept map, as well as on the quality of conceptions and linkages. There would be a significant difference between the two maps, especially in respect of the first concept map.

The data collection process consisted of three different aspects – an introductory class, concept map construction and the follow-up interviews. This section will discuss each of these aspects and report on them.

5.2.1 Introductory class

The introductory class consisted of the same concepts used in the pilot study. The introductory class was held to help the participants to understand the notion of concept mapping (Zeilik, 1998). This included construction of concept maps, do's and don'ts, and the importance of concepts in the concept map.

In each introductory class the participants completed an example concept map with simple concepts – *plants, petals, colour, fruit, green, flowers, roots, stems, leaves, seeds,* and *food*. All these concepts were supplied to the participants in a concept bank (example in Table 4.1). The example concept map showed the participants the methodology of how to construct a concept map and how to apply it for future use.

The construction of the example map proceeded effortlessly and showed the variety of different links between two concepts. Figure 5.1 is just one of the examples of maps constructed in the introductory class (to view another see Figure 4.2). Both Figure 4.2 and 5.1 contain the exact same concepts, but are different in structure. This indicated that there is more than one way to connect two concepts.

Even though concept mapping was a new concept to the participants, the introductory class, together with the methodology of concept mapping, provided no obstacles. The introductory class provided the basic foundation to help the participants construct their concept maps.

5.2.2 Concept map construction

The introductory class was followed by the construction of the participant's first concept map. Each participant received a sheet of paper together with a concept bank containing all the concepts needed to construct the first concept map. The concept bank was provided to each participant in their home language. Table 5.1 illustrates the concept bank participants received.

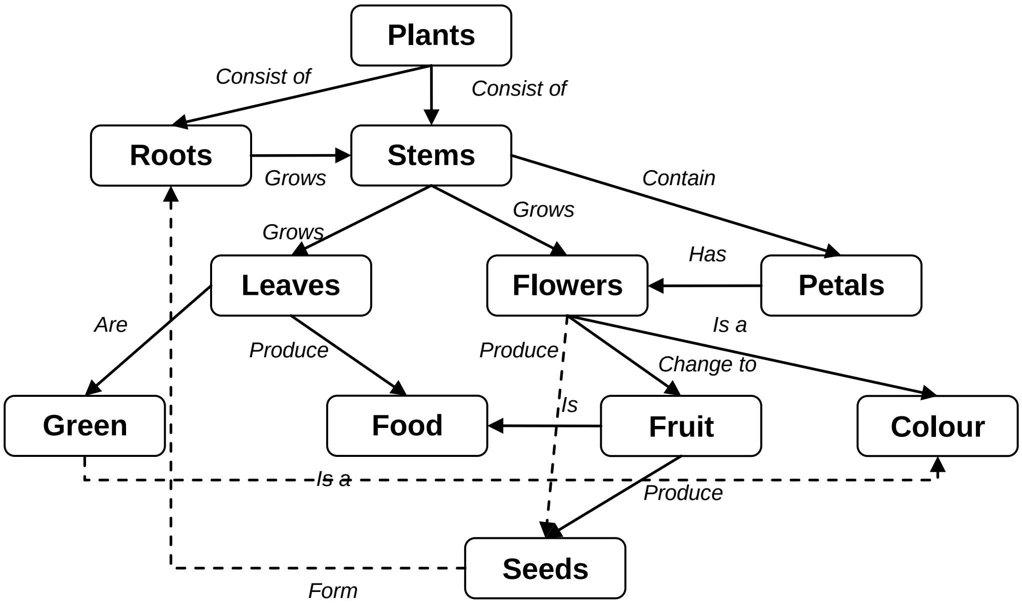

Figure 5.1: Concept map class example

Some concepts were removed and/or added to the actual study's concept bank. The concept taken out of the concept bank was *volume,* and three new concepts (*catalyst*, *endothermic* and *exothermic*) were added.

Table 5.1: Concept bank

Concepts	Concepts	Concepts
Dynamic (System)	Le Chatelier (Principle)	Changes
Products	Temperature	Chemical (State)
Pressure	Reverse (Reaction)	Catalyst
Concentration	Rate of reaction	Forward (Reaction)
Chemical equilibrium	Reactants	Shift
Closed system	Equilibrium constant (K_c)	Physical (State)
Endothermic	Exothermic	

The first concept map (Figure 5.2) was constructed purely on the participants' existing knowledge. Only Participant Three had not had any previous classes on this topic, but the other participants had studied chemical equilibrium earlier in the year.

After the construction of the first concept map more were completed. Participants One and Three were the only two that completed four concept maps (the maximum number for this study) and Participants Two, Four and Five completed only three maps. The reason for this was that their third map was acceptable.

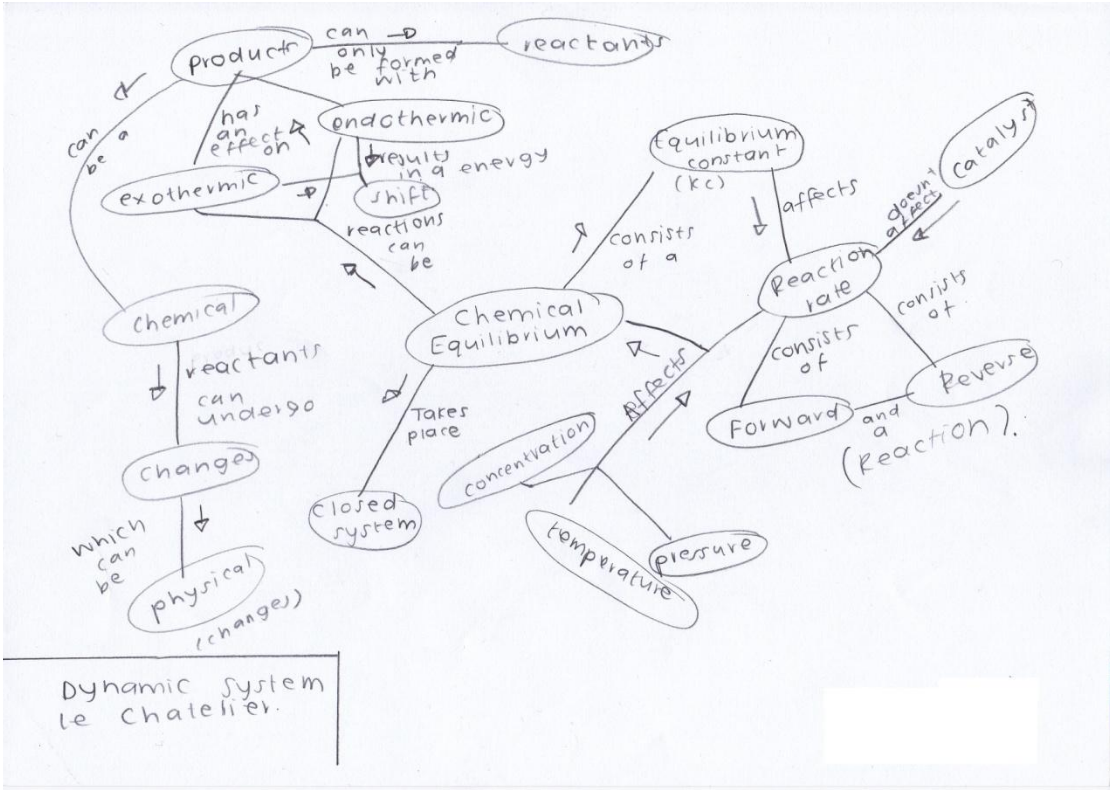

Figure 5.2: Example of a first concept map

5.2.3 Follow-up interview

The follow-up interviews were only used if there were any uncertainties in respect of the participants' concept maps, especially if the connection (linkage word or phrase) was unreadable or if the connection did not make any sense. The interviews were held after the participants had completed their maps and the maps were analysed.

The first follow-up interviews (discussions) were held after the completion of the second concept map.

Participant One (P1-HPG): Area of concern – link between chemical equilibrium and products and reactants as shown in Figure 5.3.

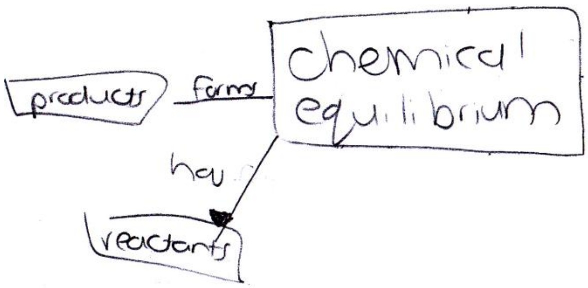

Figure 5.3: Participant One's area of concern

Participant Two (P2-HPG): Areas of concern – link between chemical equilibrium and reaction rate; link between chemical equilibrium and reverse/forward. Figure 5.4 indicates the relationship the participant used to connect *chemical equilibrium* and *forward/reverse*.

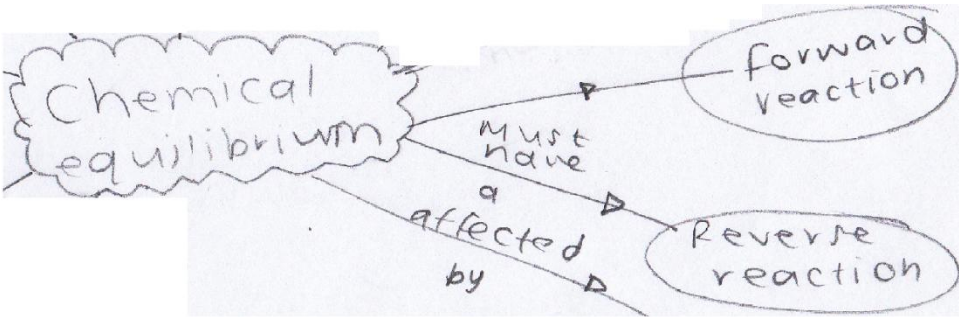

Figure 5.4: Participant Two's area of concern

Participant Three (P3-LPG): An area of concern is with temperature (and its surrounding concepts). Links:

Endothermic	*→Favours*	*→Forward*
Exothermic	*→Favours*	*→Reverse*
Temperature	*→Change*	*→Endothermic or Exothermic*

Participant Five (P5-LPB): Concerning area on the concept map is temperature with surrounding concepts – forward, reverse, endothermic and exothermic. Figure 5.5 illustrates one of these connections.

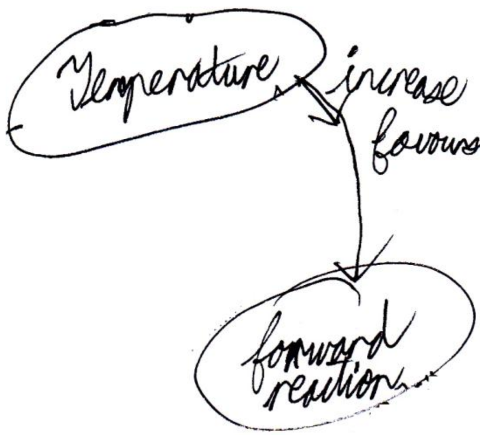

Figure 5.5: Participant Five's area of concern

After the third concept map the interviews decreased somewhat, and only Participant One and Three had one.

Participant One (P1-HPG): The link between chemical equilibrium and equilibrium constant is not ‘acceptable’. The linkage words used in this concept map, ‘is the’, do not show the relationship between the two concepts.

Participant Three (P3-LPG): Only one change needs to be made on the concept map. Half of one of the linkage words needs to shift down on the map. This will help the relationship to be more comprehensible.

The follow-up interviews were purely used for uncovering uncertainties concerning the concept maps. This method worked effectively, because the questions used were unstructured and data was obtained quickly (Seidman, 2005). The reason for unstructured questions was that none of the participants had the same alternative ideas; therefore each participant had his/her individual questions.

5.3 Data analysis process

After the data was collected through the different forms the analysis part of the study commenced. This section will discuss and report on the data analysis process. First under discussion is the data analysis method, followed by the additional classes.

5.3.1 Data analysis method

This study has a qualitative paradigm and not a quantitative paradigm. Therefore it analysed the quality of the concept maps and did not provide a ‘score’ for each map. As stated in previous chapters, a concept map cannot be ‘scored’ correctly because there are so many acceptable connections between two concepts (Kinchin *et al.*, 2000). The main focus was on the quality of connections, the quality of networking, and the quality of the learner’s knowledge framework.

The outcome of the pilot study provided two different methods to analyse the data. The two methods were the ‘*rubric-method*’ and the ‘*expert’s map-comparison-method*’. The ‘*rubric-method*’ supplied a predetermined set of quality assessments that were used on each concept map (see Table 3.4: Data analysis rubric). The rubric had set descriptions to determine the quality of the concept map in four different categories – *structure, relationship, exploratory* and *communication*. Table 5.2 shows the ‘*rubric-method*’ applied to Participant One’s first concept map.

Participant One achieved a marginal rating in all four areas (from Table 5.2), meaning that the structure was non-linear, which illustrates a relationship between ideas; that there was evident importance but it was not very distinctive (relationships are unclear or lacking); the exploratory aspect of the map shows some thinking about relationships between ideas, themes and frameworks; and communication of concepts was presented clearly with some level of understanding.

Table 5.2: Example of the '*rubric-method*'

Structure	Marginal
Relationship	Marginal
Exploratory	Marginal
Communication	Marginal

The second analysis method was used to compare the participant's concept map with an expert's. Figure 3.1 and Figure 5.6 are examples of an expert's concept map. This method was only used when necessary; it was mainly to be viewed as an example and a baseline for comparisons. The reason for the expert's map only being a comparative method is that all the connections on the map aren't the only acceptable connections. Literature shows that there are a variety of different acceptable connections between two concepts.

Assessed in the pilot study, these two methods were sufficient to conduct the analysis. The '*rubric-method*' provided a good platform to analyse the quality of data collected from the participants' maps.

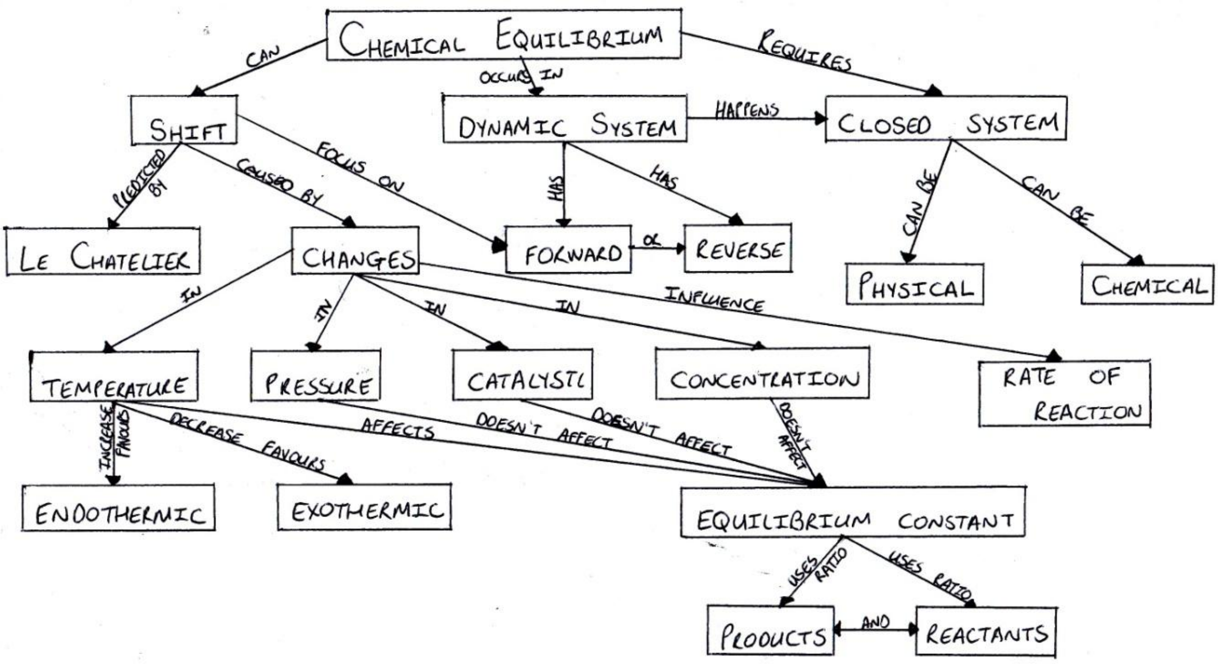

Figure 5.6: Expert's concept map

5.3.2 Additional lessons

The additional lessons were given after the analysis of each concept map. The analysis of each map determined the topic for and outcome of the additional lessons.

Lesson one: Chemical equilibrium

Lesson one was given after the first concept map was analysed. This lesson covered the whole topic on chemical equilibrium and all the concepts included in the concept bank. For Participants One, Two, Four and Five it was a revision lesson, but not for Participant Three.

Lesson two: Temperature in chemical equilibrium

Lesson two was given after the second concept map was analysed. This lesson covered temperature in chemical equilibrium and all the surrounding concepts. This lesson also included an individual follow-up interview (discussion) with each participant.

Lesson three: Follow-up interviews

For this session there was no prepared lesson, because there were no major concepts with surrounding alternative ideas. The majority of the concept maps were very good except for two. Participant Three had to make a structural change for the map (or linkage) to make sense, and Participant One had to change a recurring alternative idea.

Each of the additional lessons was specifically detailed to cover all the concepts which formed alternative ideas on the participant's maps. Each lesson provided the participant with the basic foundation to construct a new connection between concepts or to reconstruct existing connections.

5.4 Findings

In the following section the findings of the data analysis are discussed and reported upon.

5.4.1 Existing knowledge/Alternative ideas

After the participants completed their first concept map, two things were determined from the map, namely existing knowledge and alternative ideas. The existing knowledge is the prior knowledge the participant holds before any classes or tutoring have been given. This type of knowledge is described in the literature as the knowledge obtained from experience, experimentations, social interaction and/or culture (Zoller, 1990; Nakhleh, 1992). Alternative ideas have also been described in the literature as any perception of a concept that differs from the scientifically acceptable (Zoller, 1990). The participant's existing knowledge can already contain the alternative ideas.

The literature listed the following as main areas for alternative ideas in chemical equilibrium: Le Chatelier's Principle, the forward and reverse reactions, and that the catalyst affects both reactions (forward and reverse) differently (Bergquist & Heikkinen, 1990; Chiu *et al.*, 2002; Kousathana & Tsaparlis, 2002). Below is a list of most common alternative ideas in chemical equilibrium, according to Şendur *et al.* (2010: 2):

- The rate of the forward reaction is greater than the rate of the reverse reaction.
- There is no reaction occurring at equilibrium.
- A catalyst affects the rate of the forward and reverse reaction differently.
- Le Chatelier's Principle can be applied before the reaction has reached equilibrium.
- Equilibrium always shifts towards the product's side, meaning from left to right.

After the analysis of the first concept map, a number of concepts were omitted. These concepts were written on the side of the concept map. The following is a list of the omitted concepts:

- Dynamic system
- Le Chatelier
- Chemical
- Physical
- Changes
- Endothermic
- Exothermic

Table 5.3 shows the omitted concepts of each participant after each concept map (CM) had been completed.

Table 5.3: Omitted concepts

Participant	CM 1	CM 2	CM 3	CM 4
P1-HPG	Dynamic system Le Chatelier Chemical Physical	NONE	NONE	NONE
P2-HPG	Dynamic system Le Chatelier	NONE	NONE	
P3-LPG	Physical Chemical Changes	NONE	NONE	NONE
P4-HPB	Physical Endothermic Exothermic Dynamic system	Products Concentration Reactants Catalyst	NONE	
P5-LPB	NONE	NONE	NONE	

These were the concepts the participants were uncertain about which had already caused alternative ideas or could cause alternative ideas in the upcoming maps. Participants did not know how (or have the knowledge) to link the omitted concepts correctly with the others. Participant Four was the only participant that had omitted concepts in the second concept map. The strange part is that these were concepts he had used in his previous concept map; Participant Four may not have had enough time to complete his map. Participant Five was the only one that did not omit any concepts, but this did not determine the presence of alternative ideas. These concepts were also brought into account for the first tutoring class.

The first concept map also contained a number of alternative ideas. The following are alternative ideas each participant had after the first concept map:

Participant One:

- Chemical equilibrium is the equilibrium constant.
- Equilibrium constant needs a forward reaction.
- Equilibrium constant needs a reverse reaction.

Some adequate linkages included in Participant One’s first concept map:

- Chemical equilibrium has products.
- Chemical equilibrium has reactants.
- Reaction rate decreases with pressure.

Participant Two:

- Chemical equilibrium consists of the equilibrium constant.
- Equilibrium constant affects reaction rate.
- A catalyst doesn’t affect the reaction rate.
- Products can be a chemical (this is perceived as out of context).

Participant Three:

- Exothermic reactions cause a decrease in temperature.
- Endothermic reactions cause an increase in temperature.
- A decrease in temperature favours the reverse reaction.
- An increase in temperature favours the forward reaction.
- Chemical equilibrium calculates the equilibrium constant.

An adequate linkage included in Participant Three’s first concept map:

- Chemical equilibrium consists of reactants.

Participant Four:

- Chemical equilibrium is the same topic in science as chemical.
- Le Chatelier’s Principle forms products.
- Le Chatelier’s Principle uses products.

Participant Five:

- Reaction rate can be exothermic.
- Reaction rate can be endothermic.
- Reaction rate relies on equilibrium constant.

After the first concept map, each participant had the following alternative ideas for the following concept maps:

Participant One, map two:

- Chemical equilibrium is the equilibrium constant.
- Equilibrium constant has an endothermic reaction.
- Equilibrium constant has an exothermic reaction.

Participant One, map three:

- Chemical equilibrium is the equilibrium constant.

Participant Two, map two:

- All factors (catalyst, concentration, temperature and pressure) cause a shift in the equilibrium constant.

Participant Three, map two:

- Exothermic favours a reverse reaction.
- Endothermic favours a forward reaction.

Participant Five, map two:

- Exothermic favours the reverse reaction.
- Endothermic reaction favours the forward reaction.
- Changes influence the equilibrium constant.
- Temperature increase favours the forward reaction.

To summarise the alternative ideas of each participant, the following are recurring alternative ideas from the first concept map:

- Chemical equilibrium is the equilibrium constant.
- The equilibrium constant needs a forward/reverse reaction.
- The equilibrium constant affects the reaction rate.
- A catalyst doesn’t affect the equilibrium constant.
- Chemical equilibrium consists of the equilibrium constant.
- Temperature decrease only favours the reverse reaction.
- Temperature increase only favours the forward reaction.
- Chemical equilibrium influences temperature.
- All of the changes influence the equilibrium constant.
- Endothermic reaction only favours the forward reaction.
- Le Chatelier forms products.
- Le Chatelier uses reactants.

The recurring areas were Le Chatelier's Principle (linked in the concept map or omitted from the concept map); temperature and surrounding concepts; and equilibrium constant. The analysis of the first concept maps showed the existing knowledge of the participating learners. The next tutoring class focused on themes that tried to change these alternative ideas.

After the completion of the second concept map, the alternative ideas decreased significantly, but again the major focus areas were still in equilibrium constant, Le Chatelier, and temperature. From the first concept map only two alternative ideas recurred, namely '*Chemical equilibrium is the equilibrium constant*' and '*All the changes influence equilibrium constant*'. The rest of the alternative ideas are listed below:

- The equilibrium constant has an exothermic/endothermic reaction.
- Chemical equilibrium relies on the equilibrium constant.
- Reaction rate uses Le Chatelier's Principle.

Although the main focuses are the alternative ideas, some adequately perceived linkage words or phrases needed to be looked at. These include '*chemical equilibrium forms products*'; '*chemical equilibrium has reactants*'; '*an endothermic reaction favours the forward reaction*'; and '*an exothermic reaction favours the reverse reaction*'. These connections are not seen as 'incorrect', but could be used to describe some concepts in a more acceptable way.

There was a positive change from the first to the second concept map, changing most of the alternative ideas with only two recurring, but three new ideas were present. Participants One (P1-HPG), Two (P2-HPG), Three (P3-LPG) and Five (P5-LPB) did not omit any concepts, but Participant Four (P4-HPB) omitted four concepts – *products*, *reactants*, *concentration* and *catalyst*. The next tutoring class focused on these alternative ideas.

Analysis of the third concept map showed an even bigger decrease in alternative ideas with only one still remaining. Participant One (P1-HPG) used a recurring alternative idea – '*Chemical equilibrium is the equilibrium constant*'. Participants Two (P2-HPG), Four (P4-HPB) and Five (P5-LPB) did not have any alternative ideas present on their concept maps. The analysis showed that these participants provided scientifically correct linkages. Although Participant Three did not have any alternative ideas, there was a structural anomaly that needed to be changed. Participants Two (P2-HPG), Four (P4-HPB) and Five (P5-LPB) therefore did not have to complete a fourth concept map.

All of the participants' third maps showed an improvement in the area of alternative ideas as well as in the structure of the concepts on the concept map. Analysis of the fourth concept map showed that all the alternative ideas from the first concept maps had been changed or rearranged to become more scientifically acceptable.

After analysis of all the concept maps, the main concepts of concern that created alternative ideas were *Le Chatelier's Principle*, *temperature* (including its corresponding concepts, e.g., *endothermic* and *exothermic* reactions) and the *equilibrium constant*. The literature review predicted that *Le Chatelier's Principle* would be one of the areas of concern because it is a common alternative idea among learners, but the confusion surrounding *temperature* and *equilibrium constant* was not predicted. During the follow-up interviews the main focus was centred on *chemical equilibrium* and *temperature*, because these were not included in the literature as main alternative ideas. Questions were asked to P1-HPG, P2-HPG, P3-LPG and P5-LPB.

Temperature was the most area of concern in the concept map. Most of the participants knew that temperature is a factor that can affect the rate of a reaction as well as a factor that can influence the chemical equilibrium. One of the most recurring alternative ideas within this area was '*Temperature decrease only favours the reverse reaction*' and '*Temperature increase only favours the forward reaction*'. For example, an increase in temperature does not only favour the forward reaction, it can favour the reverse reaction as well. A scientifically acceptable connection would have been, '*Temperature decrease favours an exothermic reaction*' or '*Temperature increase favours an endothermic reaction*'. Temperature was one concept that stood out and P3-LPG was asked to explain why the particular connection between endothermic and forward reaction was used. P3-LPG answered as follows:

> *When the reaction taking place is endothermic the shift is to the right, meaning the forward reaction will be favoured.*

The indicated connection is not incorrect, but when the reaction is taking place the endothermic reaction can be the forward or reverse reaction. When there is a temperature increase it will favour the endothermic reaction, which can either be the forward or reverse reaction (depending on the ΔH) (Long & Victor, 2009).Class number two covered this topic and focused on all the concepts connected with *temperature*.

The other concept of concern, also not predicted in the literature review, was the *equilibrium constant*. One such an example was Participant One, where the alternative idea was '*Chemical equilibrium is the equilibrium constant*'. The participant saw the two concepts as equal, but the equilibrium constant is used at equilibrium by using the ratio of the products and reactants' concentrations. The problem with this concept was that participants knew what it was and how it works, but they did not know how to link it with other concepts.

At the end of the third or fourth concept map, all the existing alternative ideas were changed or rearranged to become scientifically acceptable. This was the fixed objective of the study where the rearranging or reconstructing of concepts is encouraged to overcome the prior knowledge which creates alternative ideas.

5.4.2 Concept map progression

The progression of the concept maps can be divided into two different categories, namely the progress in structure, and the progress in quality. This section will report on the findings in both these focus areas. The first report will be on structural progression and the second on the quality progression.

The following is an overview of the figures and their descriptions:

- Figure 5.7 shows the structure of Participant One's first concept map, whereas Figure 5.8 shows the structure of the fourth map.
- Figure 5.9 shows the structure of Participant Two's first concept map, whereas Figure 5.10 shows the structure of the third map.
- Figure 5.11 (first concept map) and Figure 5.12 (fourth concept map) indicate the difference in structure during the construction process.
- Figure 5.13 (first concept map) and Figure 5.14 (third concept map) show the different structures during the process.
- Figure 5.15 shows the structure of the first concept map (Participant Five), whereas Figure 5.16 shows the structure of the third concept map.

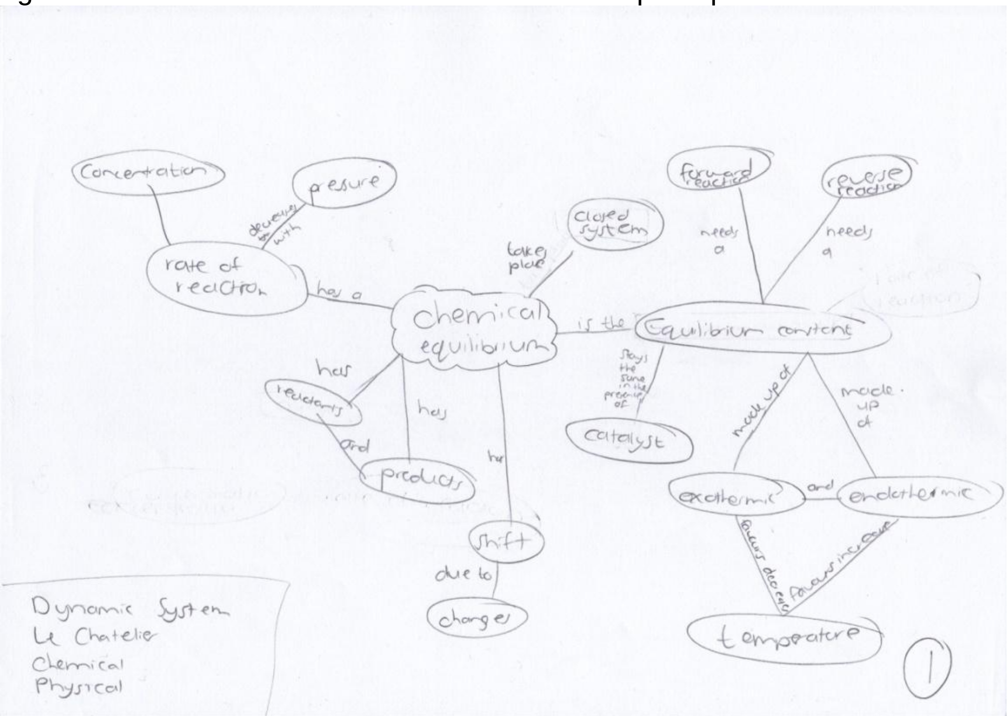

Figure 5.7: Participant One's first concept map

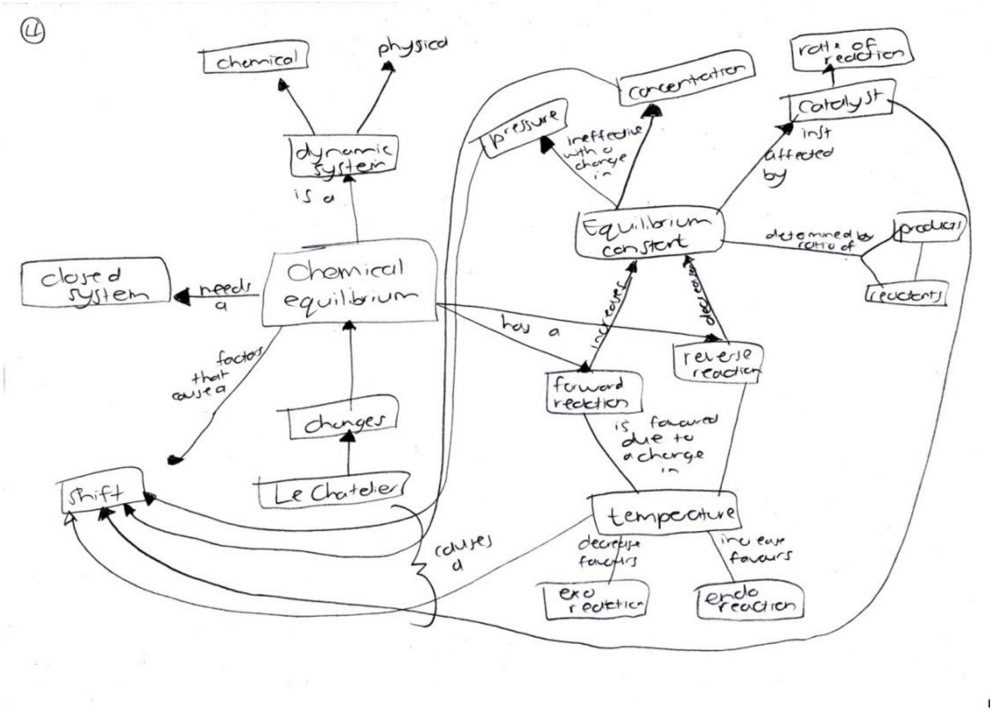

Figure 5.8: Participant One's fourth concept map

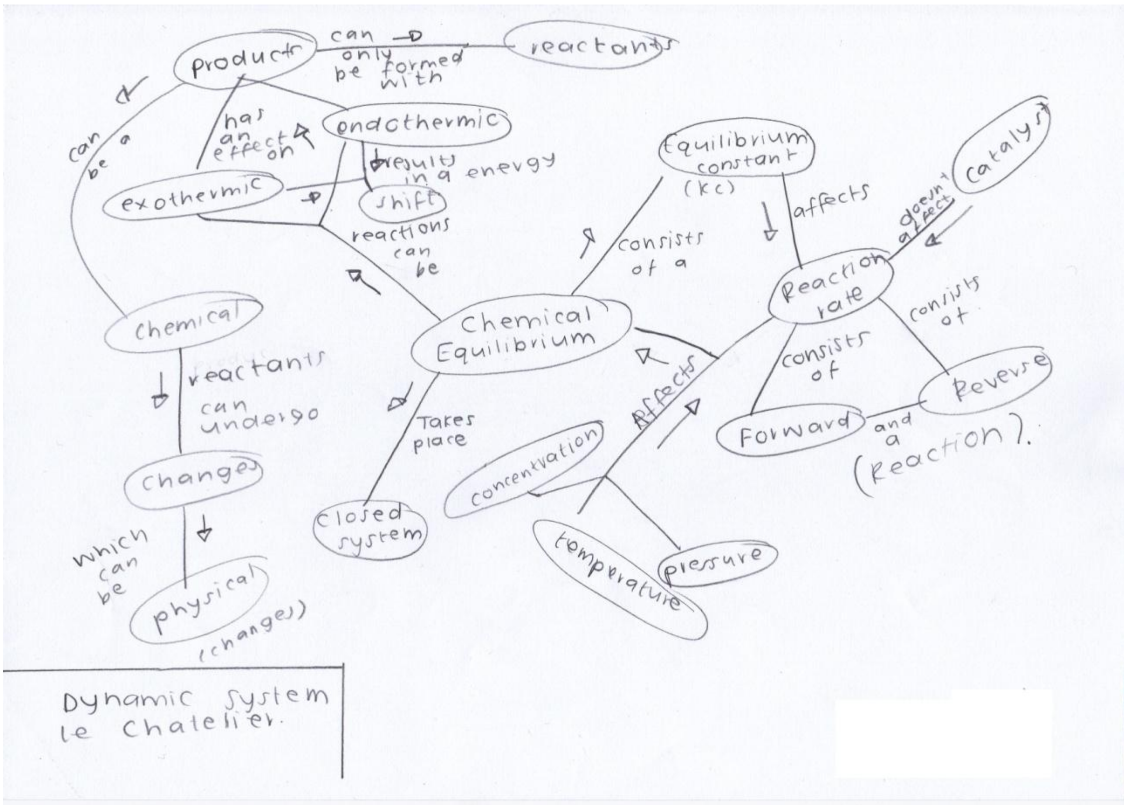

Figure 5.9: Participant Two's first concept map

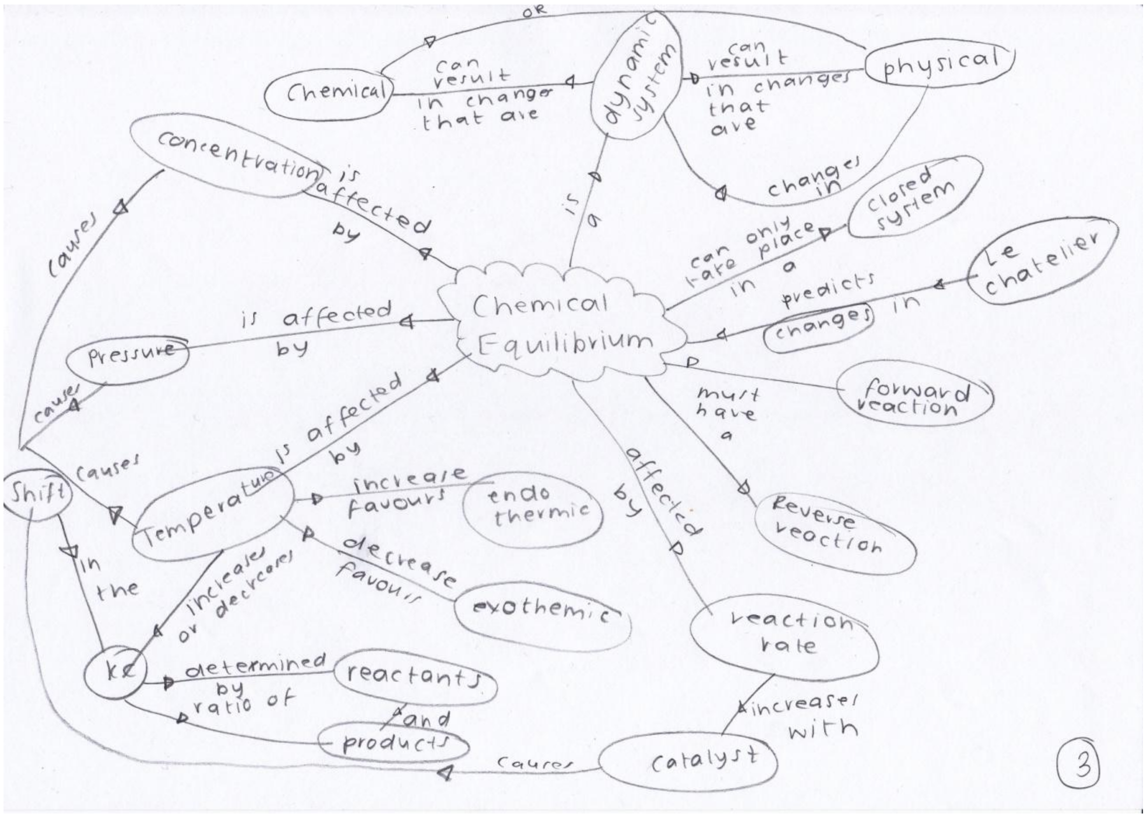

Figure 5.10: Participant Two's third concept map

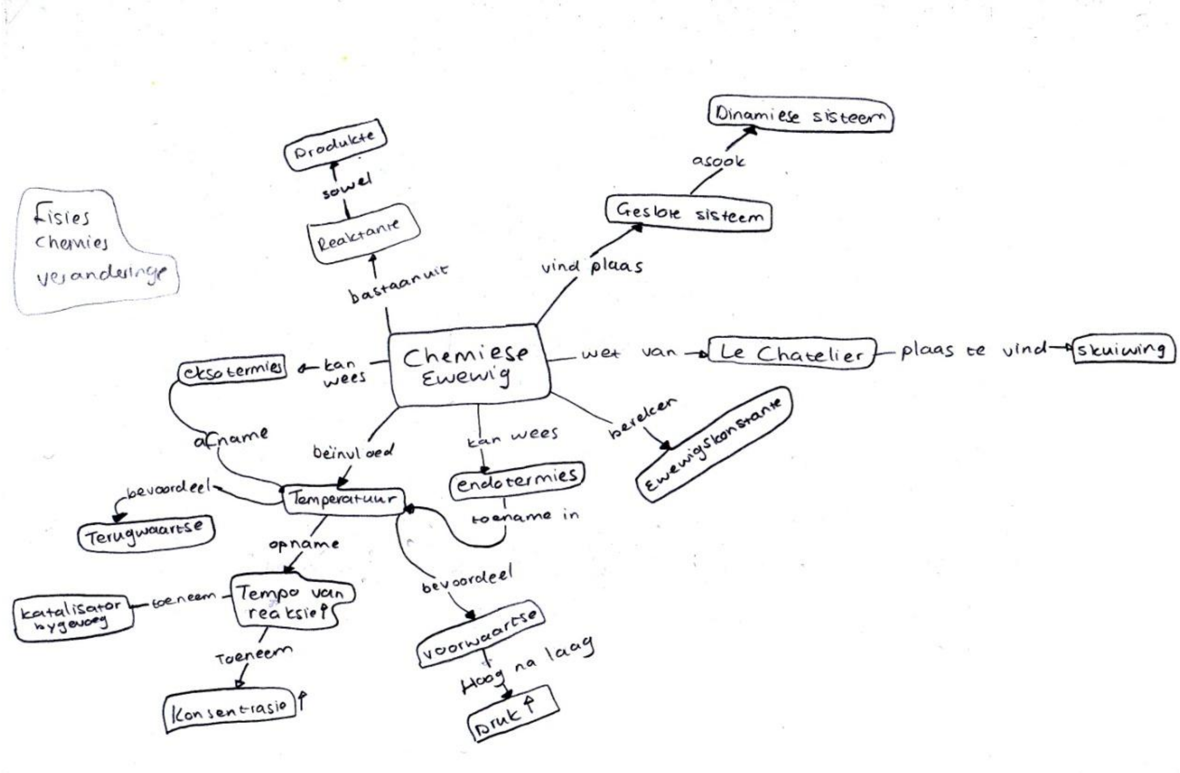

Figure 5.11: Participant Three's first concept map

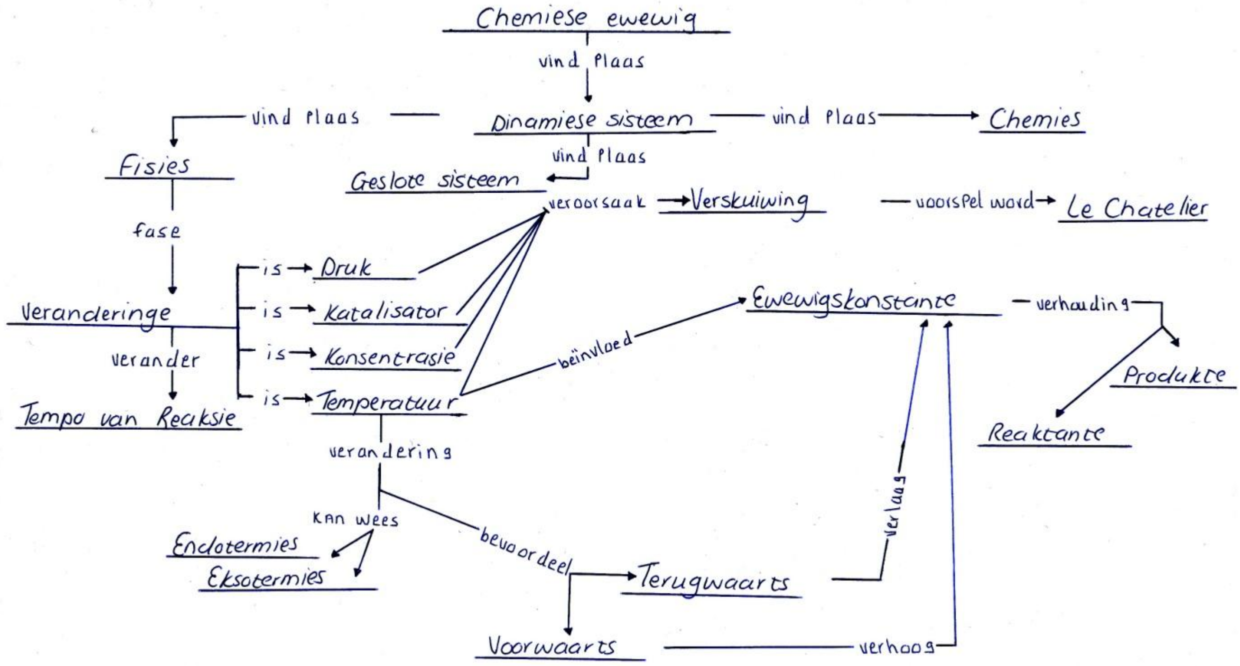

Figure 5.12: Participant Three's fourth concept map

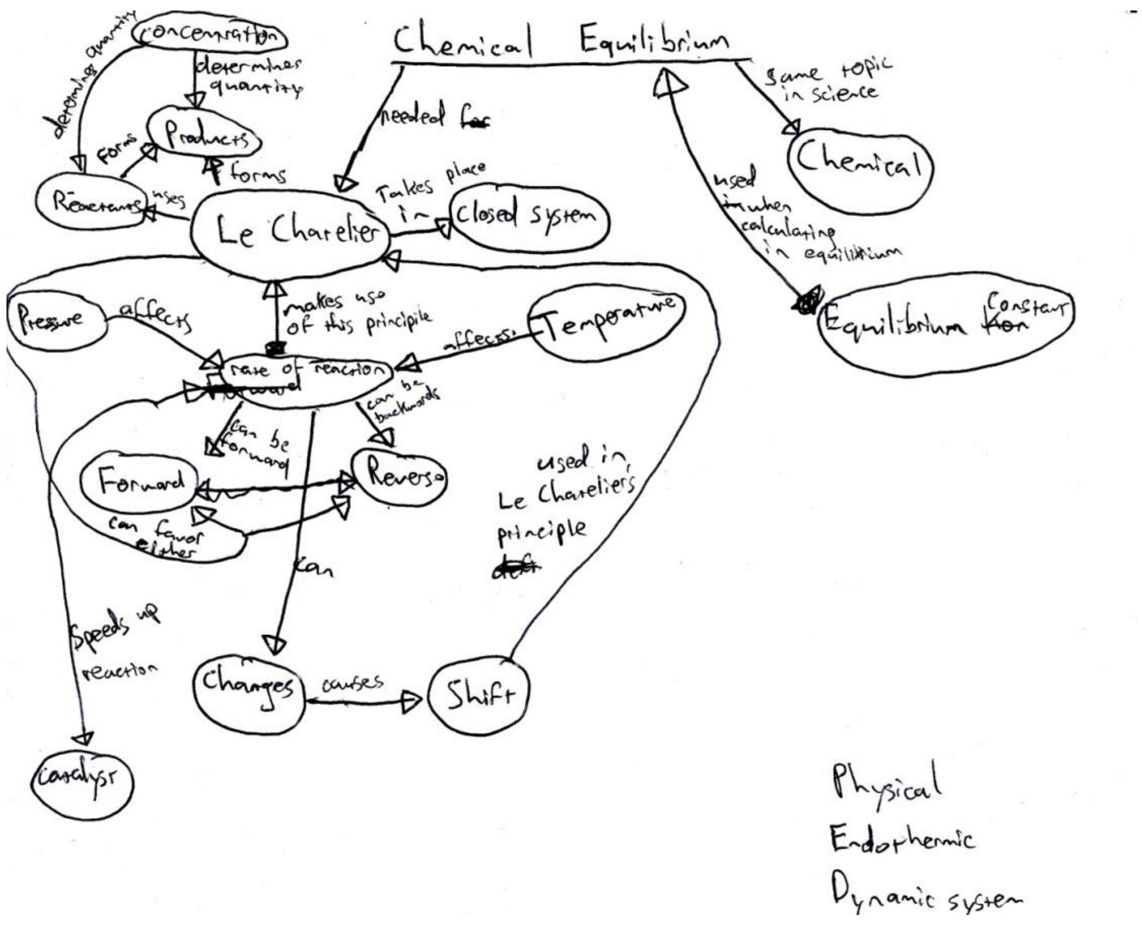

Figure 5.13: Participant Four's first concept map

Participants One, Two and Four started off with a mixture between linear and non-linear constructions. This indicated that they could see that some concepts could be connected to more than one other concept. Their structure changed from the mixture between linear and non-linear to a network structure in the third/fourth concept map. This is indicated in Figures 5.7 – 5.10 (P1-HPG and P2-HPG) as well as Figure 5.13 and 5.14 (P4-HPB).

Participant Three's first concept map has a very linear structure, and looks more like a mind map than a concept map (shown in Figure 5.11). Participant Three had the main concept (chemical equilibrium) in the middle of the page, which sprouted linear connections with other concepts. This had changed by the fourth concept map (shown in Figure 5.12), which was a good network structure. There were more connections and linkages between concepts on the final map.

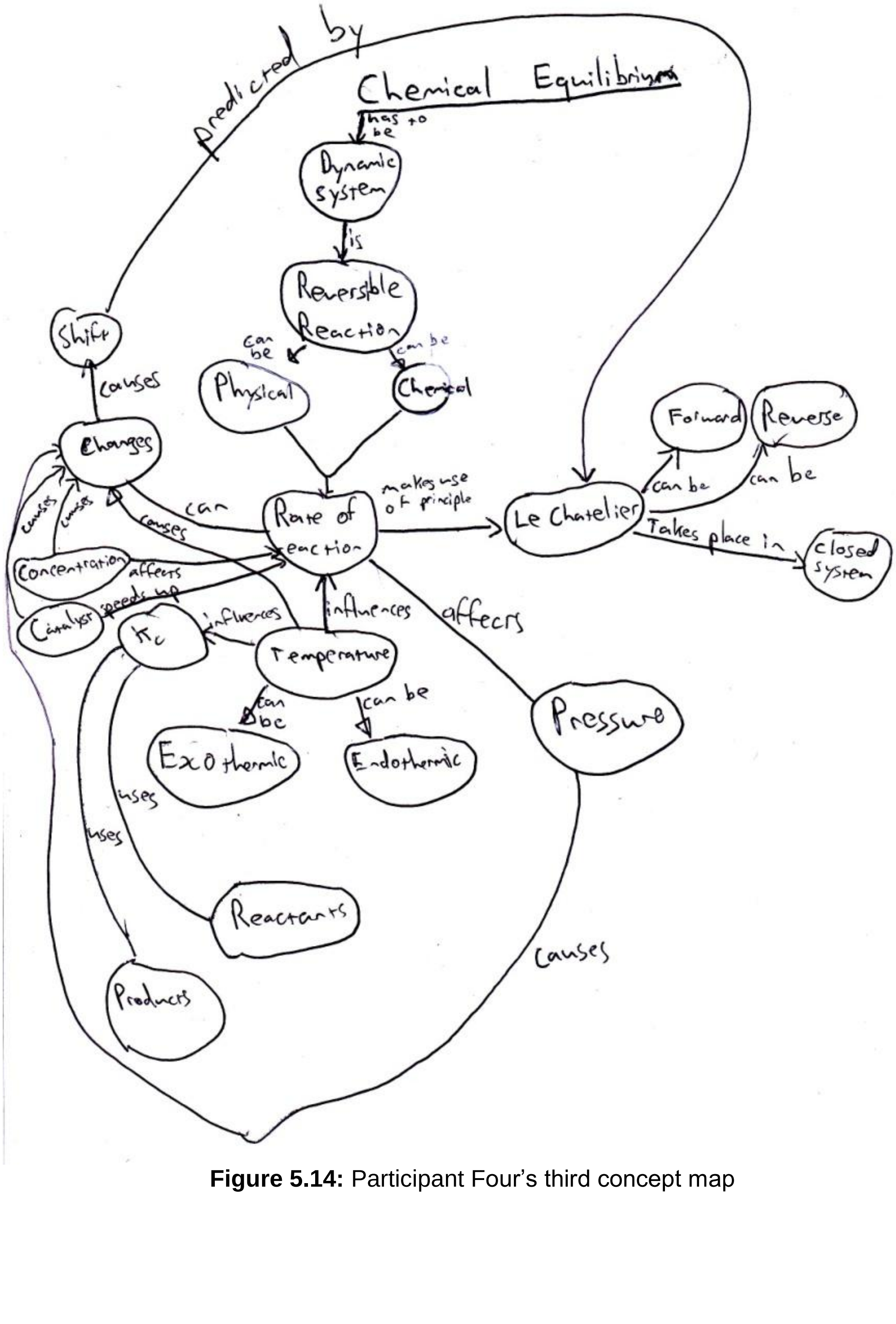

Figure 5.14: Participant Four's third concept map

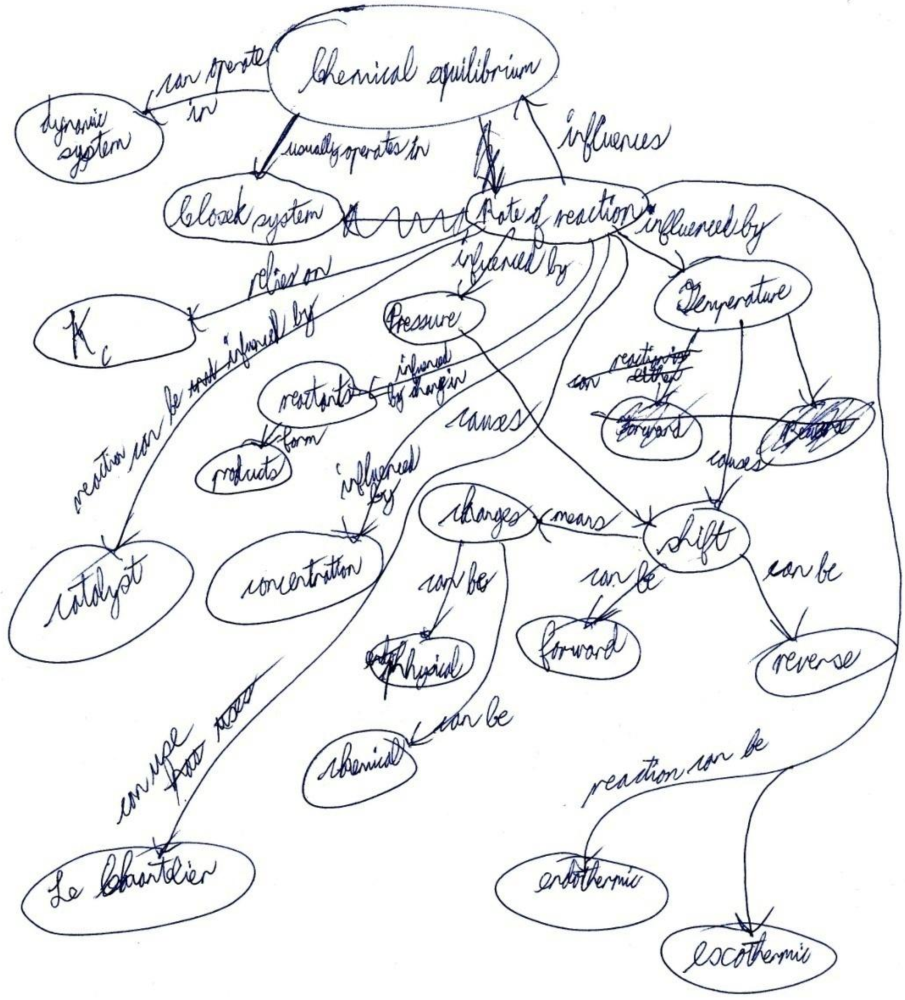

Figure 5.15: Participant Five's first concept map

Participant Five's first concept map (Figure 5.15) shows that a network-structured concept map can exist in the early stages of construction. Although the concept map showed signs of linear connections this participant knew what the map should look like.

Participant Five's structure changed rapidly with each constructed concept map and the final concept map (CM 3 in Figure 5.16) shows a very good network structure. The final map shows an increase in the number of cross-linkages between two or more concepts, helping with the network structure. The progression is shown throughout the construction process by each participant moving from the first concept map to the final (third or fourth) concept map.

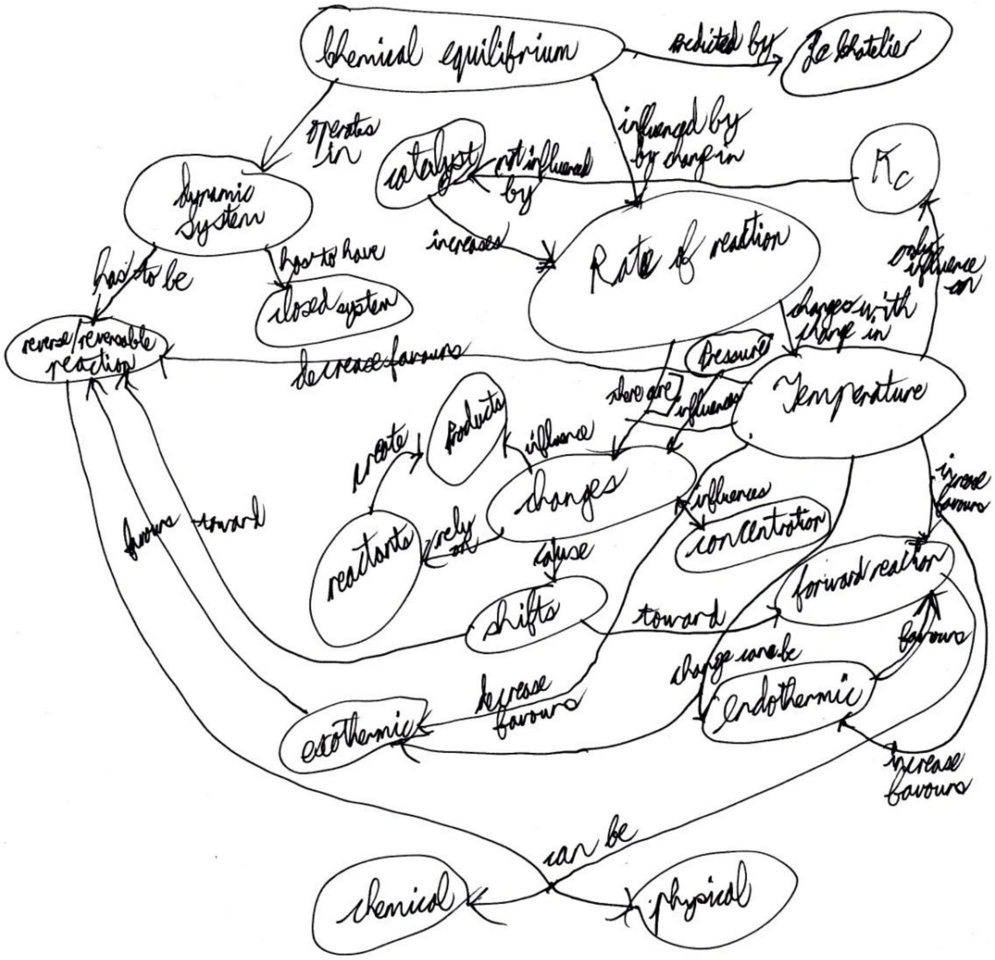

Figure 5.16: Participant Five's third concept map

Each participant showed a very good progression in their constructed maps, moving from the first map to the third or fourth. Through the different maps constructed there was a definite change in the structure of linking concepts. The movement showed progression from linear to more network-type construction; at the end the ideal type for a concept map is a network (Hay, Kinchin, & Lygo-Baker, 2008). Figure 5.11 and Figure 5.12 show the progression of Participant Three between the first concept map and the fourth concept map. In the first map the participant's structure is very linear and the map is treated as a 'mind map' with no cross-linking between the concepts. This changes through the process and the fourth maps shows a very good network between the concepts. A network-type map is the main outcome, because learners with such a map see the connections between different concepts at once.

Each participant had the same change in quality over the completion of the three or four concept maps. Each one improved on his or her previous map. Participants One to Five all added to the quality of each category (structure, relationship, exploratory and communication) over the process. The following tables show the improvement from the first concept map to the third or fourth map of each participant during the collection and analysis process.

Table 5.4: Participant One's map analysis (P1-HPG)

	CM 1	CM 2	CM 3	CM 4
Structure	Marginal	Adequate	Good	Excellent
Relationship	Marginal	Adequate	Good	Excellent
Exploratory	Marginal	Good	Good	Excellent
Communication	Marginal	Good	Excellent	Excellent

Table 5.5: Participant Two's map analysis (P2-HPG)

	CM 1	CM 2	CM 3	CM 4
Structure	Adequate	Good	Excellent	
Relationship	Adequate	Adequate	Good	
Exploratory	Adequate	Adequate	Excellent	
Communication	Adequate	Good	Excellent	

Table 5.6: Participant Three's map analysis (P3-LPG)

	CM 1	CM 2	CM 3	CM 4
Structure	Marginal	Adequate	Excellent	Excellent
Relationship	Adequate	Good	Good	Excellent
Exploratory	Adequate	Good	Excellent	Excellent
Communication	Adequate	Good	Excellent	Excellent

Table 5.7: Participant Four's map analysis (P4-HPB)

	CM 1	CM 2	CM 3	CM 4
Structure	Marginal	Adequate	Good	
Relationship	Adequate	Adequate	Good	
Exploratory	Marginal	Adequate	Good	
Communication	Adequate	Marginal	Excellent	

Table 5.8: Participant Five's map analysis (P5-LPB)

	CM 1	CM 2	CM 3	CM 4
Structure	Adequate	Excellent	Excellent	
Relationship	Adequate	Good	Good	
Exploratory	Adequate	Adequate	Excellent	
Communication	Good	Good	Excellent	

As we can see from Table 5.4 – 5.8, each participant improved the quality of his/her concept maps, using acceptable links as well as creating a network between the 20 different concepts on the map. The improvements showed a better understanding of linkages between the concepts.

Of the two aspects of progression, the progress on structure changed more rapidly. As soon as the participants saw the potential cross-linkages between concepts, the maps started to change from linear to network. The change occurred immediately after the first concept map towards the second one, but the progress of quality took a little longer. The process took longer because each participant had to change or rearrange concepts to overcome alternative ideas. Regardless of the time it took to improve both sections, there was improvement nonetheless.

5.4.3 HPL and LPL

As stated in the introductory paragraph, the expectation of the difference between HPL and LPL would be significant. The quality and nature of an HPL's concept map would be at a higher standard than that of an LPL's map. This was not the case in this study. Both HPL and LPL delivered the same quality concept maps. Table 5.9 shows the '*rubric-method*' rating for all of the participants' first concept maps.

Table 5.9: Similarity of the first concept map

Category	Structure	Relationship	Exploratory	Communication
P1-HPG	Marginal	Marginal	Marginal	Marginal
P2-HPG	Adequate	Adequate	Adequate	Adequate
P3-LPG	Marginal	Adequate	Adequate	Adequate
P4-HPB	Marginal	Adequate	Marginal	Adequate
P5-LPB	Adequate	Adequate	Adequate	Good

All the ratings ranged between 'marginal' and 'adequate', which showed no significant range between HPL and LPL.

5.5 Conclusion

The data collection and data analysis methods were well established from the findings of the pilot study as indicated by Bless *et al*. (2006) and Burns and Grove (2007). No anomalies occurred during the completion of all the processes, whether collection or analysis. The '*rubric-method*' indicated the specific quality of each category of each participant's map and this helped to indicate the progress from the first concept map to the third or fourth concept map.

The first concept map answered the first research question: "What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?" The first map concluded what concepts each participant holds in chemical equilibrium. This was indicated through the linkages made by the participants by using their existing knowledge (Kinchin *et al*., 2000; Kern & Crippen, 2008). The second research question: "How does concept mapping enhance Grade 12 learners' understanding of chemical equilibrium?" was answered during the analysis process. Each participant completed the series of maps with a positive improvement in structure and quality. The concept maps directly indicated the problem areas within the topic and where the focus needs to fall. When challenged with conflicting knowledge, the learners could see that their links did not make sense. This statement was an important aspect of conceptual change (Trochim, 1993). This helped the learners to change or rearrange their existing knowledge structure.

The surprise alternative idea not mentioned in the literature review was *temperature*. This concept was not included in Bergquist and Heikkinen's (1990); Nakhleh's (1992); Kousathana and Tsaparlis' (2002); or Şendur *et al.* (2010: 2) findings. Most of the confusion on the participants' concept maps surrounded this concept and this led to further alternative ideas of surrounding concepts. Temperature is an important factor in chemical equilibrium, therefore more emphasis should be given to this concept.

Another surprise alternative idea was the *equilibrium constant*, which was not mentioned in the literature review. The analysis determined that the participants knew everything about the concept (how to use it and what it is), but they had trouble connecting it with other concepts. After the second tutoring class, the participants found it easier to connect this concept with others.

Learners were classified as high- and low-performing learners, but as demonstrated in this study, that did not have an effect on their way of thinking. HPL and LPL gained more or less the same ratings on their first concept maps.

CHAPTER SIX
REFLECTION ON STUDY

6.1 Introduction

The final chapter reflects on the study as a whole by answering the research questions through the collected data, reflecting on the data, as well as discussing it. Furthermore this chapter will supply limitations and recommendations to improve further research on this topic or surrounding topics.

The purpose of the study was to investigate how the use of concept mapping could contribute to enhancing the teaching of chemical equilibrium in a Grade 12 science tutoring classroom. ‘Enhancing’ within this study, refers to high- (HPL) and low-performing learners (LPL) changing their existing unacceptable concepts of the topic with scientifically correct concepts under the framework of conceptual change theory, all the while using concept mapping.

The analysis of the data mainly occurred with the help of a data analysis rubric (Table 3.4) which was adapted from Kern and Crippen’s (2008) assessment rubric. After each learner completed a concept map, it was analysed in four different categories using the data analysis rubric: *structure*, *relationships*, *exploratory* and *communication*. Each category is individually described in five different levels: *no credit* (it is unacceptable to review), *marginal*, *adequate*, *good* and *excellent*. In each category the progression is shown by the description of each level. This analysis method was referred to as the ‘r*ubric-method*’. Each learner completes either three or four concept maps depending on the level of progression between the links, and if the linkages are acceptable or not.

The second analysis method is only used as a reference or baseline to which the learners’ concept maps could be compared. This method uses an expert’s concept map as a baseline for comparison to analyse the quality of linkages between concepts made by the learners. This method was also known as the ‘e*xpert’s map-comparison-method*’. Figure 3.1 and Figure 5.6 are examples of an expert’s concept map. Not every concept map is compared with the expert’s map; only the first map of each learner was compared.

The learners struggled with the first concept map, which was expected for a new type of data representation. But after the first map all the participants shared an excitement to complete the next maps; all of them kept asking when the next map would be completed. Each learner also shared an interest in what the study wanted to accomplish; they wanted to know what the purpose of the study was and how the study could help them. This made the learners active participants in the study. The participants also became actively involved in the data collection process, for example, they wanted to know where they had made ‘mistakes’ in the connections. This was an eye opener to see learners ‘wanting to learn’.

6.2 Reflection and discussion

This study uses a *5-C-framework*, which highlights five main constructs important to the study. *C1: Constructivism* and *C2: Conceptual change* form the dual theoretical framework for this study. Constructivism supplies the basis for how learners form their existing knowledge by assimilating concepts/ideas/frameworks through experiences, experiments and social interactions; in some situations these assimilated concepts are deemed as inadequate. While using *C4: Concept mapping,* we identify the inadequate concepts (alternative ideas) created by the learner; but conceptual change helps the learner to accommodate the unacceptable concepts by reorganising or replacing them.

Throughout the process of creating concept maps and accommodating concepts a high level of *cognitive thinking (C3)* is expected of the learner. Conceptual change uses an instructional cognitive model to change the concepts in a learner’s framework. The previous four C’s were placed in a field of interest (the topic): *C5: Chemical equilibrium*. Chemical equilibrium is one of the most difficult topics of chemistry within Physical Sciences, making it a worthwhile topic to investigate. Scholarly literature states that chemical equilibrium forms the basis of chemistry, acting as the building block on which other concepts build.

The *5-C-framework* provides a functional structure for the research to take place. Every ‘C’ is linked with the other, creating a network between the main constructs of the study. Previous research gives a sound methodological platform on which to base the study, using concept maps as the primary tool to gather and analyse the data with the ‘r*ubric-method*’.

Literature mentions a range of alternative ideas found in research which focuses on concepts like Le Chatelier’s Principle, chemical equilibrium as a dynamic system (this includes both the forward and reverse reactions), and the rate of a reaction. Two out of the three mentioned alternative ideas did not even feature in the analysis: Le Chatelier’s Principle was expected, because it plays a very important role in chemical equilibrium. Surprisingly another set of alternative ideas (not mentioned in the literature) surrounding two concepts appeared in the analysis, namely *temperature* and *equilibrium constant*. *Temperature* provides the greatest concern for chemical equilibrium within this study, because most of the alternative ideas came from this topic. The participating learners struggled with placing *equilibrium* *constant* within the framework of chemical equilibrium. Strangely enough all the participants came from different schools, but had more or less the same alternative ideas, especially about *temperature* and *equilibrium constant*.

6.3 Answering the research questions

The following section will use the data collected and analysed to answer both research questions of the study. The two research questions were: “What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?” and: “How does concept mapping enhance Grade 12 learners’ understanding of chemical equilibrium?”

6.3.1 Research Question One

“What concepts of chemical equilibrium (existing concepts) do Grade 12 learners have?” Literature describes existing concepts as those a learner accumulates through the social environment during experiences, experimentations and interactions with other knowledgeable people. Therefore if we take the learner’s first concept map into account, this map is constructed before any extra tutorial classes are given to the learner; therefore the map will supply us with all the learner’s existing concepts surrounding a topic. For this study the topic is chemical equilibrium.

A large part of the existing concepts contains alternative ideas; this is when the concept a learner has deviates from the acceptable one. After analysis of the first concept map, the following alternative ideas were found among Grade 12 Physical Sciences learners:

- Chemical equilibrium is the equilibrium constant.
- The equilibrium constant needs a forward/reverse reaction.
- The equilibrium constant affects the reaction rate.
- A catalyst doesn’t affect the equilibrium constant.
- Chemical equilibrium consists of the equilibrium constant.
- Temperature decrease only favours the reverse reaction.
- Temperature increase only favours the forward reaction.
- Chemical equilibrium influences temperature.
- All of the changes influence the equilibrium constant.
- Endothermic reaction only favours the forward reaction.
- Le Chatelier forms products.
- Le Chatelier uses reactants.

This indicates the existing knowledge and alternative ideas found among Grade 12 learners. In all five of the first concept maps, alternative ideas were found. The expectation between the HPL and LPL were that HPL would have fewer alternative ideas than LPL; however this was not the case. Both HPL and LPL had more or less the same amount of confusion surrounding certain topics. Neither of the two had more than the other.

6.3.2 Research Question Two

“How does concept mapping enhance Grade 12 learners’ understanding of chemical equilibrium?” was answered throughout the analysis process. After the first map, the learner is given tutorials which create a conflict situation with the existing knowledge. Here the learner is given the conflict situation to change or rearrange the existing framework to make it more acceptable. As the process progresses, the learners use these newly obtained concepts in the following concept maps.

During the process when the learner changes or rearranges concepts, ideas or frameworks, he/she develops a new understanding of the concepts deeming it scientifically acceptable. With better understanding, learners can connect more than one topic to chemical equilibrium, for example, connecting acids and bases with chemical equilibrium.

At the end of the third or fourth concept map, the learner can observe chemical equilibrium as a whole, with a network of linkages between concepts. When learners can observe their linkages, the ‘bigger picture’ is presented. Concept mapping has the ability to act as a long-term memory helping the learner to study chemical equilibrium. All of these aspects enhance the Grade 12 learner’s understanding of chemical equilibrium.

6.4 Personal reflection

From the beginning to the end this study, this research was the highlight of the day. There was no limit to useful information and gathering it provided no problem. The method of the study provided a good platform for gathering data, which would in turn answer the relevant research questions. The pilot study evinced some difficulties, but did establish what form of methodology would be used in the final data collection.

The construction process of the concept maps was interesting to observe, especially how uniquely individual each participant was. This included observing the way each participant perceived how concepts influence one another.

This study influenced participating learners in more ways than one. It developed a ‘hunger’ for learning, which could be observed from day to day. This was an unanticipated effect at the end, but nevertheless a positive one.

There is no doubt that this study and its findings can be used to improve certain aspects in the science classroom.

6.5 Limitations of the study

As in every study, whether it is a large or small one, it is necessary to identify the limitations. The research under discussion was conducted on a small scale in a tutoring classroom with the following limitations.

Learners are treated as individuals, therefore none of them will have the same alternative ideas. This makes identifying recurring data more difficult. Each concept map is unique to the individual that created the map, therefore the study is very hard to replicate. The findings for this study are different from those of previous or future studies. Another study would obtain other alternative ideas, different existing knowledge and other frameworks.

Not much focus was given to the cognitive and critical thinking aspect of the study, which is also a very important construct when working with assimilating and accommodating concepts. Cognitive apprenticeship was merely mentioned, but this construct could provide an in-depth observation on how learners change concepts.

6.6 Recommendations

Upon reflecting on the study, the following recommendations come to mind, and these recommendations were made purely on observation. Some recommendations can be made to the teacher, the Department of Basic Education (DBE), and/or for the improvement of curriculum.

Teachers can use concept mapping in their classrooms, but they need to keep in mind that each learner is an individual. Performing this study on a larger scale (that is, with the high learner numbers currently in school classrooms), would make use of generalisation, and that one needs to keep to a minimum.

The DBE can also use concept mapping as a tool in Physical Sciences as well as mathematics; this could help them to achieve their targets within the time needed. The DBE could use it as an intricate part of the curriculum.

Within the curriculum, the concept maps will help the learners to see the ‘bigger’ picture, especially how concepts connect with one another. This could be applied at the end of each chapter, or at the end of a section. Concept maps could also be used to show the relationship between overlapping chapters and topics.

Although there were no problems with the creation process of the concept maps, the *pencil-and-paper* method was not very modern. Various literatures describe a more up-to-date method for constructing concept maps, where the learner can use a computer or laptop to create his/her concept map. Some of the more popular concept mapping software on the market is CMAP (Concept Map Program) and VUE (Visual Understanding Environment). Constructing concept maps on a piece of paper with a pencil can also be time consuming.

In some of the classes the time given to the participants was not sufficient; this was observed by the lack of ‘extra’ connection that could have been made on the concept maps. Therefore in future research studies, the time limit could be lengthened to supply the participants with enough time to construct ‘extra’ connections. ‘Extra’ connections refer to more networking between concepts.

The field of interest can broaden to contain more than one topic showing the network linkage model of different concepts overlapping between the topics. This enables the learner to broaden his/her knowledge to build upon a baseline topic (chemical equilibrium) with further topics (acid and base concepts or electrochemical cells).

6.7 Conclusion

Each participant (HPL and LPL) gave a unique transformation of concepts using concept mapping with the quality and understanding of chemical equilibrium concepts increasing throughout the process.

Implementing concept mapping on certain topics will help teachers or tutors identify any alternative ideas created among learners. This enhances both the learner’s understanding of the topic at hand and the teacher’s understanding of how the learner sees the topic, as well as identifying alternative ideas. Teachers can then arrange classes to focus on these problem areas.

Concept mapping not only creates understanding, but also generates an active learner.

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APPENDICES

APPENDIX A: WCED approval letter

Western Cape Government

Education

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ENQUIRIES: Dr A T Wyngaard

Mr Derẻ Langford
CPUT
Wellington Campus

Dear Mr Derẻ Langford

RESEARCH PROPOSAL: THE USE OF CONCEPT MAPPING TO ENHANCE THE TEACHING OF CHEMICAL EQUILIBRIUM IN A GRADE 12 PHYSICAL SCIENCE TUTORING CLASSROOM

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Approval for projects should be confirmed by the District Director of the schools where the project will be conducted.
5. Educators' programmes are not to be interrupted.
6. The Study is to be conducted from **10 April 2012 till 28 September 2012**
7. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
8. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number.
9. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
10. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
11. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
12. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000

We wish you success in your research.

Kind regards.
Signed: Audrey T Wyngaard
for: **HEAD: EDUCATION**
DATE: 21 February 2012

APPENDIX B: CPUT (Ethics committee) approval letter

APPENDIX II

ETHICS FORM FOR ORIGINAL RESEARCH

This form is to be completed by the student, member of staff and other researchers intending to undertake research in the Faculty. It is to be completed for any piece of research the aim of which is to make an original contribution to the public body of knowledge.

For students this type of work will also have educational goals and will be linked to gaining credit - it is the type of work that will be the basis for a Masters/Doctoral thesis or any research project for which ethical clearance is deemed necessary:

Name(s) of applicant	D. Langford
Project Title	The use of concept mapping to enhance the teaching of chemical equilibrium in a Grade 12 physical science tutoring classroom
Is this a staff research project?	No
Degree	M.Ed
Supervisor(s)	Dr. K. Whittles
Funding sources	N/A

Attached: Information sheet x Consent form € Questionnaire € Other (Specify)

Questions for Consideration in the Summary

(i) How will you recruit participants? Is there any possibility that participants might feel coerced to take part and if so how can you manage this issue?
All participants attend tutoring classes, where I coordinate these classes. No, they have the option of refusing to partake in the research project.

(ii) How will participants be made aware of what is involved in the research [prior to, during and after data collection]? This will be discussed with them.

(iii) How will you ensure that participants really do understand their rights? All the relevant information will be discussed and shared with the participants.

(iv) Attach your instrument for data collection (if applicable).

(v) Is there a risk of harm to participants, to the participants' community, to the researcher/s, to the research community or to the University? If so how will these risks be managed?
No

(vi) What plans do you have for managing the confidentiality and anonymity of participants in this study?
Using letters of the alphabet to refer to learners and indicate 1 and 2 for the different cycles of data collection, e.g. A1 (learner A in cycle one)

(vii) Are there any potential conflicts of interest for you in undertaking this study?
No

(viii) How will the findings be used on completion of the study?
Feedback will given to all relevant stakeholders partaking in the study.

(ix) Does this work raise any other ethical issues and if so, how will you manage these?
No

(x) What training or experience do you bring to the project or will enable you to recognize and manage the potential ethical issues?
My experience in tutoring learners from diverse backgrounds and the writing of reports for the WCED.

Research Checklist:		**Yes**	**No**
1:	Does the study involve participants who are unable to give informed consent? Examples include children, people with learning disabilities, or your own students. Animals?		X
2:	Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? Examples include students at school, members of self-help groups, residents of nursing homes — anyone who is under the legal care of another.		X
3:	Will it be necessary for participants to participate in the study without their knowledge and consent at the time — for example, covert observation of people in non-public places?		X
4:	Will the study with the research subject involve discussion of sensitive topics? Examples would include questions on sexual activity or drug use.		X
5:	Will the study involve invasive, intrusive, or potentially harmful procedures of any kind (e.g. drugs, placebos or other substances to be administered to the study participants)?		X
6:	Will the study involve prolonged or repetitive testing on sentient subjects?		X
7:	Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?		X
8:	Does your research involve environmental studies which could be contentious or use materials or processes that could damage the environment? Particularly the outcome of your research?		X

Signatures:

Researcher/Applicant:		Supervisor
Date: 23/02/2012		Date:

Please note that in signing this form, supervisors are indicating that they are satisfied that the ethical issues raised by this work have been adequately identified and that the proposal includes appropriate plans for their effective management.

Faculty Research Ethics Committee comments:

Education Faculty Ethics Committee unconditionally grants ethical clearance for a study titled 'The use of Concept mapping to enhance the teaching of chemical equilibrium in Grade 12 Physical Science Tutoring classroom.' The certificate is valid for 2 years

Approved	Referred back	Approved subject to adaptations	Chairperson		Date: 16/4/12

Approval Certificate/Reference: EFEC 1-4/2012

APPENDIX C: TEST Learning Centre approval letter

LEARNING CENTRE

"Education to prosper"

Mr. Dere Langford
King's Place No. 6
Market Street
Paarl
7646

18 April 2012

Re: Request to conduct research at TEST Learning Centre

Dear Dere

With regards to your letter dated 21st February 2012, requesting permission to do research at our institution and with our temporary learners, we confirm that permission has been granted by management based on the outline of your letter.

Wishing you well with your research project and your further studies.

Kind regards.

Justin Brockman

082 9331569

APPENDIX D: Parental consent form

Dear parent or guardian:

I am a master's degree student in the educational department at Cape Peninsula University of Technology. I am conducting a research project on the quality of concept maps in the physical science tutor classroom to overcome the challenges certain concepts hold. I request permission for your child to participate.

The study consists of the learner completing four concept maps helping them to understand certain concepts in physical science better. Extra classes would also be given on certain topics. The project will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only I and members of the company staff will have access to information from your child. At the conclusion of the study, children's responses will be reported as group results only.

Participation into this study is voluntary. Your decision whether or not to allow your child to participate will not affect the service normally provided to your child by TEST Learning Centre. Even if you give your permission for your child to participate, your child is free to refuse to participate. The study will be greatly beneficial to the participating learner. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this study.

If there is any questions about the above study please contact you may contact either the researcher Mr. D. Langford (021 870 1055, dere@triclineducation.co.za) or research supervisor Dr. K. Whittles (021 864 5287, whittlesk@cput.ac.za).

Respectfully

Mr. Deré Langford
Lead Researcher:
Physical Science

Dr. Kalvin Whittles
D. Ed (PhD)
Research Supervisor

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below, signing your name and returning the tear-off with your child.

I grant permission for my child to participate in the study.

I do not grant permission for my child to participate in the study.

____
Signature of parent/guardian

____
Printed parent/guardian name

____
Printed name of child

____
Date

APPENDIX E: Participant consent form

Dear Physical Science learner:

This letter serves to request your participation in the Research study of 2012 (Research title: The use of concept mapping to enhance teaching of chemical equilibrium in a Grade 12 tutoring science classroom). The study will research the quality of concept maps in the physical science tutor classroom to overcome the challenges certain concepts hold. Participating learners will include individual and group class learners.

There are no financial benefits that will accrue to the participating company and university. This study will instead benefit the company in future training and the gained expertise can be share with counterparts. In addition, once the reports have been produced, data collected will belong to the researcher for further analysis.

Respectfully

Mr. Deré Langford
Lead Researcher:
Physical Science

Dr. Kalvin Whittles
D. Ed (PhD)
Research Supervisor

If there is any questions about the above study please contact you may contact either the researcher Mr. D. Langford (021 870 1055, dere@triclineducation.co.za) or research supervisor Dr. K. Whittles (021 864 5287, whittlesk@cput.ac.za).

Please indicate whether or not you wish to participate in this project by checking one of the statements below, signing your name and returning the tear-off when you come for your next class.

I grant permission to participate in the study.

I do not grant permission to participate in the study.

____
Signature of participant

____
Printed name of participant

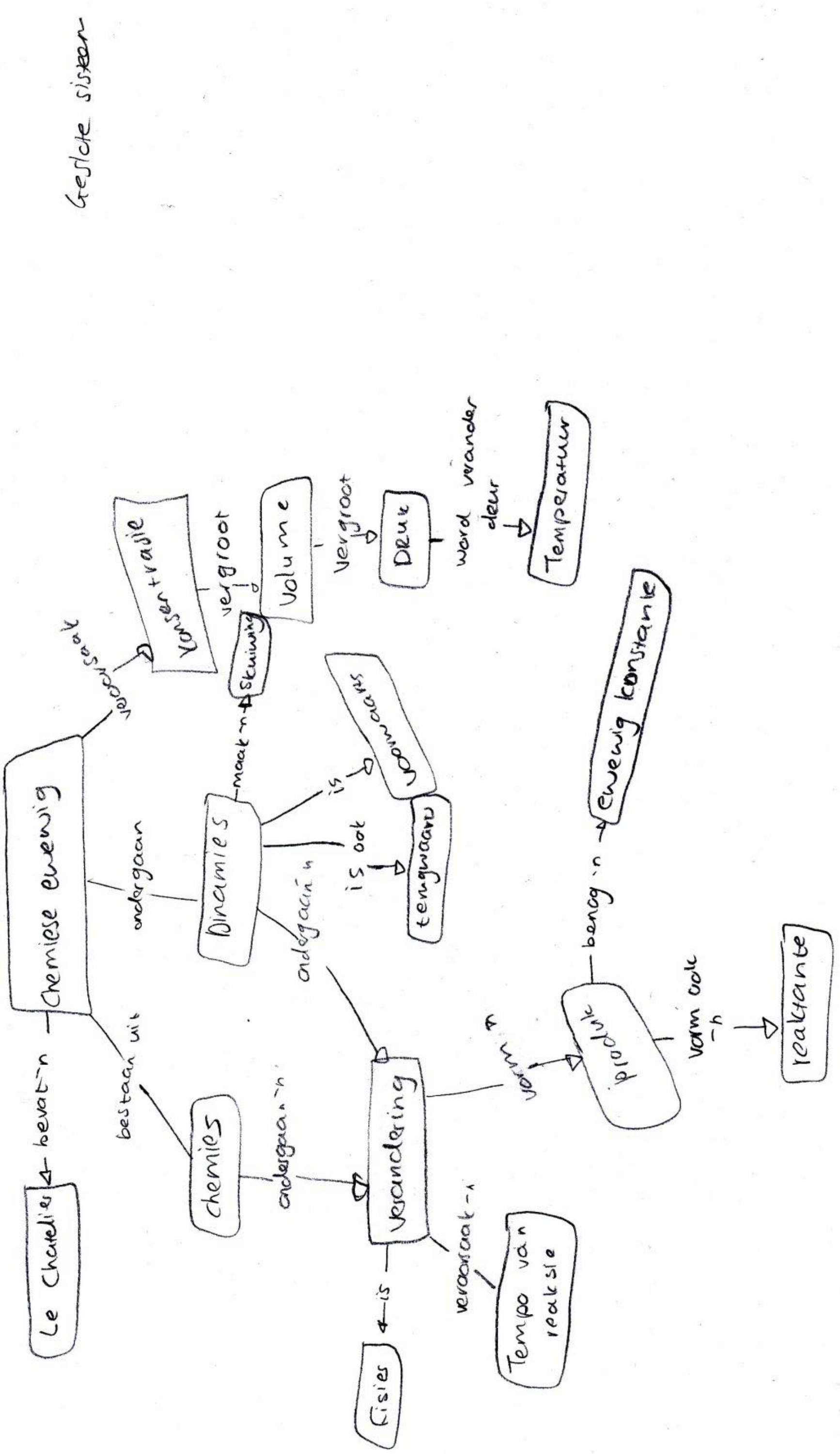
____
Date

APPENDIX F: Pilot study concept maps

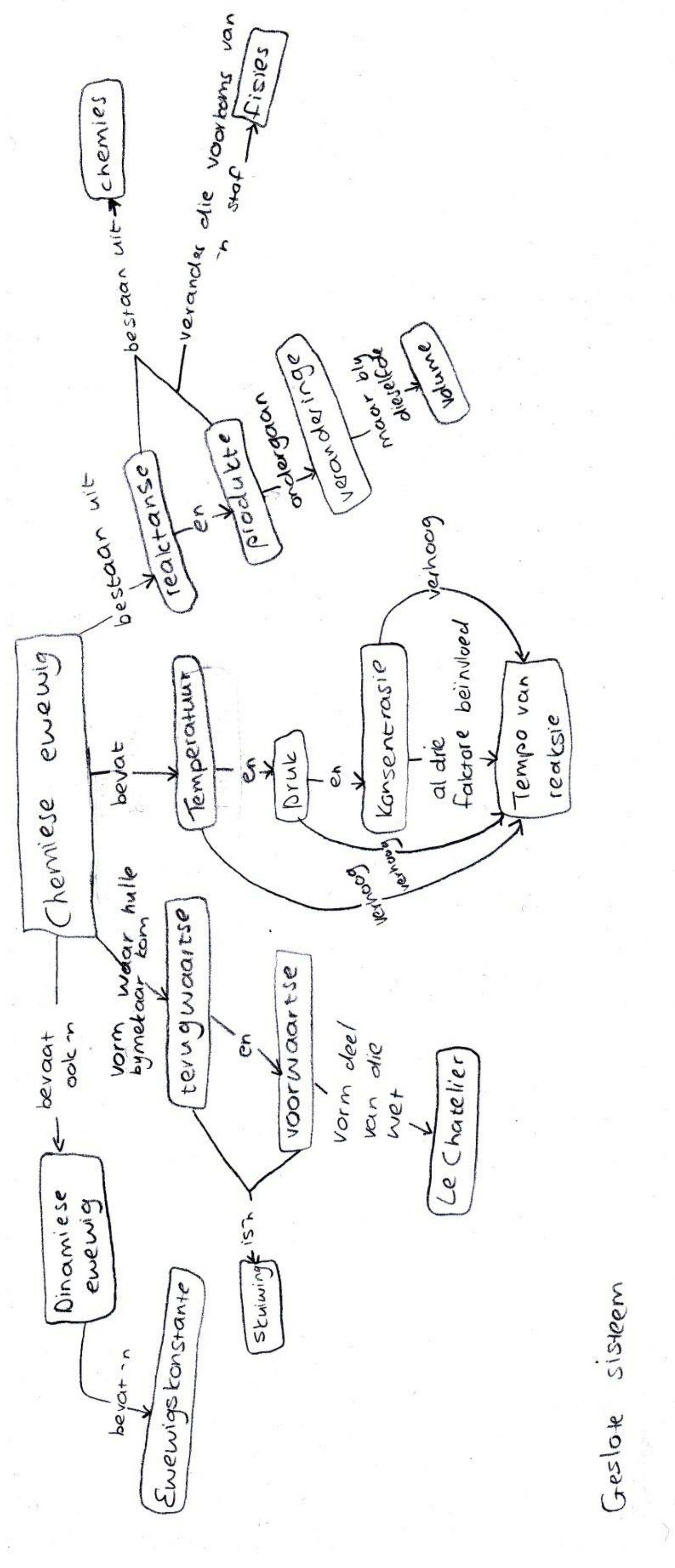
This appendix contains the concept maps completed by two participants in the pilot study. One of the participants completed four concept maps whereas the other participant only completed the first concept map. This appendix contains the following:

APPENDIX F1: Participant one concept map one
APPENDIX F2: Participant one concept map two
APPENDIX F3: Participant one concept map three
APPENDIX F4: Participant one concept map four
APPENDIX F5: Participant two concept map one

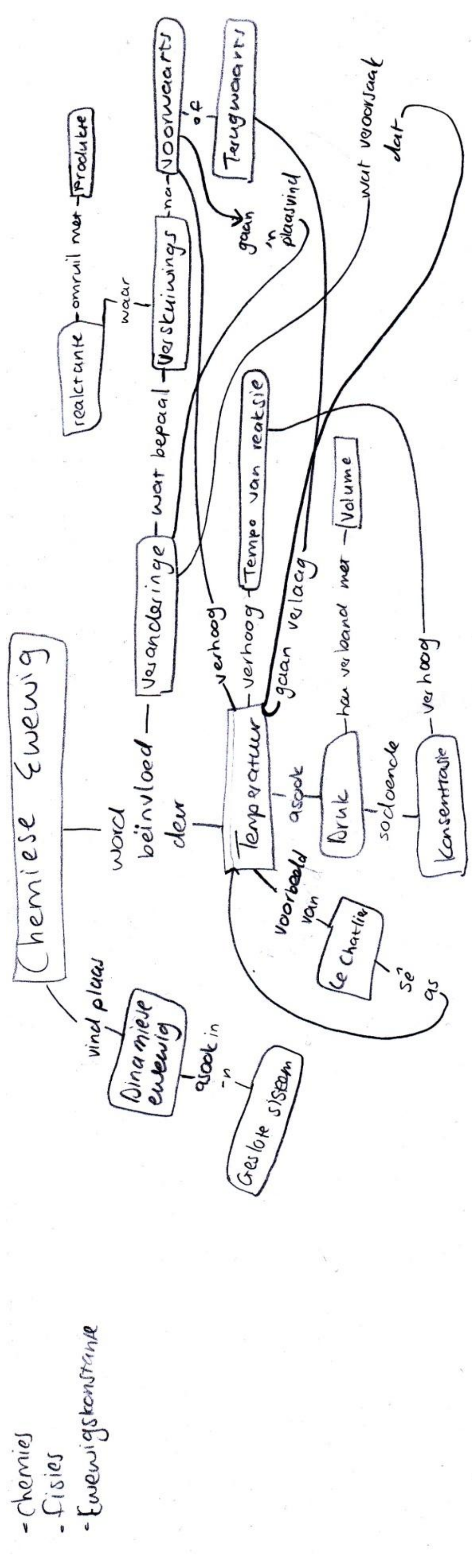
APPENDIX F1: Participant one concept map one



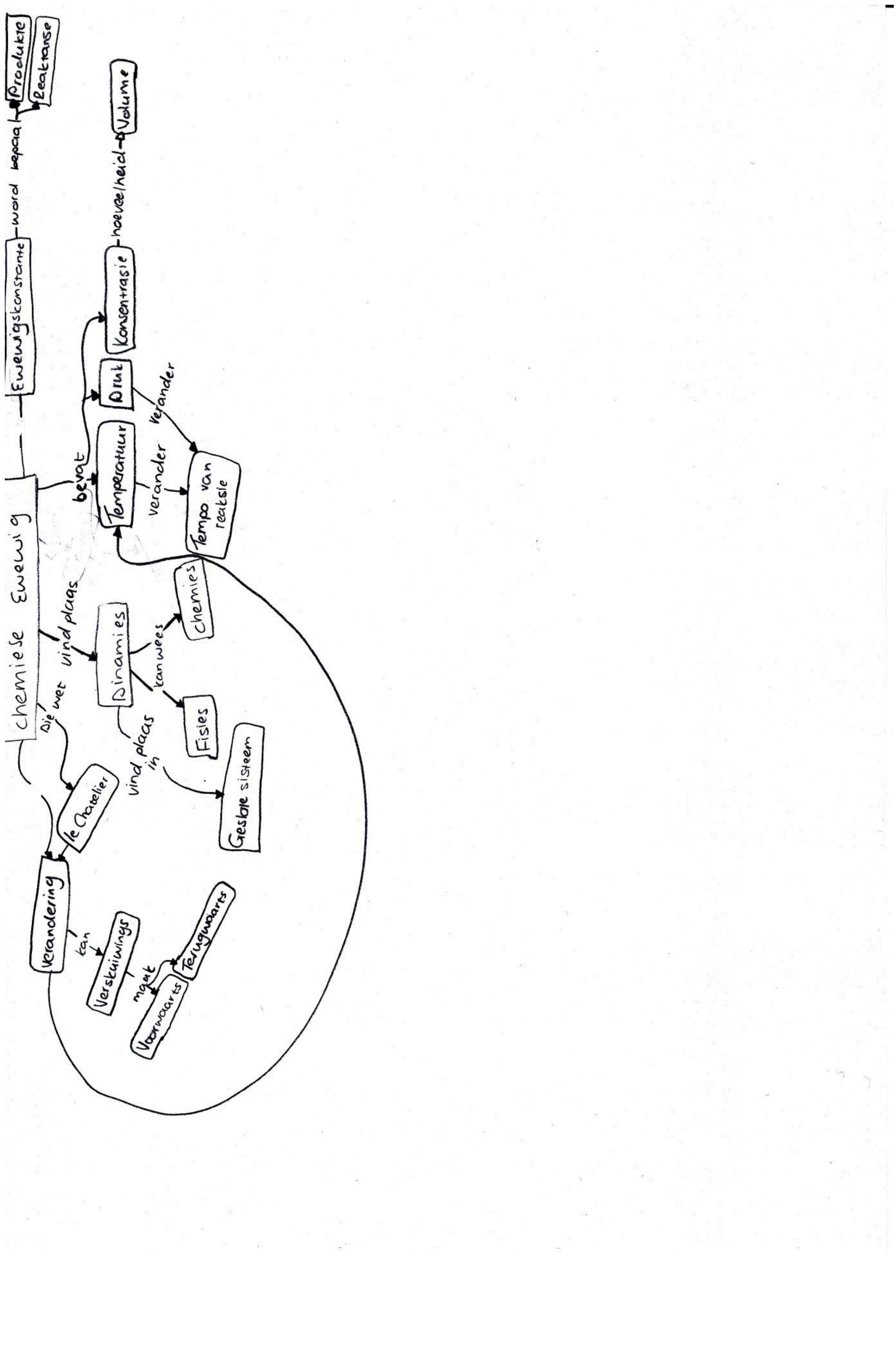
APPENDIX F2: Participant one concept map two



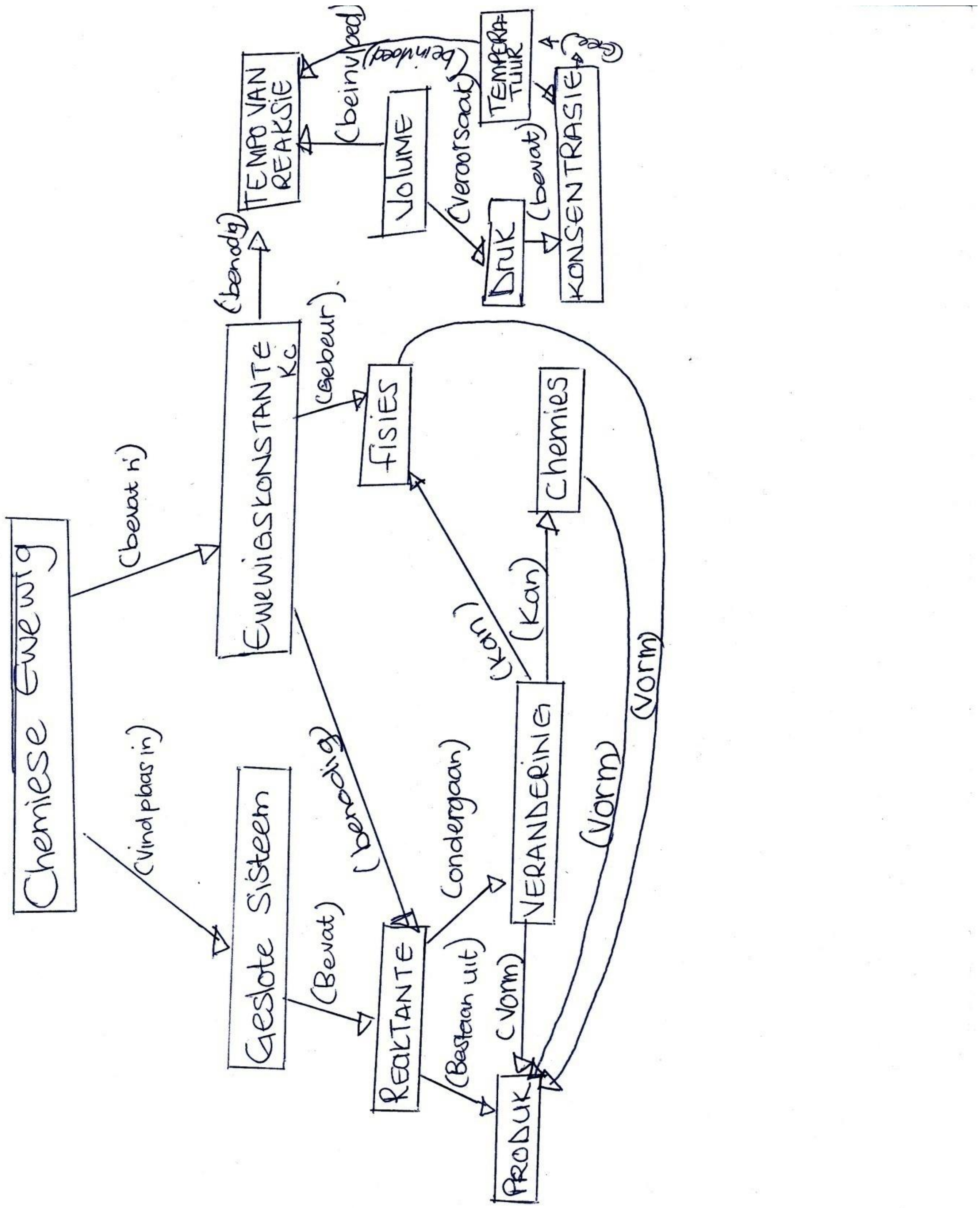
APPENDIX F3: Participant one concept map three



APPENDIX F4: Participant one concept map four



APPENDIX F5: Participant two concept map one



APPENDIX G: Pilot study concept bank

Concept bank:

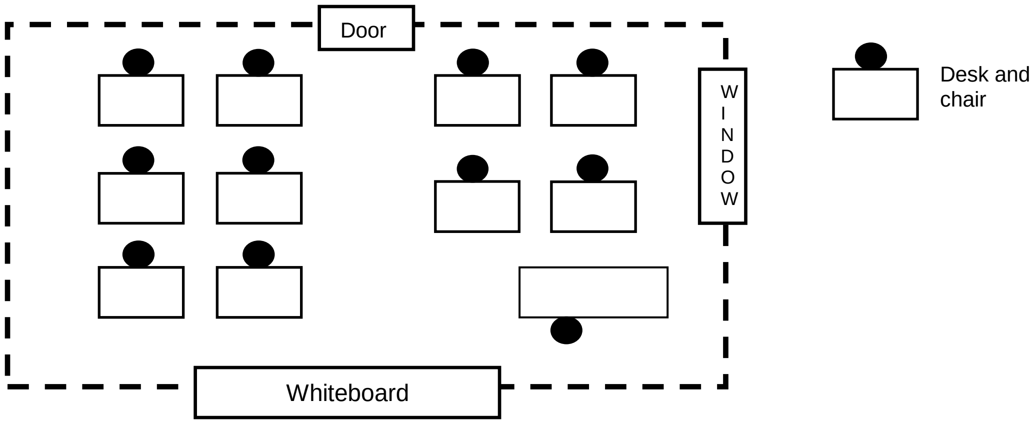
1. Dynamic
2. Le Chatelier
3. Changes
4. Products
5. Temperature
6. Chemical
7. Pressure
8. Reverse
9. Volume
10. Concentration
11. Rate of Reaction
12. Forward
13. Chemical Equilibrium
14. Reactants
15. Shift
16. Closed System
17. Equilibrium Constant (K_c)
18. Physical

Konsepte-bank:

1. Dinamies
2. Le Chatelier
3. Veranderinge
4. Produkte
5. Temperatuur
6. Chemies
7. Druk
8. Terugwaarts
9. Volume
10. Konsentrasie
11. Tempo van reaksie
12. Voorwaarts
13. Chemiese Ewewig
14. Reaktante
15. Skuiwing
16. Geslote Sisteem
17. Ewewigskonstante (K_c)
18. Fisies

APPENDIX H: Pilot study notes

The class setup for the pilot study will be exactly the same as for the actual study. There will be ten desks each with a chair in the classroom; a whiteboard in front of the class with a teacher's desk. There is one big window in the classroom.



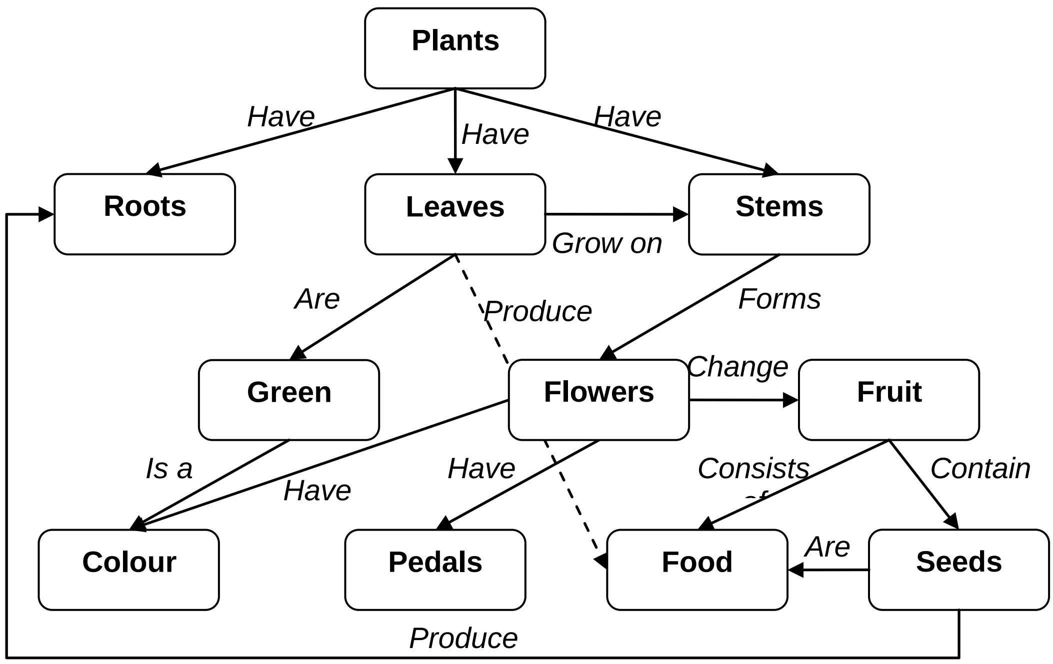
Day one (16 April 2012)

Introductory class was given to participant one and it went excellently. The following came out of the introductory class.

Concept bank:

Concept	**Concept**	**Concept**	**Concept**
Plants	Petals	Colour	Fruit
Green	Flowers	Roots	Stems
Leaves	Seeds	Food	

Concept map example:



Data analysis:

“Scoring-method”

See participant one’s first concept map.

-1	+1	+1	-1	-1	-1	+1
-1	+1	-1	-1	+1	-1	+1
-1	-1	+1			**TOTAL:**	**-3**

“Rubric-method”

Participant one map one:

Structure	Marginal
Relationship	Adequate
Exploratory	Marginal
Communication	Adequate

Comments and notes:

The “*scoring-method*” would not work because there are too many possible linkages between two concepts. Another reason for not using the “scoring-method” is that scoring is quantitative and not qualitative. The “*expert’s map-comparison-method*” was used to compare the linkage between two concepts on the participants map.

Furthermore the first map is very linear, but the concepts are connected well enough. Only one concept was not used in the first concept map: Closed system. Sensitive areas on the map are – Le Chatelier; connecting chemical and physical inside chemical equilibrium and connecting the changes (temperature, volume, pressure and concentration).

<u>Day two (17 April 2012)</u>

The first chemical equilibrium class was given. Participant one did not have any previous knowledge on the topic therefore the class covers all of the concepts in this topic.

Notes on class:

- Possible concept additions or changes:
  - Collision theory – Concerning temperature and concentration.
  - Enthalpy:
    - Endothermic ($\Delta H > 0$)
    - Exothermic ($\Delta H < 0$)
    - $\Delta H = E_{Products} - E_{Reactants}$
  - Reaction surface

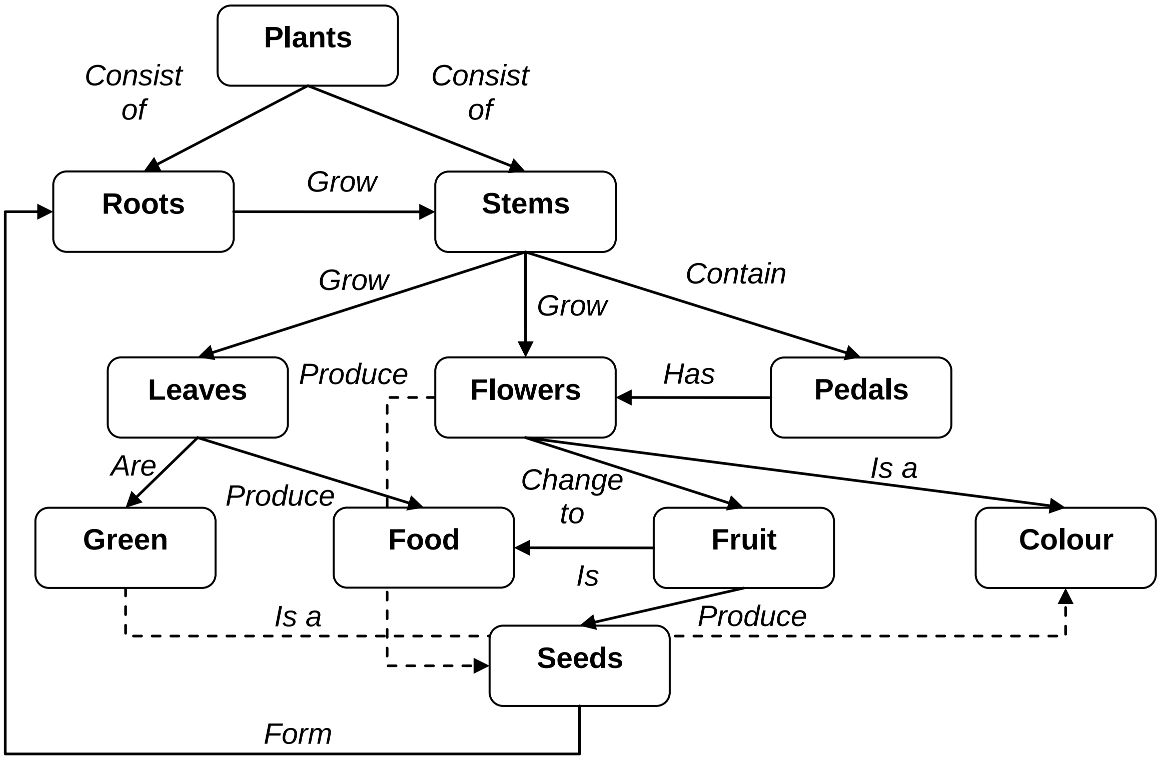
Participant one was given her second map to complete after the first class.

On the same day participant two got her introductory class and completed her first concept map.

Concept bank:

Concept	Concept	Concept	Concept
Plants	Petals	Colour	Fruit
Green	Flowers	Roots	Stems
Leaves	Seeds	Food	

Concept map example:



Data analysis:

Participant one map two:

Structure	Marginal
Relationship	Adequate
Exploratory	Adequate
Communication	Adequate

Participant two map one:

Structure	Marginal
Relationship	Marginal
Exploratory	Marginal
Communication	Marginal

Comments and notes:

There are still problems with the construction of the concept maps, mainly with linkage words; position of concepts and the structure of the maps are too linear. Change the concept "*Dynamic*" to "*Dynamic system*". Another concept to consider adding to the concept bank is "*Catalyst*". Both participants use the linkage word "*and*", which is not considered as a linkage word. The word "and" does not describe the linkage between two concepts.

Furthermore participant one's second map showed an improvement only leaving out concept "*closed system*". Participant one is showing a very basic cross-linkage system. One problem on the second map is the use of single-function word, such as increase, when the linkage between the two concepts can increase and decrease.

Participant two's first map showed a basic cross-linkage system, but left out more than one concept. The concepts left out include *Dynamic system*, *Le Chatelier*, *Reverse reaction*, *forward reaction* and *shift*. Some of the linkage words are not suitable for connecting two concepts.

Day three (19 April 2012)

After the analysis of participant one's second concept map the tutoring class was given about the following concepts:

- Chemical equilibrium
- Dynamic
- Closed system
- Le Chatelier

Copy of the board:

Chemical equilibrium can only occur when two conditions are met. There has to be a dynamic system, in other words a reversible reaction and it has to take place in a closed system where there is no influence by external forces.

Le Chatelier

- Changes "determine" shift (which includes the following)
    - Temperature (increase and decrease)
    - Concentration (increase and decrease)
    - Pressure (gasses only) – linked with volume (think of a syringe)
    - Catalyst

$$H_{2(g)} + I_{2(g)} \leftrightarrow 2HI_{(g)}$$

And participant one must keep in mind the following:

- Concept map should be less linear and more network.
- Don't use the word "*and*".

Data analysis:

Participant one map three:

Structure	Good
Relationship	Adequate
Exploratory	Good
Communication	Good

Comments and notes:

The following concepts were not used:

- Chemical
- Physical
- Equilibrium constant

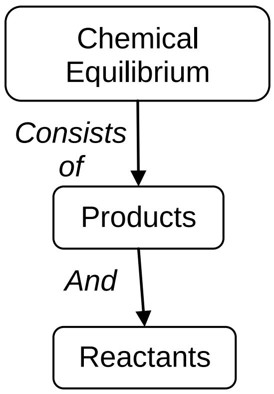
Participant needs to make more connections. Use a multi-functional word rather than a single-functional word. For example if the participant uses the word "*increase*" it indicates just one thing (this linkage in not incorrect), but the word "*decrease*" can also be used, therefore rather use a word such as "*influences*" (which combines decrease and increase). Temperature is not an example of Le Chatelier. Participant one has shown a very good improvement from her first concept map.

<u>Day four (23 April 2012)</u>

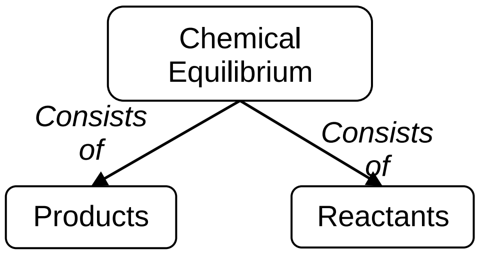
Class given around the following:

- Connections between concepts:

Incorrect:



Correct:



- Equilibrium constant (K_c)

$$K_c = \frac{[Products]}{[Reactants]}$$

Therefore:

$$K_c = \frac{c_{Products}}{c_{Reactants}}$$

- Dynamic can be physical (think the water cycle) or chemical ($HF \leftrightarrow H^+ + F^-$).

Participant one completed her fourth and final concept map after the tutoring class.

Data analysis:

Participant one map four:

Structure	Good
Relationship	Good
Exploratory	Excellent
Communication	Excellent

Comments and notes:

Some of the links between concepts are missing linkage words. All of the concepts in the concept bank are accounted for on the concept map. The participant can make more connection between concepts.

Conclusion

Participant one finished all four concept maps and therefore completed the process. Participant two only completed the first concept map and did not show up for the remainder of the concept map constructions. The pilot study was therefore based on the concept maps that were completed.

The incomplete concept maps of participant two did not influence any of the processes and a definite analysis, interpretation and result was obtained through the pilot study.

APPENDIX I: Concept maps of final data collection

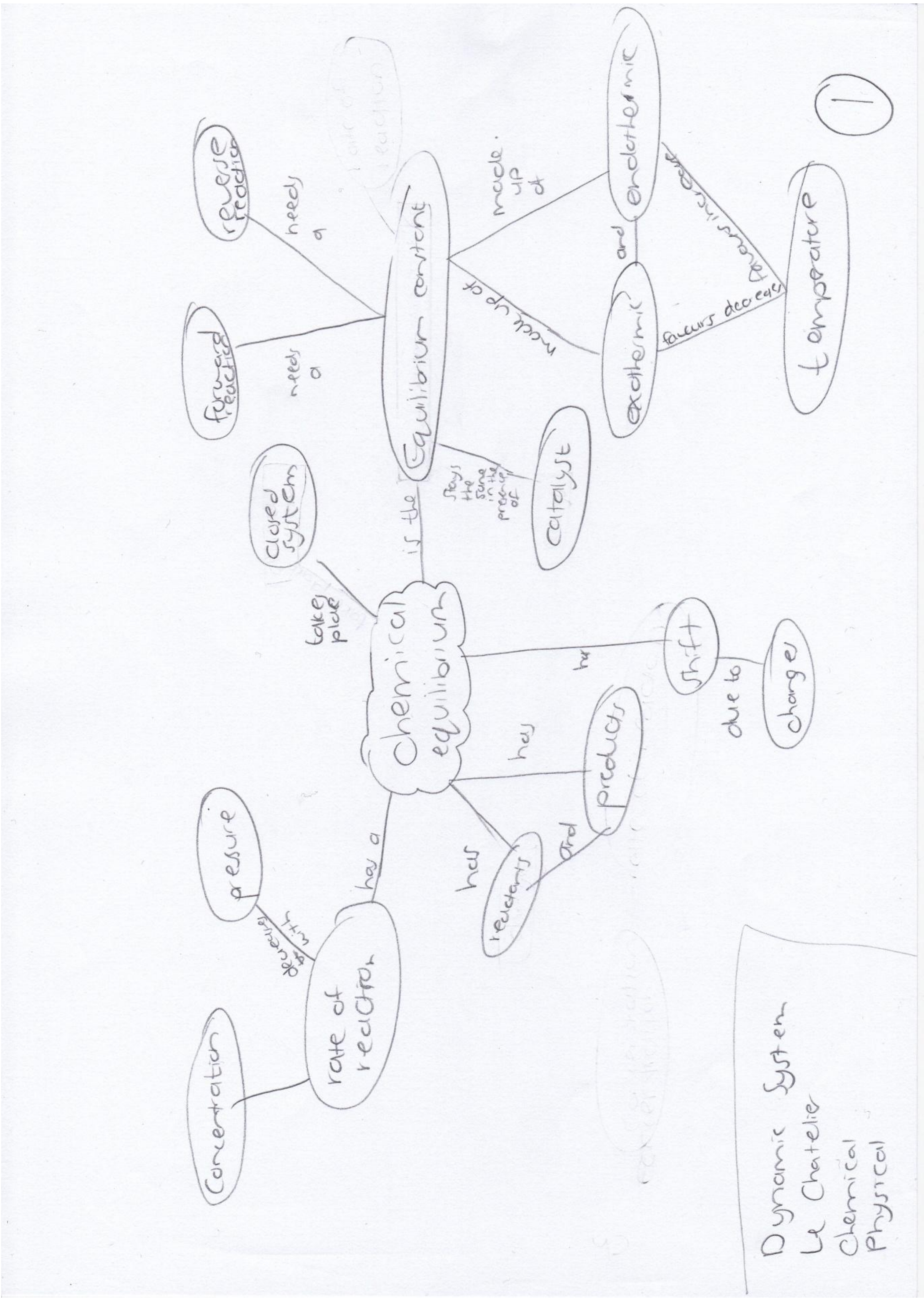
This appendix contains all the concept maps constructed by five participants for the final data collection. The following indicates how many concept maps all the participants constructed:

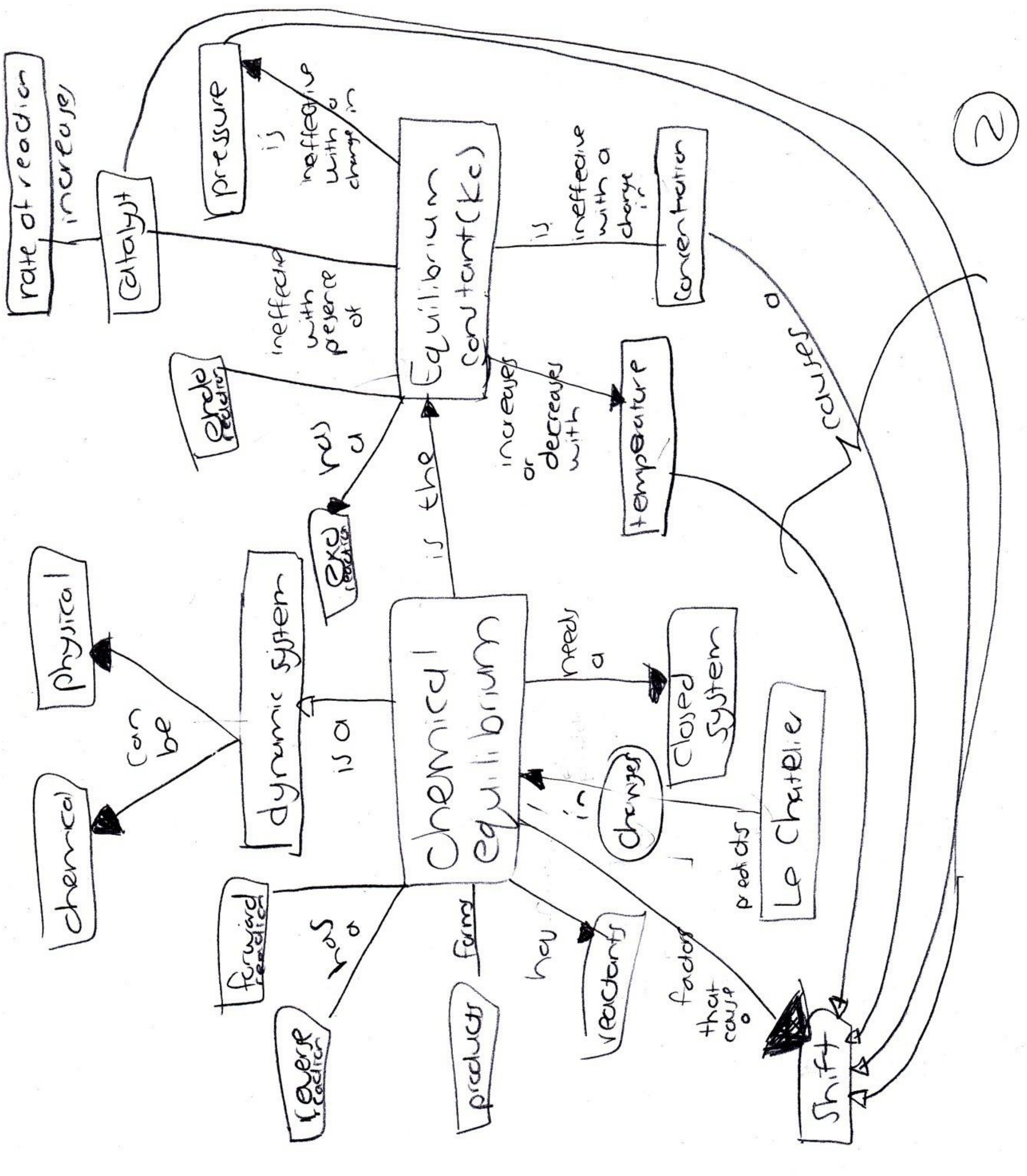
- Participant one (P1) completed four concept maps.
- Participant two (P2) completed three concept maps.
- Participant three (P3) completed four concept maps.
- Participant four (P4) completed three concept maps.
- Participant five (P5) completed three concept maps.

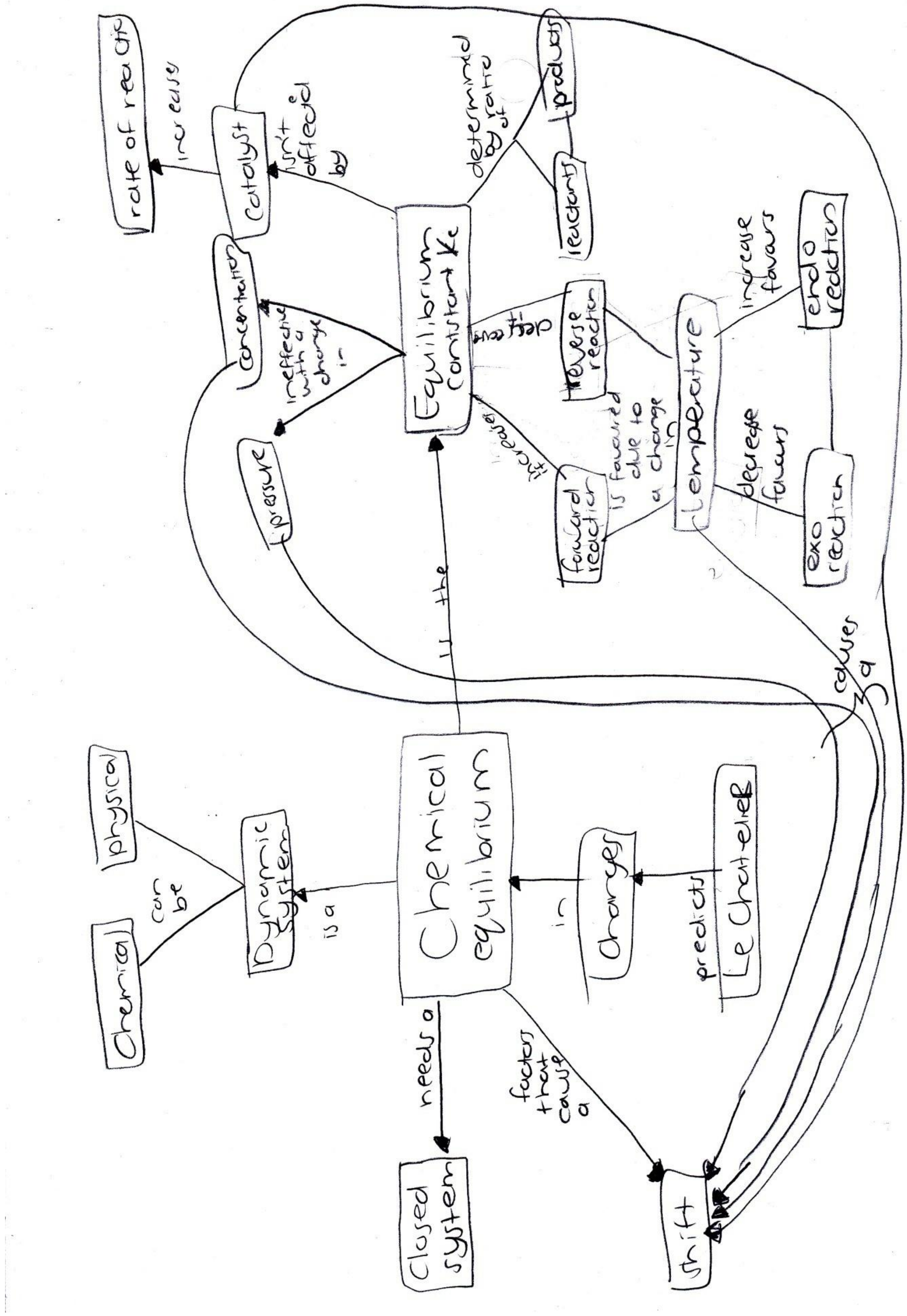
Each participant's concept maps are in order from one to three or one to four.

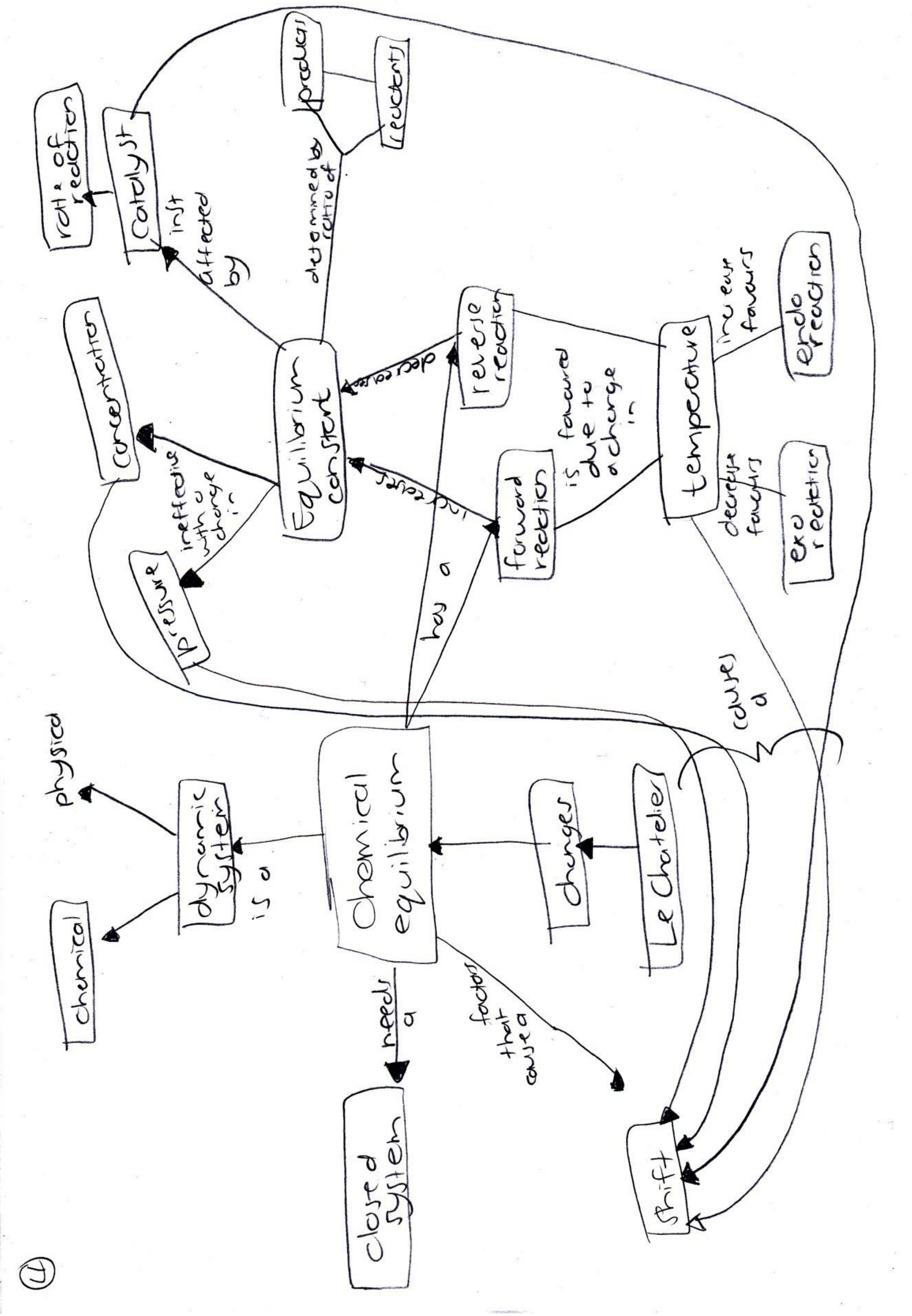
APPENDIX I1: Concept maps – P1
APPENDIX I2: Concept maps – P2
APPENDIX I3: Concept maps – P3
APPENDIX I4: Concept maps – P4
APPENDIX I5: Concept maps – P5

APPENDIX I1: Concept maps – P1

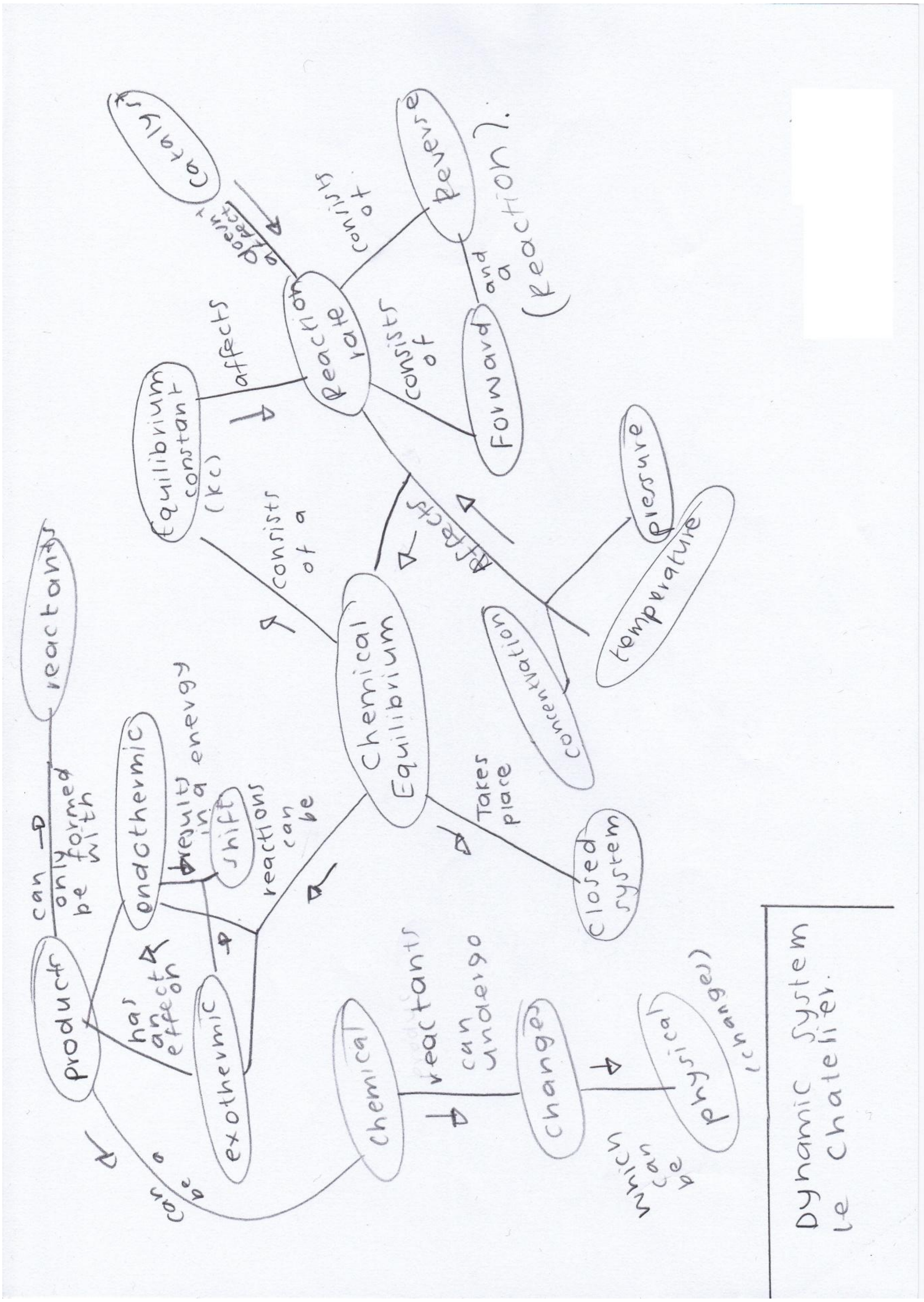


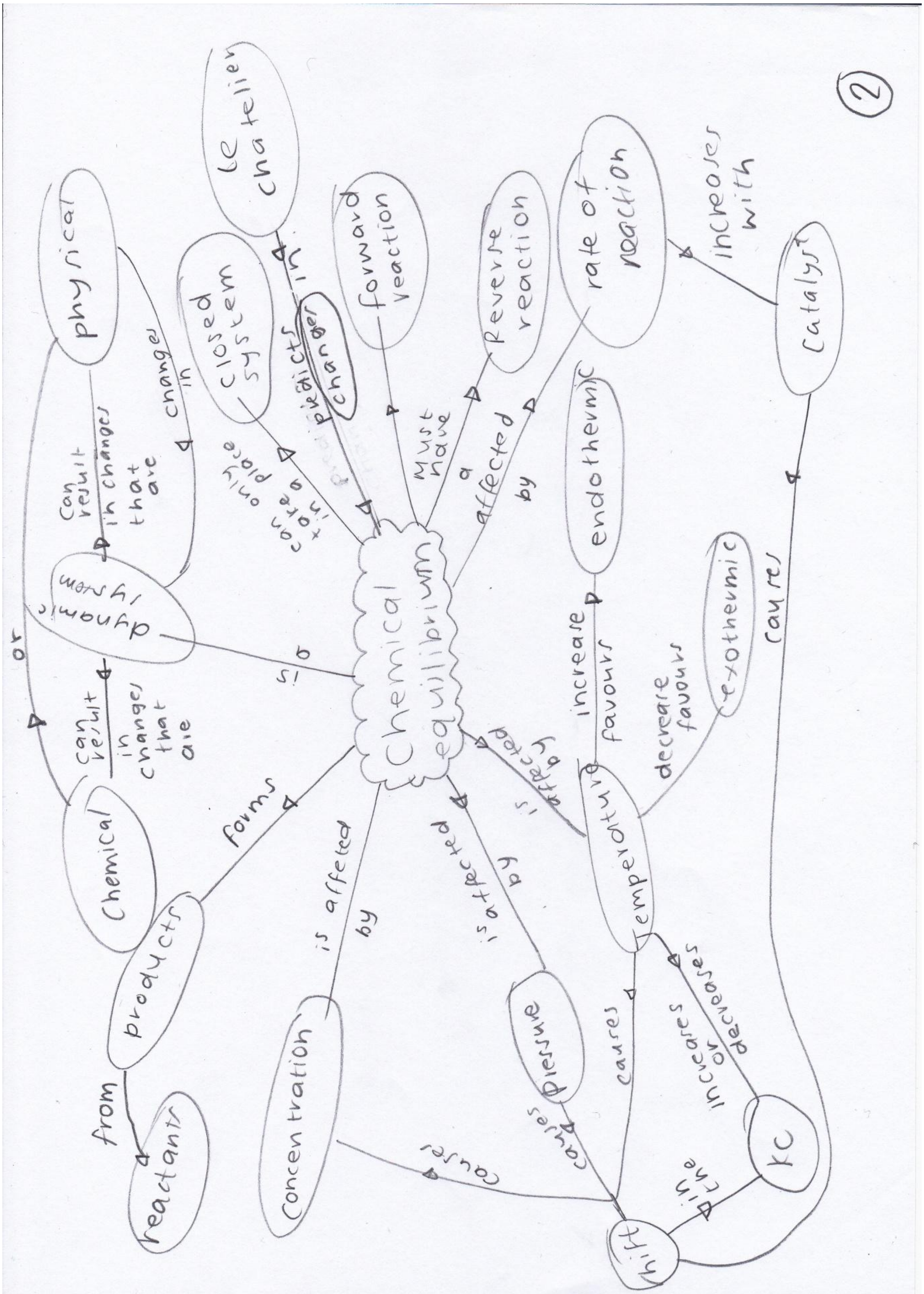

2
rate of reaction
increases
catalyst
pressure
is ineffective with a change in
Equilibrium constant (Kc)
is ineffective with a change in
concentration
ineffective with presence of
endo reaction
has a
exo reaction
is the
increases or decreases with
temperature
causes a
physical
can be
chemical
dynamic system
is a
chemical equilibrium
needs a
closed system
changes
in
Le Chatelier
predicts
forward reaction
has a
reverse reaction
forms
products
has
reactants
factors that cause a
shift

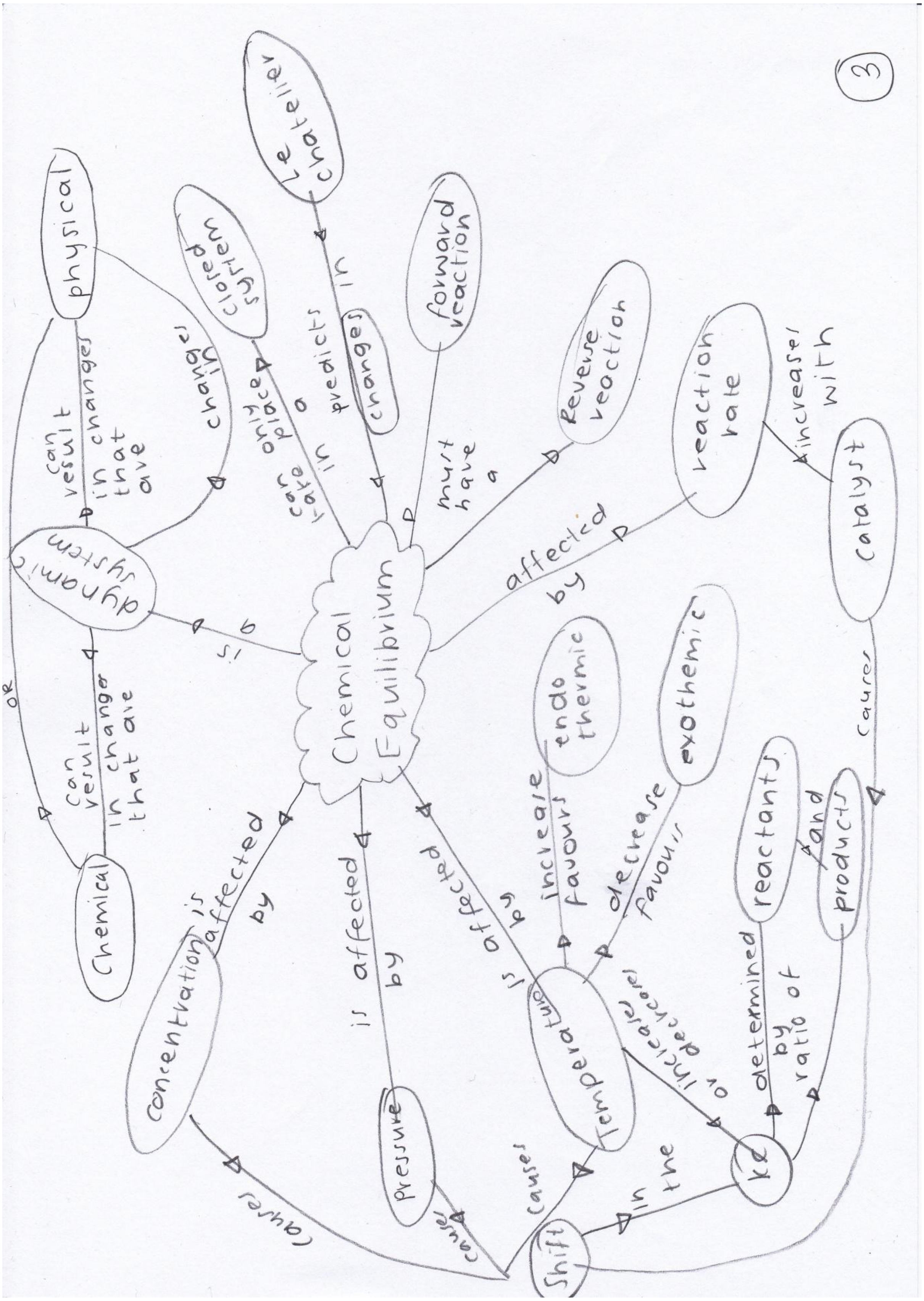

Chemical equilibrium
is a
Dynamic system
can be
Chemical
physical
needs a
Closed system
factors that cause a
shift
in
changes
predicts
Le Chatelier
is the
Equilibrium Constant Kc
ineffective with a change in
pressure
concentration
isn't affected by
catalyst
increase
rate of reactio
determined by ratio of
reactants
products
reverse reaction
forward reaction
is favoured due to a change in
temperature
increase favours
decrease favours
endo reaction
exo reaction
causes a


4
Chemical equilibrium
is a
dynamic system
physical
chemical
needs a
closed system
factors that cause a
shift
changes
Le Chatelier
causes a
has a
forward reaction
reverse reaction
increases
decreases
Equilibrium constant
ineffective with a change in
concentration
pressure
isn't affected by
catalyst
rate of reaction
determined by ratio of
products
reactants
is favoured due to a change in
temperature
increase favours
endo reaction
decrease favours
exo reaction

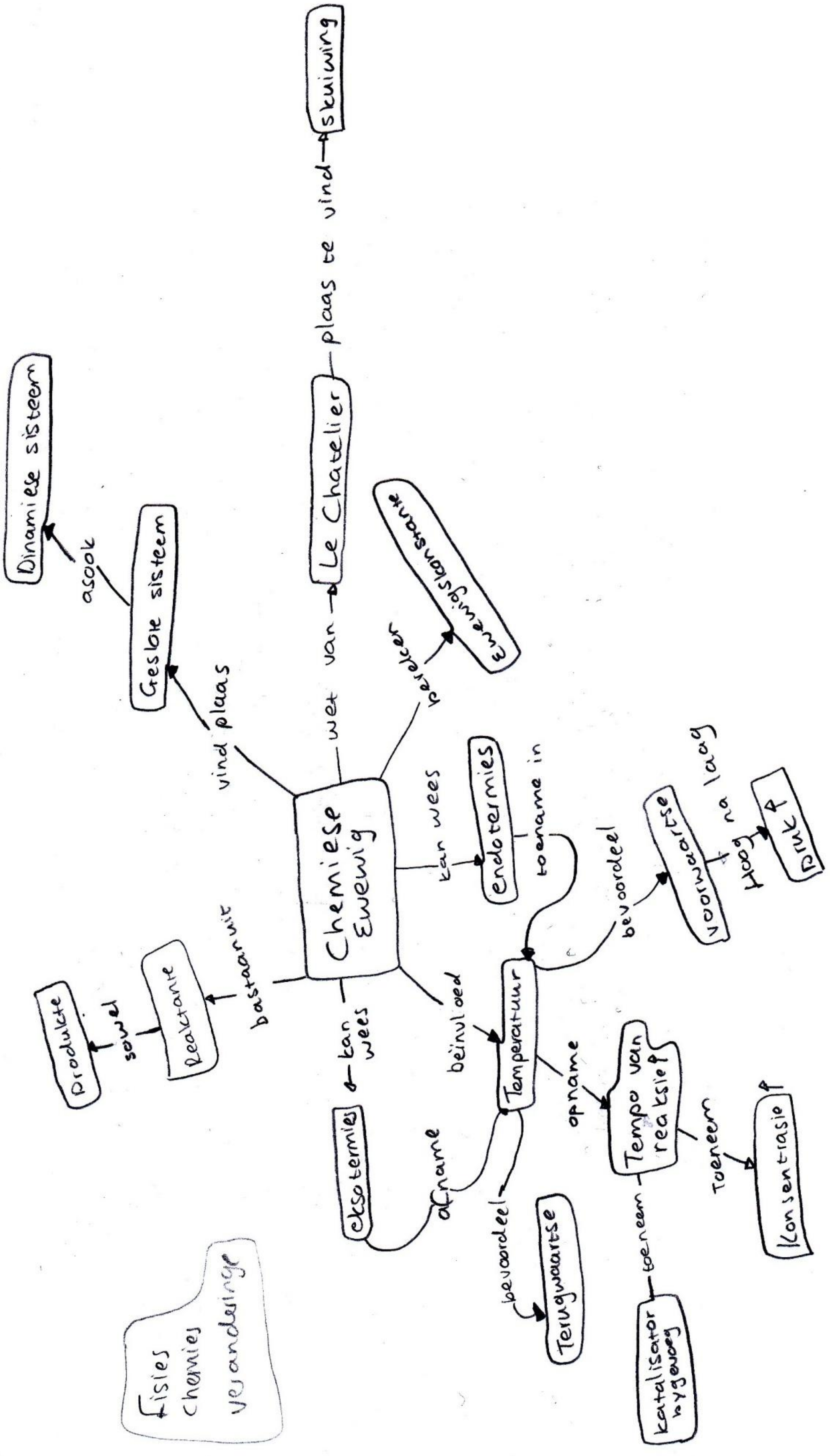
APPENDIX I2: Concept maps – P2

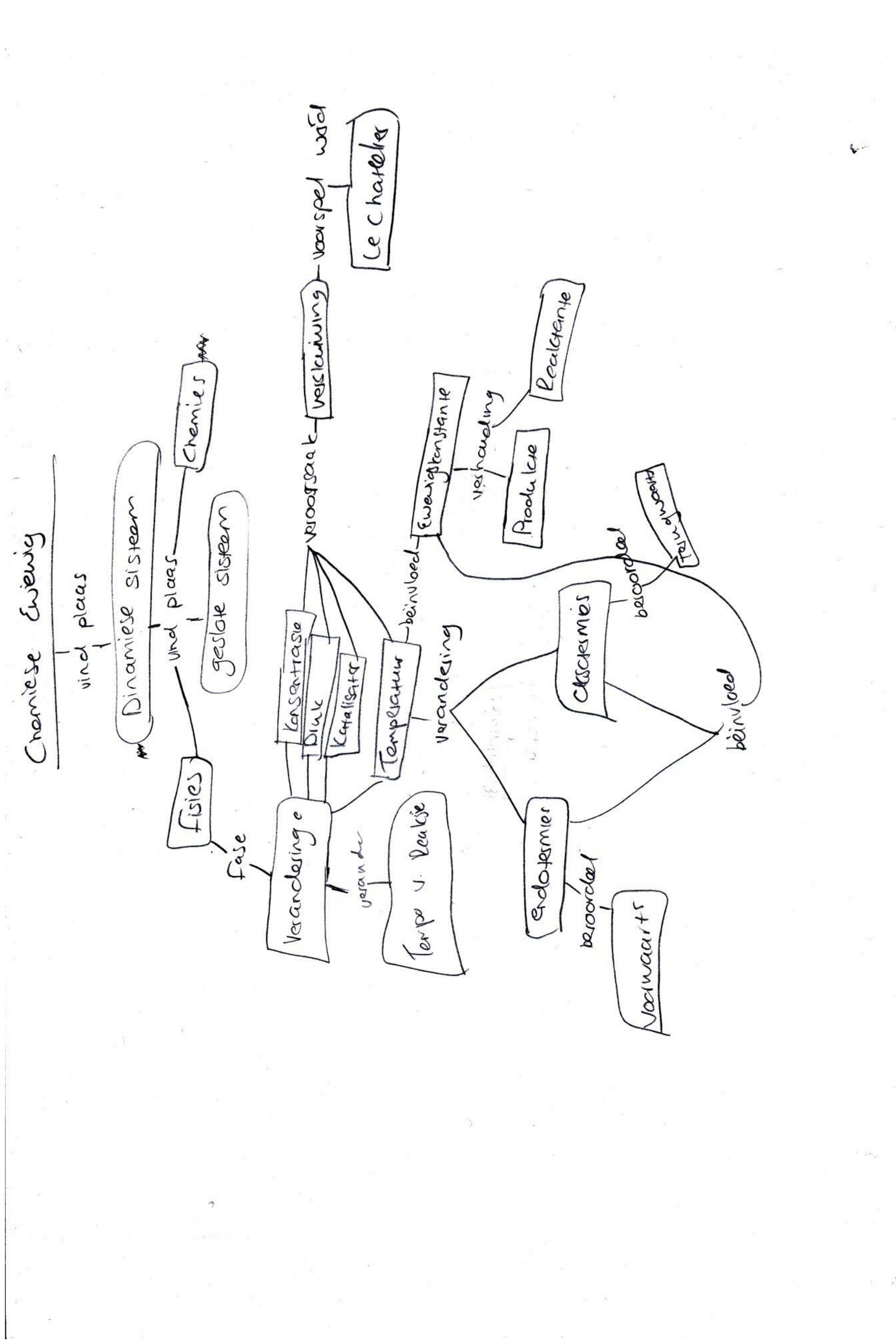


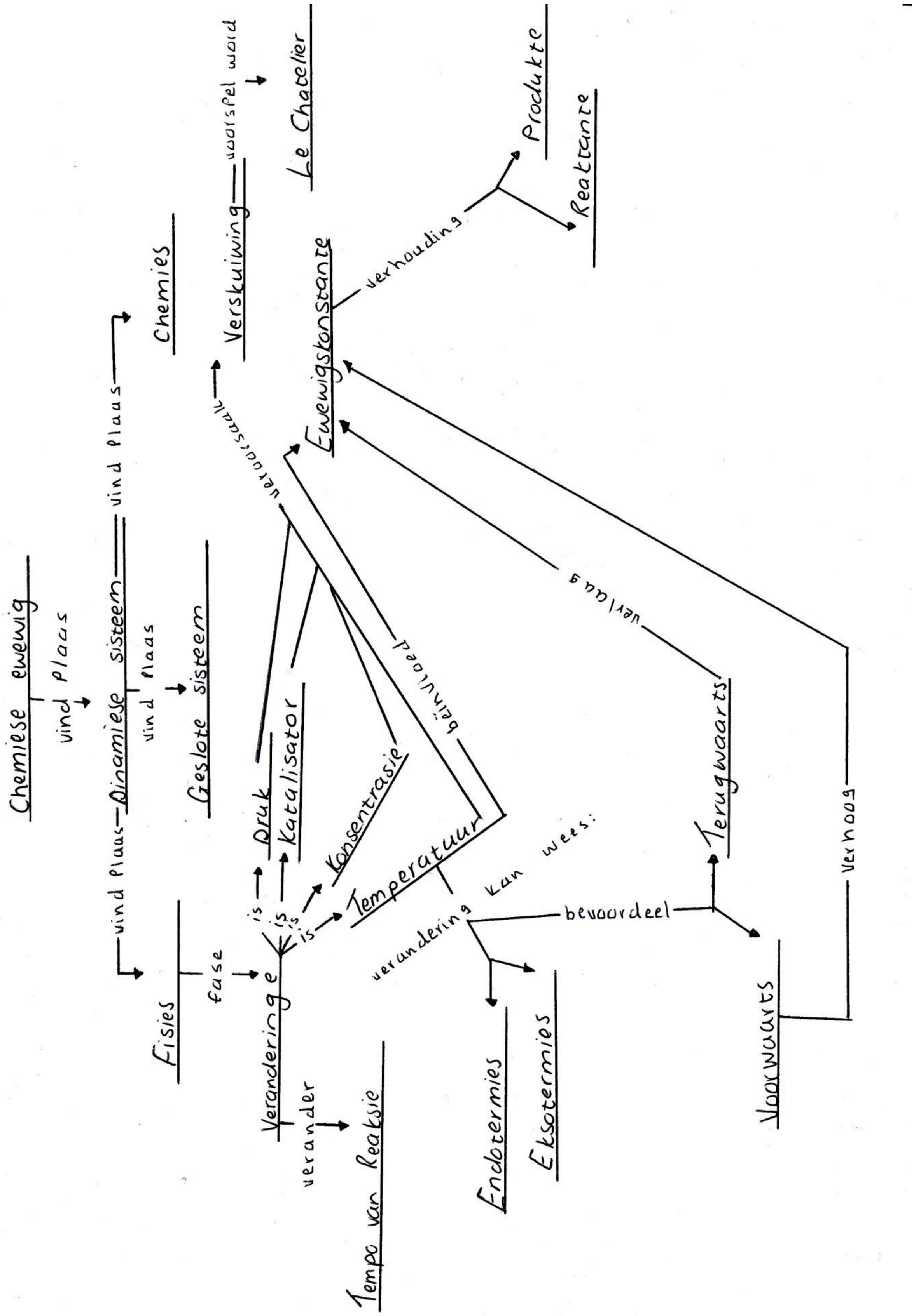

Chemical equilibrium
is a
dynamic system
can result in changes that are
Chemical
or
physical
can result in changes that are
changes in
closed system
predicts
changes
in
le chatelier
forward reaction
must have a
Reverse reaction
affected by
rate of reaction
increases with
Catalyst
causes
endothermic
increase favours
exothermic
decrease favours
is affected by
temperature
is affected by
pressure
is affected by
concentration
forms
products
from
reactants
causes
causes
causes
shift
in the
Kc
increases or decreases
2


3
Chemical Equilibrium
is a
dynamic system
can result in changes that are
physical
can result in changes that are
Chemical
OR
changes in
can take place only in a
closed system
predicts changes in
Le Chatelier
must have a
forward reaction
Reverse reaction
affected by
reaction rate
increases with
catalyst
causes
is affected by
Concentration
is affected by
Pressure
is affected by
Temperature
increase favours
endo thermic
decrease favours
exothemic
increases or decreases
Kc
determined by ratio of
reactants
and products
causes
in the
Shift

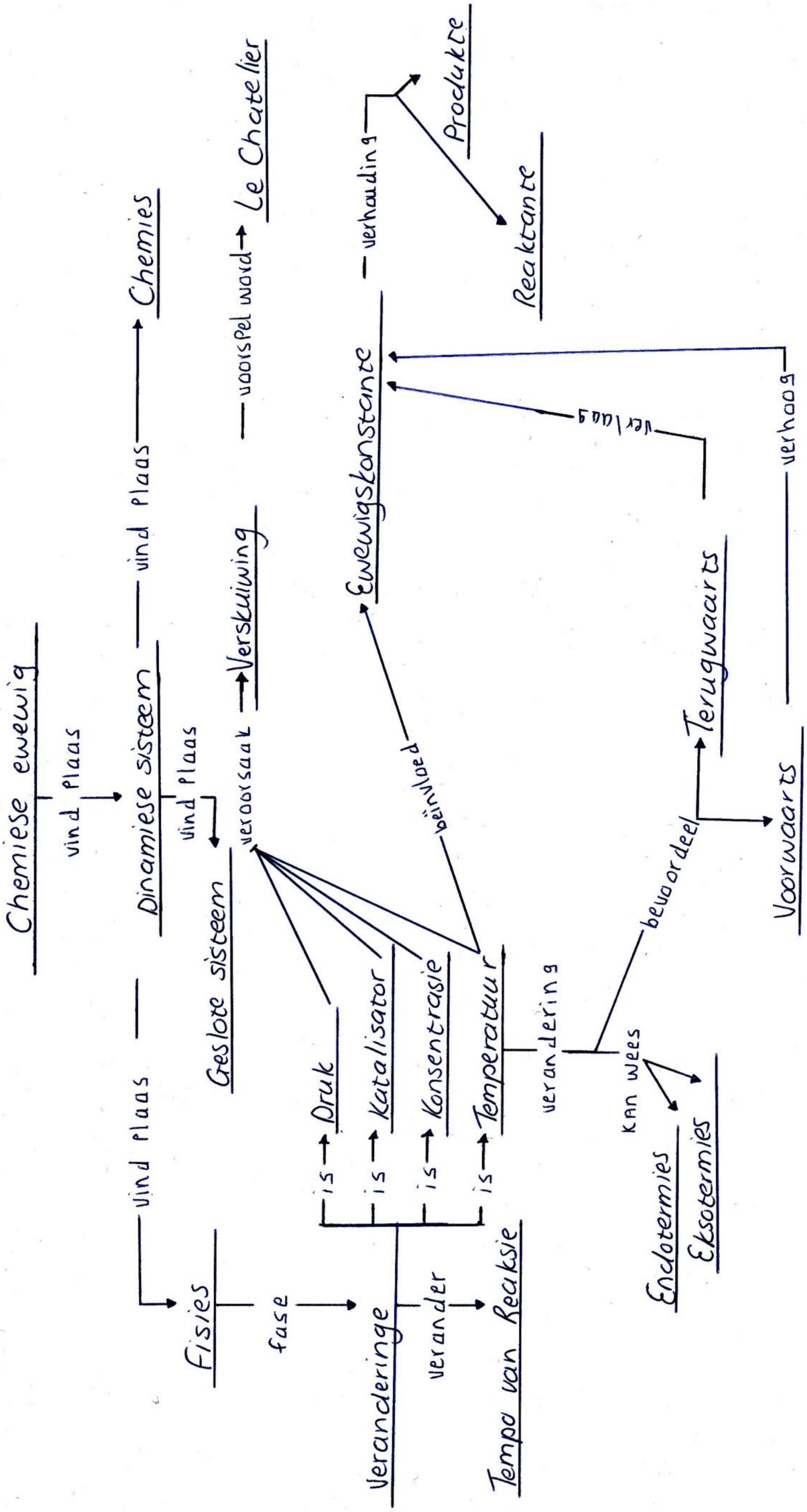
APPENDIX I3: Concept maps – P3



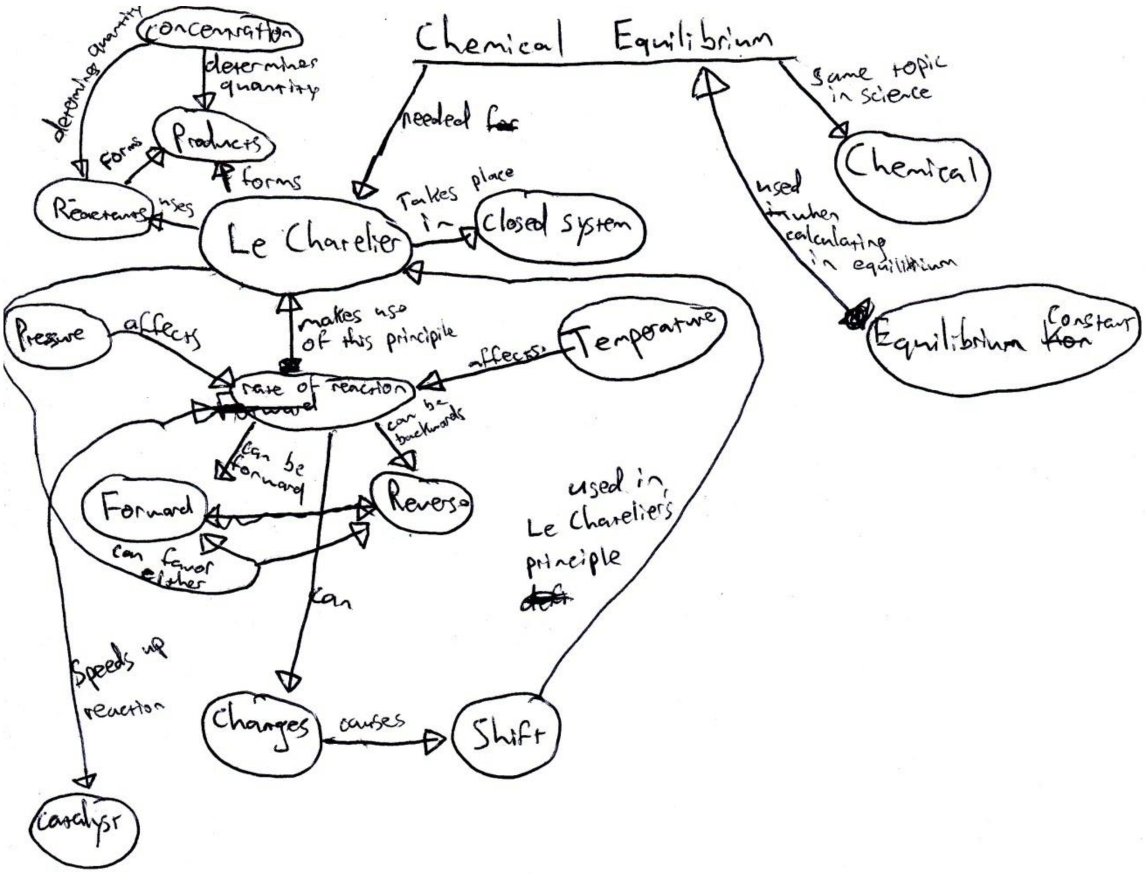

Chemiese Ewewig
vind plaas
Dinamiese sisteem
vind plaas
geslote sisteem
Chemies
Fisies
fase
Veranderinge
Konsentrasie
Druk
Katalisator
Temperatuur
veroorsaak
verskuiwing
voorspel word
Le Chatelier
beïnvloed
Ewewigskonstante
verhouding
Produkte
Reaktante
verandering
verander
Tempo v. Reaksie
Eksotermies
Endotermies
bevoordeel
Voorwaarts
Terugwaarts
beïnvloed



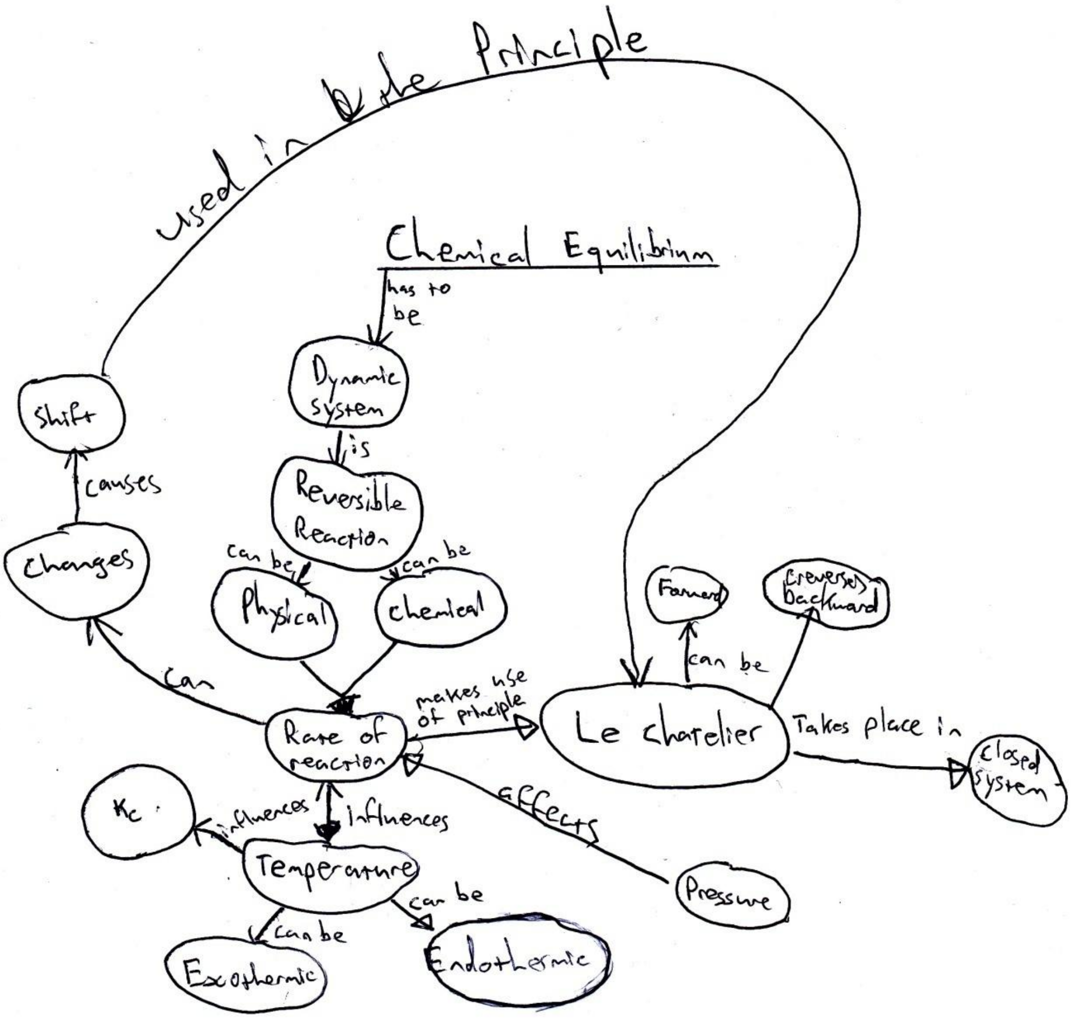
Chemiese ewewig
vind plaas
Dinamiese sisteem
vind plaas
Geslote sisteem
vind plaas
Chemies
vind plaas
Fisies
fase
Veranderinge
is
Druk
Katalisator
Konsentrasie
Temperatuur
verander
Tempo van Reaksie
beïnvloed
veroorsaak
Verskuiwing
voorspel word
Le Chatelier
Ewewigskonstante
verhouding
Produkte
Reaktante
verandering kan wees:
Endotermies
Eksotermies
bevoordeel
Terugwaarts
Voorwaarts
verlaag
verhoog

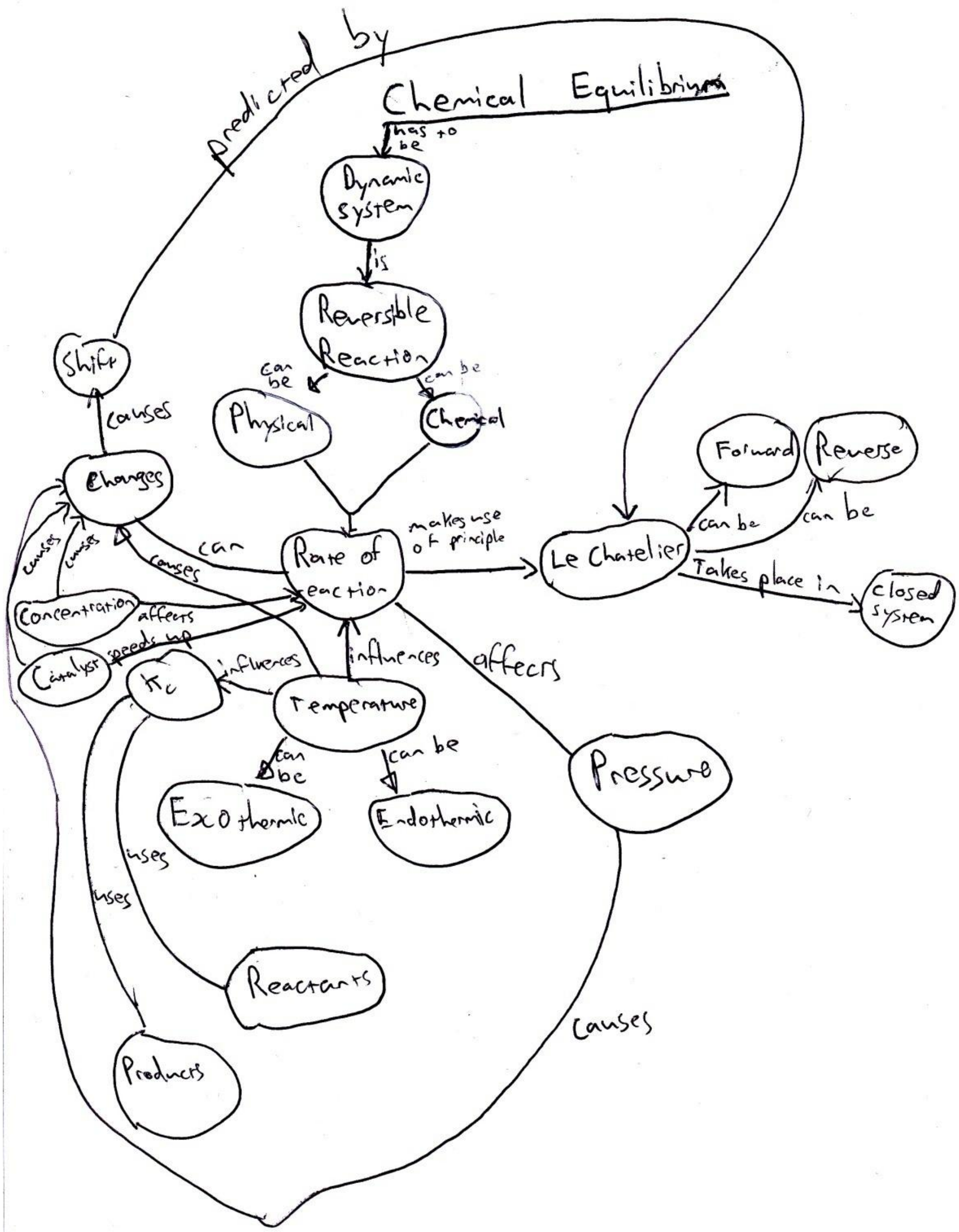

Chemiese ewewig
vind plaas
Dinamiese sisteem
vind plaas
Chemies
vind plaas
Geslote sisteem
veroorsaak
Verskuiwing
voorspel word
Le Chatelier
Fisies
fase
Veranderinge
verander
Tempo van Reaksie
is
Druk
Katalisator
Konsentrasie
Temperatuur
beïnvloed
Ewewigskonstante
verhouding
Produkte
Reaktante
verandering
kan wees
Endotermies
Eksotermies
bevoordeel
Terugwaarts
Voorwaarts
verlaag
verhoog

APPENDIX I4: Concept maps – P4



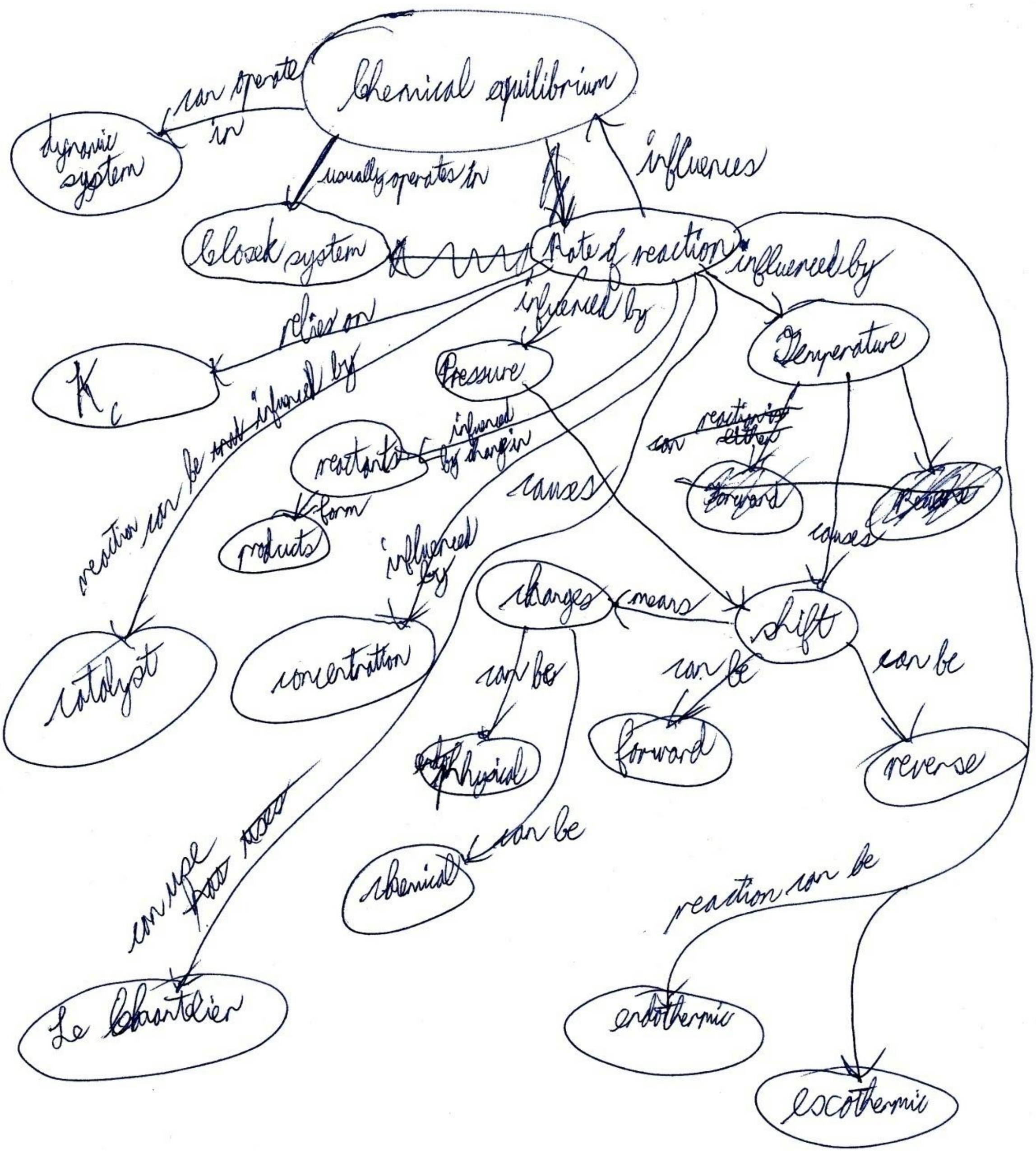
~~Chemi~~
Physical
Endothermic
Dynamic system
Exo

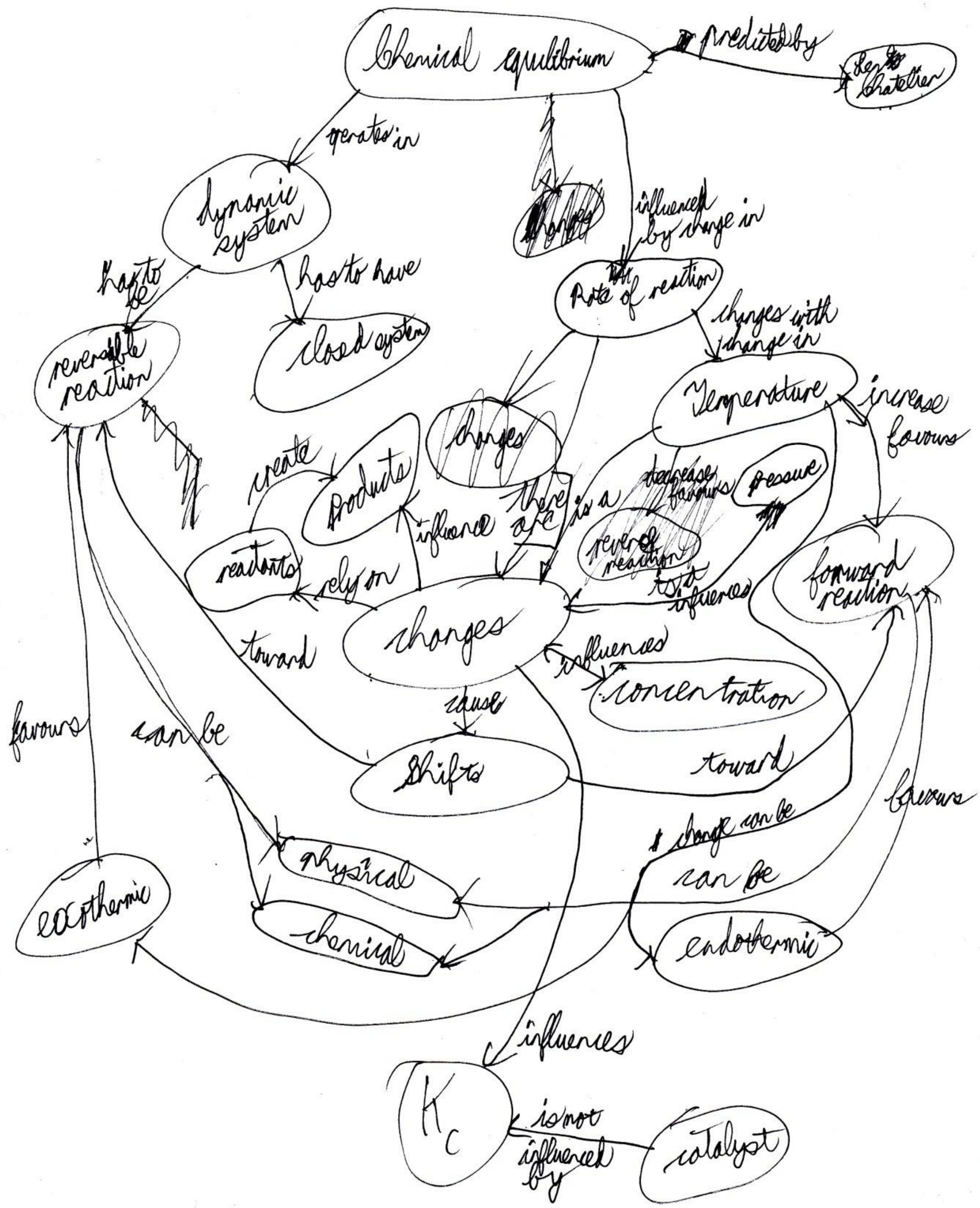

used in the Principle
Chemical Equilibrium
has to be
Dynamic system
is
Reversible Reaction
can be
Physical
can be
chemical
Shift
causes
Changes
can
Rate of reaction
makes use of principle
Le chatelier
can be
Forward
(reverse) backward
Takes place in
closed system
effects
Pressure
influences
influences
Kc
Temperature
can be
can be
Exothermic
Endothermic



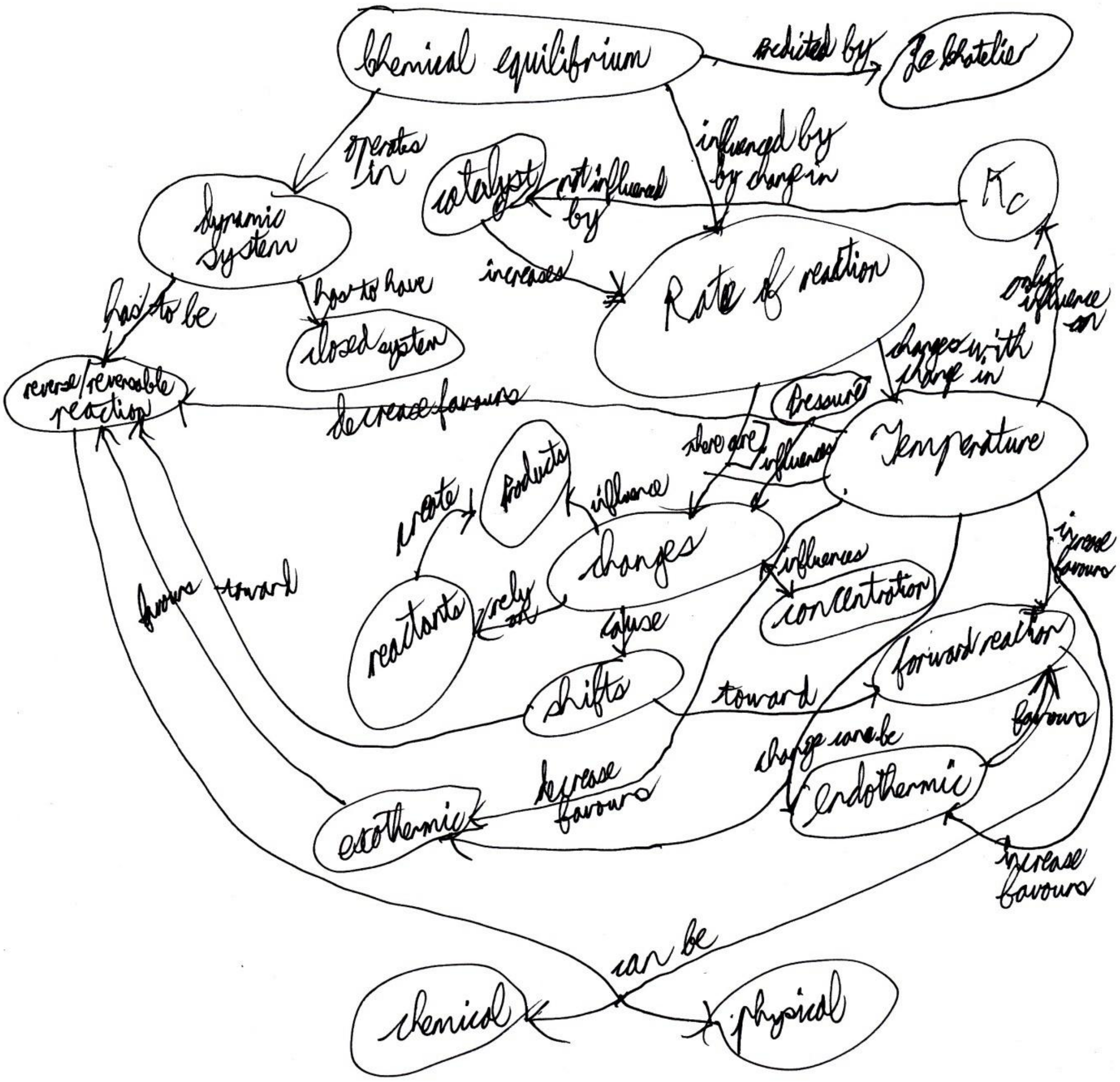
Chemical Equilibrium
has to be
Dynamic system
is
Reversible Reaction
can be
Physical
can be
Chemical
Rate of reaction
makes use of principle
Le Chatelier
can be
Forward
can be
Reverse
Takes place in
Closed system
predicted by
Shift
causes
Changes
can
causes
causes
causes
Concentration
affects
Catalyst
speeds up
Kc
influences
influences
Temperature
can be
Exothermic
can be
Endothermic
affects
Pressure
causes
uses
uses
Reactants
Products

APPENDIX I5: Concept maps – P5





Chemical equilibrium
predicted by
Le Chatelier
operates in
dynamic system
influenced by change in
Rate of reaction
has to be
has to have
reversible reaction
closed system
changes with change in
Temperature
increase favours
changes
create
products
reactants
influence
there are
is a
decrease favours
pressure
reverse reaction
influences
forward reaction
rely on
changes
toward
influences
concentration
cause
favours
can be
Shifts
toward
favours
physical
change can be
can be
exothermic
chemical
endothermic
influences
Kc
is not influenced by
catalyst


Chemical equilibrium
Le Chatelier
operates in
dynamic system
catalyst
not influenced by
influenced by by change in
Kc
Rate of reaction
increases
has to be
has to have
closed system
reverse/reversible reaction
decrease favours
changes with change in
only influence on
Pressure
Temperature
influences
create
products
influence
changes
influences
concentration
reactants
rely on
cause
shifts
toward
forward reaction
favours toward
decrease favours
endothermic
favours
exothermic
increase favours
can be
chemical
physical

APPENDIX J: Final data collection concept bank

Concept bank:

19. Dynamic System
20. Le Chatelier
21. Changes
22. Products
23. Temperature
24. Chemical
25. Pressure
26. Reverse
27. Concentration
28. Rate of Reaction
29. Forward
30. Chemical Equilibrium
31. Reactants
32. Shift
33. Closed System
34. Equilibrium Constant (K_c)
35. Physical
36. Endothermic
37. Exothermic
38. Catalyst

Konsepte-bank:

19. Dinamies Sisteem
20. Le Chatelier
21. Veranderinge
22. Produkte
23. Temperatuur
24. Chemies
25. Druk
26. Terugwaarts
27. Konsentrasie
28. Tempo van reaksie
29. Voorwaarts
30. Chemiese Ewewig
31. Reaktante
32. Skuiwing
33. Geslote Sisteem
34. Ewewigskonstante (K_c)
35. Fisies
36. Endotermies
37. Eksotermies
38. Katalisator

APPENDIX K: Data collection and analysis notes

Day one (17 May 2012)

The introductory class was given to participants one, two and five. After the introductory class participants one and two completed their first concept maps with the new additional concept words:

- Endothermic
- Exothermic
- Catalyst

Volume was removed as a concept word.

Day two (21 May 2012)

Analysis of participant one and two's first concept maps:

Participant one map one:

Structure	Marginal
Relationship	Marginal
Exploratory	Marginal
Communication	Marginal

Participant two map one:

Structure	Adequate
Relationship	Adequate
Exploratory	Adequate
Communication	Adequate

Comments and notes:

The construction of the concept maps went well; participant two already showed an adequate understanding of the relationship between the concepts. There are just a few minor issues surrounding the construction. Participants need to watch out for "meaningless" linkage words such as "and" and single-functional words such as "decrease" and "increase". Always use your directional arrows when linking concepts. Some of the linkages between two concepts are missing linkage words.

The following are missing concepts from the maps – Dynamic system; Le Chatelier; Chemical; and Physical. Alternative ideas on the concept maps include areas surrounding equilibrium constant, exothermic, endothermic, dynamic system, Le Chatelier, physical and chemical.

Day three (24 May 2012)

Participant five completed the first concept map. Thereafter the map was analysed.

Participant five map one:

Structure	Adequate
Relationship	Adequate
Exploratory	Adequate
Communication	Good

Comments and notes:

There is no link between the main concept (chemical equilibrium) and the other concepts. There was confusion between rate of reaction and equilibrium constant; and rate of reaction and Le Chatelier. Participant five supplied a very good concept map showing a good network for a first concept map.

Participant can make more linkages between concepts. Participant five can try to make more cross-linkages.

Concepts that need attention are rate of reaction, equilibrium constant and Le Chatelier.

<u>Day four (11 June 2012)</u>

Participant three completed the first concept map. Map analysis of participant three's map followed.

Participant three map one:

Structure	Marginal
Relationship	Adequate
Exploratory	Adequate
Communication	Adequate

Comments and notes:

The map showed the use of linkage words such as "and" and single-functional linkage words such as "increase" and "decrease". Try to use other words that explain the connection between two concepts better. From this the analyser can determine the participant's understanding.

Missing concepts included physical, chemical and change. There was confusion with Le Chatelier and equilibrium constant. The participant did make excellent connections with temperature, endothermic and exothermic.

Remember the following – do not use any concepts other the supplied ones; stay away from single-functional words and linkage words such as "and" or "as well as".

<u>Day five (26 July 2012)</u>

Participants one, two, three and five completed their second concept map after the class and participant four completed the first concept map.

Participant one map two

Structure	Adequate
Relationship	Adequate
Exploratory	Good
Communication	Good

Participant two map two

Structure	Good
Relationship	Adequate
Exploratory	Adequate
Communication	Good

Participant three map two

Structure	Adequate
Relationship	Good
Exploratory	Good
Communication	Good

Participant four map one

Structure	Marginal
Relationship	Adequate
Exploratory	Marginal
Communication	Adequate

Participant five map two

Structure	Excellent
Relationship	Good
Exploratory	Adequate
Communication	Good

Comments and notes:

First of all the class given on the previous map's alternative ideas and frameworks, went very well.

In one of the concept maps the participant changed one of the concepts, but after an interview the confusion was diverted. Each participant had his or her own unique alternative ideas and adequate linkages between concepts. Each of these will be discussed with the participant on his or her own.

There were some very good maps on this day, even so good that the third concept map could be their last map construction. Just need to remember the following: Directional arrows will indicate the appropriate path of the linkages, always include your linkage words, and do not add any concepts only use the ones supplied (although adding a concept does not mean that the connection is "incorrect").

The major area to focus upon is temperature and its surrounding concepts; this includes endothermic and exothermic reactions.

Day six (2 August 2012)

A discussion of each participant's previous map was given and a follow-up class on temperature within chemical equilibrium was given to participants one, two, three and five. Thereafter each participant completed their third map, which could be their final map if it shows a good level of understanding and each linkage is deemed acceptable.

Participant one map three

Structure	Good
Relationship	Good
Exploratory	Good
Communication	Excellent

Participant two map three

Structure	Excellent
Relationship	Good
Exploratory	Excellent
Communication	Excellent

Participant three map three

Structure	Excellent
Relationship	Good
Exploratory	Excellent
Communication	Excellent

Participant five map three

Structure	Excellent
Relationship	Good
Exploratory	Excellent
Communication	Excellent

Comments and notes:

Participant one made an alternative idea between chemical equilibrium and equilibrium constant, but the rest of the map was very good. Participant two had a very good map, but could have made more links between concepts. Participant three can shift "can be" down to make more sense, but all in all a very good map. Participant five created a very good network frame between all twenty concepts. At times it looked a bit unorganised but this is overshadowed by the complexity of the relationships.

Day seven (16 August 2012)

Participants one and three completed a forth concept map and participant four completed a second map. Participants two and five did not have to complete a forth concept map because their previous maps were acceptable and showed an excellent and a complex way of thinking as well as a very good relationship between the concepts.

Participant one map four

Structure	Excellent
Relationship	Excellent
Exploratory	Excellent
Communication	Excellent

Participant three map four

Structure	Excellent
Relationship	Excellent
Exploratory	Excellent
Communication	Excellent

Participant four map two

Structure	Adequate
Relationship	Adequate
Exploratory	Adequate
Communication	Marginal

Comments and notes:

Participant one made only one change to the concept map (the one we talked about). All the connections between the concepts were very good and showed a high level of thinking. The concept map showed a very good level of networking with two linear exceptions. Participant one could have made more connections between the concepts, but all in all it was a very good map.

Participant three made the necessary changes to the linkages (there was one that we talked about). It was a very good network-type map. Participant three had very good connections between concepts showing the complexity of thinking.

Participant four completed a second concept map and left out the following concepts – products, concentration, reactants and catalyst. Some missing linkage words, added an extra concept (reversible reaction) to the existing concepts. On the positive side the map is showing signs of a network-type concept map and some of the links are very good for a second concept map.

<u>Day eight (23 August 2012)</u>

A discussion was held with participant four concerning certain aspects about the second concept map. Major areas for the prepared class concentrated on reactants, products, catalyst and concentration. These are also the concepts the participant left out of the second concept map.

Participant four map three

Structure	Good
Relationship	Good
Exploratory	Good
Communication	Excellent

Comments and notes:

Participant four constructed a very good third concept map which showed a very good network structure. The third map was acceptable and participant four therefore does not need to complete a forth concept map.

This concept map used all the available concepts (none were left out), but more connections could have been made between the concepts. The reason for this being, that in some instances some of the connections were viewed as “too” linear.

APPENDIX L1: Class one

1.1 Discussions

Remember the following tips with the construction of concept maps:

- Don't leave out linkage words (without linkage words there is no relationship between two concepts).
- Watch out for linkage words such as "and" and any single-functional words such as "increase" or "decrease".
- Use linkage arrows.
- Linkage arrows should be the correct way around.
- Try and make as many linkages as possible.

Concerning concepts:

- Dynamic system
- Le Chatelier('s principle)
- Chemical
- Physical
- Connection between chemical equilibrium and equilibrium constant.
- Connection between equilibrium constant and endothermic or exothermic.
- Connection between reaction rate and equilibrium constant.
- Connection between reaction rate and Le Chatelier's principle.

1.2 Prepared class

1.2.1 Definitions

Chemical equilibrium – When the forward and reverse reactions have the same rate forming equilibrium (balance).

Le Chatelier's principle – If we increase/decrease the temperature (or pressure or concentration) of a substance, there will be a shift to decrease/increase the temperature (or pressure or concentration of the substance, and vice versa.

Dynamic system – If the process inside a closed container is ongoing we call it a dynamic system. The reaction never stops.

Physical (change) – A physical change is when a substance changes between phases, for example, water in liquid phase changes to water in a gaseous phase (water vapour) when the temperature is increased.

Chemical (change) – A chemical change is when two or more substances (element or compound) changes to one or more substances (element or compounds). Ex.: $H_2(g) + I_2(g) \leftrightarrow 2HI$

Equilibrium constant (K_c) – The ratio between the concentration of the products over the concentration of the reactants.

$$K_c = \frac{[Products]}{[Reactants]}$$

Rate of reactions – The rate at which the reaction is taking place.

Endothermic (reaction) – More energy is absorbed than released in a reaction.

Exothermic (reaction) – More energy is released than absorbed in a reaction.

1.2.2 Explanations

Chemical equilibrium and dynamic system

It is important to remember that chemical equilibrium can only take place when two conditions are met. These two conditions are:

- The reaction must take place in a closed system; and
- The reaction must be reversible. A reversible reaction is a reaction that has a forward and a reverse reaction. Ex.:

$$H_2(g) + I_2(g) \leftrightarrow 2HI$$

When these conditions are met the chemical equilibrium formed creates a dynamic system, where there is an ongoing process between the forward and reverse reactions. This is always occurring even though we cannot observe it.

In the reverse process the change can be physical or chemical. The following is such an example:

Physical:

$$H_2O(l) \leftrightarrow H_2O(g)$$

Only change is physical or we can say there was a phase change.

Chemical:

$$2H_2O(g) \leftrightarrow 2H_2(g) + I_2(g)$$

New elements were formed during the reaction, but all of them are in the same phase.

Equilibrium constant

The equilibrium constant indicates the effectiveness of the reaction:

- A high K_c-value indicates that a high percentage of the reactants are changed into products, therefore the reaction is effective.
- A low K_c-value indicates that a low percentage of the reactants are changed into products, therefore the reaction is ineffective.

The K_c-value is only affected by a change in temperature (the other conditions do not influence the K_c-value):

- If the change in temperature favours the forward reaction the K_c-value would increase.
- If the change in temperature favours the reverse reaction the K_c-value would decrease.

A temperature increase favours an endothermic reaction, therefore $\Delta H > 0$.
A temperature decrease favours an exothermic reaction, therefore $\Delta H < 0$.

Rate of reactions

The rate of reactions is the rate at which reactions are taking place.

$$Rate\ of\ reaction = \frac{\Delta R\ or\ \Delta P}{\Delta t}$$

Le Chatelier's principle

This principle is used to predict how a chemical equilibrium will react to a change (disturbance) in that equilibrium. The change can be an increase/decrease in temperature/concentration/pressure.

APPENDIX L2: Class two

2.1 Discussions

This class starts off with an individual discussion with each of the participants. The discussion will help to eradicate any uncertainties on their concept maps.

Participant one: Very good network of concepts. Concerning connection – link between Chemical equilibrium and products and reactants.

Participant two: Concerning area – link between Chemical equilibrium and reaction rate; link between Chemical equilibrium and reverse/forward.

Participant three: It was a very good second map, but the participant can try to make more connections between concepts. A concerning area is with temperature (and its surrounding concepts). Links:

Endothermic →Favours →Forward

Exothermic →Favours →Reverse

Temperature →Change →Endothermic or Exothermic

Participant four: Left out the following concepts – Products, Reactants, Catalyst and Concentration. All other links are acceptable.

Participant five: Showed a very good network of concepts. Needs to change one word ("Influences") on the map. Concerning area on the concept map is temperature with surrounding concepts – Forward, reverse, endothermic and exothermic.

2.2 Prepared class

2.2.1 Temperature in chemical equilibrium

The main topic for this class is temperature in chemical equilibrium. The following is some of the main concepts surrounding temperature in chemical equilibrium: Endothermic and exothermic reactions and Temperature and the equilibrium constant.

Temperature is a factor that affects the rate of a reaction. A temperature increase would also increase the rate of the reaction, whereas a temperature decrease will decrease the rate of the reaction.

Other factors which can affect the chemical equilibrium are concentration, pressure and a catalyst.

2.2.2 Endothermic and exothermic reactions

Exothermic reaction is a reaction where energy is released through decreasing the chemical potential energy. The reaction will become warmer.

Endothermic reaction is a reaction where energy is added to the reaction for the reaction to take place. The reaction will become cooler.

When working with a reaction that has reached equilibrium, look for the enthalpy (ΔH). If $\Delta H>0$ or ΔH has a positive value:

- The forward reaction is endothermic and the reverse reaction is exothermic.

If *ΔH<0* or *ΔH* has a negative value:

- The forward reaction is exothermic and the reverse reaction is exothermic.

Example:

$$2SO_3(g) \leftrightarrow 2SO_2(g) + O_2(g) \quad \Delta H = -275$$

- Forward reaction: $2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$ is exothermic.
- Reverse reaction: $O_2(g) + 2SO_2(g) \rightarrow 2SO_3(g)$ is endothermic.

Keep in mind the following:

- A temperature increase favours an endothermic reaction. (Therefore if the forward reaction is endothermic then the forward reaction will be favoured with a temperature increase.)
- A temperature decrease favours an exothermic reaction. (Therefore if the forward reaction is exothermic then the forward reaction will be favoured with a temperature decrease.)

Summary on temperature, rate of reaction and chemical equilibrium:

Rate of reaction		**Chemical equilibrium**	
Factor	**Effect**	**Factor**	**Effect**
Temperature	Increase in temperature increases the rate of reaction.	*Temperature*	Apply Le Chatelier's principle.
	More particles have sufficient energy to react.		If the temperature is increased a reaction will occur to decrease the temperature.

2.2.3 Temperature and the equilibrium constant

Temperature change is the only factor in chemical equilibrium that can influence the equilibrium constant.

Equilibrium constant (K_c) – The ratio between the concentration of the products over the concentration of the reactants.

$$K_c = \frac{[Products]}{[Reactants]}$$

The K_c-value is only affected by a change in temperature (the other conditions do not influence the K_c-value):

- If the change in temperature favours the forward reaction the K_c-value would increase.
- If the change in temperature favours the reverse reaction the K_c-value would decrease.

APPENDIX L3: Class three

3.1 Discussions

This class starts off with an individual discussion with each of the participants. The discussion will help to eradicate any uncertainties on their concept maps.

Participant one: The link between chemical equilibrium and equilibrium constant is not "acceptable". The linkage word used in this concept map, "is the", does not show the relationship between the two concepts.

Participant two: All the concept words were used and all the linkages are seen as good enough to describe a relationship between concepts. The participant could have made more connections between concepts – cross-linking.

Participant three: Only one change needs to be made on the concept map. Half of one of the linkage words needs to shift down on the map. This will help the relationship to make more sense.

Participant four: Participant four could have made more connections between concepts, because some of the connections are seen as "too" linear. But all in all very good concept map.

Participant five: Very good network-type concept map. The concept map was a bit unorganised but that was overshadowed by the complexity of the relationships between concepts.

3.2 Prepared class

For this session there was no prepared class, because there were no major concepts with surrounding alternative ideas. The majority of the concept maps were very good except for that of two participants who had to make structural changes for the map (or linkage) to make sense.

Participants one and three had to make the structural changes to their maps; as discussed with them and participants two, four and five did not have to complete a fourth concept map, because they created an acceptable third concept map without any alternative ideas.

APPENDIX M: Data analysis rubric

The following rubric will be used to assess the learner's concept maps during the research process. This rubric was used in the "*Rubric-method*".

Criteria	**Excellent**	**Good**	**Adequate**	**Marginal**	**No credit (It is unacceptable to review)**
Structure	Non-linear structure providing a very complete picture of ideas.	Non-linear structure providing a complete picture of ideas.	Non-linear structure providing a picture of ideas.	Non-linear structure that illustrates a relationship between ideas.	Inappropriate structure.
Relationships	Relative importance of ideas is shown. Simple and complex relationships are very effectively mapped.	Relative importance of ideas is shown. Relationships are very effectively mapped.	Relative importance of ideas is shown. Relationships mapped.	Importance is evident, but not very distinctive. Relations are unclear or lacking.	No differentiation between ideas. No evidence of meaningful relationships.
Exploratory	Map indicates complex thinking about meaningful relationships between ideas, themes, and frameworks.	Map indicates effective thinking about meaningful relationships between ideas, themes, and frameworks.	Map indicates definite thinking about relationships between ideas, themes, and frameworks.	Map indicates some thinking about relationships between ideas, themes, and frameworks.	Thinking process is not clear.
Communication	Concepts are presented clearly. High level of understanding.	Concepts are presented clearly. Good level of understanding.	Concepts are presented clearly. Basic level of understanding.	Concepts are presented clearly. Some level of understanding.	Information is not clear and is very difficult to understand.

Kern, C. & Crippen, K.J. (2008). Mapping for Conceptual Change. *The Science Teacher. ProQuest Education Journals, 75*(6), 33-38.

APPENDIX N: Follow-up interviews

1.1 After the second concept map

1.1.1 Participant one (P1-HPG)

What did you imply with the connection between chemical equilibrium and products and chemical equilibrium and reactants?

Chemical equilibrium needs reactants to form products during its process.

Advice: Try connecting reactants and products with another concept.

1.1.2 Participant two (P2-HPG)

What was your intention with the linkage word between chemical equilibrium and forward reaction and reverse reaction?

Chemical equilibrium always consists of a forward reaction and reverse reaction.

Advice: The connection you made between chemical equilibrium and forward/reverse reaction is not incorrect; just see if you can't link the two concepts in another way. If not keep it that way.

What did you imply with the link between chemical equilibrium and reaction rate?

When the reaction rate changes it affects the chemical equilibrium, this causes the equilibrium to shift.

1.1.3 Participant three (P3-LPG)

Explain your connection between endothermic and forward reaction.

When the reaction taking place is endothermic the shift is to the right, meaning the forward reaction will be favoured.

Advice: Your connection is not incorrect, but is a half truth. When the reaction is taking place the endothermic reaction can be the forward or reverse reaction. When there is a temperature increase it will favour the endothermic reaction, which can either be the forward or reverse reaction (depending on the ΔH). Try connecting it in another way.

Explain your link between exothermic and reverse reaction.

When the reaction is an exothermic reaction the reverse reaction will be favoured.

Advice: When the reaction is taking place the exothermic reaction can be the forward or reverse reaction. When there is a temperature decrease it will favour the exothermic reaction, which can either be the forward or reverse reaction (depending on the ΔH). Try making another connection.

1.1.4 Participant five (P5-LPB)

Why did you use "increase favours" as a linkage word between temperature and forward reaction?

When the temperature of the reaction is increased it will favour the forward reaction.

Advice: This can be correct or incorrect, because it is dependent on certain things. When the temperature is increased it favours the endothermic reaction which can be the forward or reverse reaction. Try connecting it in another way.

Explain what is meant by “endothermic favours forward reaction?

An endothermic reaction favours the forward reaction.

Advice: This can be true, but not always. In some reactions the reverse reaction is the endothermic reaction; therefore if there is a temperature increase the reverse reaction will be favoured.

2.1 After the third concept map

2.1.1 Participant one (P1-HPG)

What is meant by chemical equilibrium “is the” equilibrium constant?

The chemical equilibrium is directly linked to the equilibrium constant, meaning that if the one changes the other one will as well.

Advice: Try linking it in another way, because all the changes affect the chemical equilibrium whereas only temperature affects the equilibrium constant.

2.1.2 Participant three (P3-LPG)

Only one change needs to be made on the concept map. Half of one of the linkage words needs to shift down on the map. This will help the relationship to make more sense.