THE APPLICATION OF REPERTORY GRID ANALYSIS COMBINED WITH CONCEPT MAPPING IN THE ELICITATION OF CHILDREN'S CONSTRUCTIONS OF PLANT NUTRITION.

Dublin City University

St. Patrick's College

Yvonne Marie Naughton

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by

Yvonne Marie Naughton

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Dr. Thomas McCloughlin

Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Masters of Education by Research is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed:	ID No.:	Date:
Yvonne Naughton	13264435	12/10/15
Yvonne Naughton	13264435	12th October 2015

Dedication

This work is dedicated to my family and friends.

To my parents, Maureen & Eamonn, who have given everything so

graciously for the benefit of their children.

I am who I am today, because of you.

To my friends, who have richly influenced my life

in more ways than words can express.

Thank you for everything,

always.

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- To those who have warmed my heart and truly believe that there is no limit to what one can do, I can only hope that my life is filled with people like you.
- To the people who may no longer be in my life, you are always in my heart and this work is for you too.

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Abstract

Concepts shape our view of the world. They enable us as humans to construct new meanings and actively form more accurate viewings. Student's conceptual structures have been an area of study and research in science education, however, minimal study has been carried out on children's constructions of plant nutrition. This project seeks to find the relationship of the learners' conceptual knowledge as they have constructed it in plant nutrition with the application of Repertory Grid Analysis (RGA) as an instrument for analysing the learners' presented constructs. RGA is a means whereby constructs are represented in matrical and graphical form, and concept mapping, which is a visual structural representation of a child's understanding and ideas. In this work, the use of concept maps will be employed and combined with RGA to form a detailed visual representation of a learner's ideas in plant nutrition. The study, as it is currently conceptualised, consists of a pre-test free concept map, a questionnaire and a structured post-test concept map containing four branches from the core concept of PLANTS administered to convenience samples involving two groups of sixth class primary students. In the closed concept-map task, the four branches will consist of the concepts ANIMALS, REPRODUCTION, GROWTH and PHOTOSYNTHESIS. Both sixth class groups will be involved in varying lessons based on plant nutrition and then requested to complete a post-test concept map. Both concept maps were coded and analysed using RGA under principal component analysis (PCA) and co-ordinate grid analysis (CGA). Similar concepts and links between concepts can be visually represented on graphs produced using the results, and that these have a relationship to the visual representations the children would produce in their concept maps. The findings of this study will highlight the rich insight into children's constructions in plant nutrition, which were visually represented using RGA combined with the method of concept mapping and triangulated with CGA. The study will contribute to raising the need for greater awareness of the structures of children's thinking about plants but also in general.

Contents

Appendices exist only for chapters 4 and 5.

There is no appendix for chapters 1 to 3 or chapter 6.

Chapter 1: Background, aims and objectives

The scariest moment is always just before you start.

King (2000)[1]

This thesis is concerned with structuralizations of the learners' conceptual knowledge as they have constructed it with a view of examining the many elements that make up science conceptual knowledge as they learn.

1.1 Biographical origin of this thesis

I first encountered the idea of learning on attending a small rural national school underpinned by the old primary curriculum, *Curaclam na Bunscoile (1971).* Through a series of tedious rote learning exercises, as I perceived them, without any real outcome, upon reaching secondary school I began to question the aspect of how a person is taught, and indeed how a person learns. As a student, I worked hard but often found it difficult to memorize all that seemingly necessary information for a test, or an exam.

I believe I was a successful student and received results which granted me a position at a prestigious college enabling others to be educated in a way that would allow me to teach young children. Over three years as a Bachelor of Education student in St. Patrick's College, Drumcondra, I began to strengthen the idea of a new way of learning, presented with an active, child-centred approach to learning.

A major departure in the history of primary education began upon the introduction of the *Primary School Curriculum (1999)* The new curriculum was no longer concerned with the

[1] King, Stephen. (2000) On Writing: A Memoir of the Craft

aspect of learning times-tables off by heart, but concern was finally given to the important goal of enabling children to learn to their full potential and laying a foundation for happiness and fulfilment in later education and adult life (Primary School Curriculum, 1999, p.14-15). A change in the way pupils learn had been brought to the attention of the nation. This forced me to think about problems faced with learning. As a primary school teacher, I wish to provide a child with not only an education, but a lifelong love of learning, for it is that love of learning that laid the path for the writing of this thesis. Although the revised curriculum had notable and noble intents, it remains to be seen if these intents have been met.

1.2 Aims of the research

This work aims to:

(a) Investigate children's preconceptions of scientific concepts and investigate if these preconceptions have an effect on the gaining of new knowledge in a positive or negative manner.

(b) Review/Analyse the current literature on constructivist approaches to children's learning in science and improve teaching and learning of photosynthesis in plants.

The research question, which embodies this entire thesis, is to examine primary students' conceptual structures concerning photosynthesis in plants and whether these can be done using existing means of examining conceptual structures. The underlying theoretical framework of this work will be George Kelly's idea of Personal Construct Psychology using his repertory grid analysis (RGA) to examine the structure of conceptions held by the student. The methodology employed throughout this work will be relating concept maps to repertory grids in order to portray a clear, whole, image of students' conceptions regarding photosynthesis. RGA elicit hidden ideas, thoughts, perceptions and conceptions whether they are considered prior conceptions, therefore 'pre-conceptions' (Novak, 1977), or 'alternative conceptions' (Driver & Easley, 1978) seeking so-called 'correct'[2] knowledge. This idea forms the basis of this study. An in-depth background into George Kelly's RGA will be presented in Chapter 2.

Figure 1.1 George Kelly, 1905-1967[3]

Repertory Grid Analysis – RGA, was devised to identify and investigate the relationships between a person's constructs. The basis of RGA is the elicitation of a grid or matrix of integers where each number is a score of relevance of a feature to a range of constructs. Once a numerical matrix is formed, it can be subjected to many kinds of statistical analysis (Fransella & Bannister,1977; Fransella, Bell & Bannister, 2004) by computer, e.g., Idiogrid (Grice, 2004) or RepGrid VI (Shaw, 2009).

The analyses produce graphs that are representations of a person's set of constructs with the co-ordinates of the constructs plotted as points in two, or more, dimensions (Jankowicz, 2004; McCloughlin & Matthews, 2002; Slater, 1977). Kelly (1969) used the

[2] 'Correct' knowledge – meaning that which is acceptable to the scientific community.

[3] Image taken from http://pages.cpsc.ucalgary.ca/~gaines/pcp/Kelly/Kelly.html Last active 31st May 2015.

phrase "geometry of psychological space" to describe this outcome of RGA. Chapter 2 will present in-depth research into RGA.

George Kelly (1969) pioneered the mathematical approach to psychology which resulted in his *opus magnus*: 'The Psychology of Personal Constructs' Kelly (1992). In it, he investigated the structure of particular types of concept that he labelled as 'constructs' highlighting the bipolarity of concepts, and their position in a cognitive structure of the mind: "the construct is a basis for making a distinction...a dichotomous reference axis" (Kelly, 1969). The author will examine George Kelly's theory of Personal Construct Psychology in detail in a literature review in chapter 2.

Chapter 3 will act as part 2 of a literature review. This chapter outlines Joseph Novak's method of concept mapping, scoring a concept map and the many uses associated with concept mapping, while also presenting the limitations of this method.

Chapter 4 outlines the methodology of this study, employed through the combination of concept maps and the repertory grid system, relating both methods together in an effort to portray a more detailed image into the structural conceptions and learning of the child.

The results of the studies for this work will be outlined and analysed in chapter 5 and discussed in detail in chapter 6. Opportunities for further study will be presented and recommendations will be made in chapter 6. The chapter outlines are summarized below in Table 1.1. Chapter 6 also concludes the thesis, with evaluation of the results and studies undertaken, contrary to the original research question and aims outlined above.

Table 1.1 *Outline of chapters in this thesis*

Chapter Number	Chapter Outline
1	Introduction: Aims, Objectives and Background
2	Literature Review: Personal Construct Psychology, Repertory Grid Analysis/Technique
3	Literature Review: Concept Mapping
4	Methodology: Relating Concept Maps to Repertory Grids, Questionnaire, Concept Mapping
5	Research Findings & Analysis
6	Discussion, Recommendations & Conclusion: Evaluation of results/studies contrary to original aims

1.3 Method and technique

The set of pre-existing concepts and alternative conceptions selected for investigation are based on plants, specifically the way in which plants make their food through the process of photosynthesis. George Kelly, and others (Shaw, 1980)Slater, 1977), believed that people are "personal scientists" in anticipating the world, and that they engage in "anticipatory modelling activity" (Kelly, 1992).

This study aims to respect each child as a "personal scientist" in the world around them and investigate the structure of children's pre-conceptions and alternative conceptions in science education through the use of concept mapping as a method of extracting pre-existing and new knowledge. This study aims to combine Novak's method of concept mapping and Kelly's RGA method in order to present a structure of the knowledge gained through active teaching and learning in the primary classroom.

This study is also an attempt to improve the quality of teaching learning in science education in the primary school, highlighting the differences learned through active teaching and learning and passive teaching and learning.

1.4 Further Study

Opportunities for further study may be present in the combining of Kelly's method of RGA and Novak's method of concept mapping. Issues arise around concept mapping such as comparison of concept maps between students or education and it is thought that RGA overcomes some of these issues (McCloughlin & Matthews, 2012). It is the hope that by combining these two methods that one would be given an insight into the structural learning of each student, whilst also being able to compare the learning between students in an effective manner.

1.5 Summary

The main aim of this study is to investigate children's conceptions or conceptual structure in science. This study combines the work of Kelly's Repertory Grid Analysis and Novak's method of concept mapping in the study of plants in the primary classroom and highlight further insights into the ways children structuralize the conceptions of plants. The two studies undertaken to realise these aims are summarized in the table 1.2.

Table 1.2 *Studies carried out using concept maps and RGA to elicit pre-existing and gained knowledge from the learner.*

Chapter Number	Concept Employed	Objectives
5	Concept Map - Marked	To determine pre-existing knowledge on plants
	Questionnaire – Images of various plants included with scale rating (Strongly Agree-Agree-Neutral-Disagree-Strongly Disagree)	To investigate knowledge when given a question, and when given a question linked with an image.
	Questionnaire analysed using RGA	To observe how the rating scale was employed by the learner.
5 & 6	Lesson on Plants taught in passive manner with one class and in active, hands-on manner with a different class.	To examine which teaching and learning style best suited the learners.
	Concept map based on plants completed by both classes given four outside links to add to (Photosynthesis, Reproduction, Growth, Animals)	To establish the structure of conceptions and what has been learned using the concept map as a method of assessment.
	RGA & Concept maps	To gain a visual of structural conceptions and compare concept maps from the students in each class against each other using RGA.

Chapter 2: Literature Review

> *Education studies... are a 'practical science' in the sense that we do not only want to know facts and to understand relations for the sake of knowledge, we want to know and understand in order to be able to act and act 'better' than we did before.*
>
> Langeveld (1965: 4)

2.1 Introduction

This literature review will explore structuralizations of the learners' conceptual knowledge regarding photosynthesis in plants under the theoretical framework Personal Construct Psychology (PCP). This approach will investigate children's preconceptions of scientific concepts and analyse the data using George Kelly's RGA technique. Joseph Novak's method of concept mapping will be outlined and discussed in detail in chapter 3 as part of this literature review. Structuralizations of the learner's conceptual knowledge as they have constructed it will be examined by the many elements that make up science conceptual knowledge as they learn.

2.1.1 Role of the literature review

The role of a literature review is to gain an understanding of existing literature and research in the field (Randolph, 2009; Boote and Beile, 2005; Copper, 1988) and to situate the topic within the broader academic literature (Boote and Beile, 2005). This thesis is concerned with the elicitation of children's constructions in plant nutrition and the teaching and learning of primary science education. It is situated within a broad range of literature based on the teaching and learning of science.

2.1.2 Scope of the literature review

There are a large number of studies on George Kelly's RGA and his theory of PCP and indeed numerous studies associated with Novak's method of concept mapping. The focus of this research is to examine children's structures of preconceptions and alternative conceptions concerning photosynthesis in plants and investigate if these conceptions have an effect on the gaining of new knowledge, therefore the studies represented in this literature review will only be referred to as appropriate to the area of science education.

2.2 George Alexander Kelly

This chapter will outline Kelly's biography. It is important to discuss the man behind the theory that forms the theoretical framework behind this study.

2.2.1 Biography

Born on the 28th April 1905, George Kelly was the only child of Theodore and Elfleda Kelly living on a farm near Perth, Kansas. Originally a Presbyterian Minister, Kelly's father gave up his ministry to take up farming. Fransella and Neimeyer (2005) discuss the way in which Kelly's "spirit of adventure" seems to have come from his maternal grandfather. His mother was the daughter of a Nova Scotian captain of a sailing ship, and she herself had the benefit of travelling across many oceans.

Kelly was educated by his parents on his return to the Kansas farm in 1913 and received little or no formal education for the first twelve years of his life. His formal education began at the age of sixteen, whereby he attended Friends' University academy in Wichita. In 1926, Kelly majored in physics and mathematics and graduated with a master's degree in educational sociology at the University of Kansas. Kelly continued to move around academe and he received an exchange fellowship to go to Edinburgh University in Scotland to study for a Bachelor of Education degree, which he completed in 1930. In 1931, Kelly accomplished a doctorate degree at the University of Iowa under Carl Seashore in the Department of Psychology.

From here, his promising career began. During the Great Depression (1929-1939), he developed his clinical techniques in Fort Hays Kansas State College. Kelly served as a flight-programme and aviation psychologist with the Navy during World War II where he went on to hold an academic post at the University of Maryland. He became the director of Ohio State University's clinical program in 1946 and it was here that he wrote his two-volume work *The Psychology of Personal Constructs* (1955) where both his interests in comprehensive theorizing and mathematics can be found. As a Professor of Behavioural Science at Brandeis University, Boston, USA, George Kelly died on 6 March 1967 (Fransella & Neimeyer, 2005, pp. 4-5).

2.2.2 The man himself

An essential feature of Kelly's theory, reflexivity, aids in the discussion of the man himself, looking at him through the eyes of his own theory. Fransella (1995) states the way in which a student of Kelly's claimed, "his hopes went way beyond himself". The bipolarity of constructs in inevitably, all constructs have opposites and such construing will be discussed in detail when outlining Kelly's RGA technique.

2.2.3 Influences on Kelly's theory

> *That George Kelly was a very deep, original, refreshing voice was always evident to all who knew him well. What has surprised me was not the brilliance with which he first spoke but the accuracy with which he anticipated the directions into which psychology would move two decades later.*
>
> Mischel (1980, p. 85)

The author must highlight the influences on Kelly's theory of PCP, which originally stem from his study of psychology, philosophy, physics and mathematics throughout his lifetime. A comparison between behaviourism, one of Kelly's negative influences, and personal construct theory is provided by Bannister (2003) whereby we ourselves, are forms of motion, driving ourselves to new heights. Although Kelly rejected much of established psychology and its teachings, he often cited John Dewey as one of the main philosophers to influence him (Fransella & Neimeyer, 2005, p. 7).

It is evident that Kelly drew on Alfred Korzybski's (1933) ideas around linguistic philosophy and the idea that "constructs" are interpretations. These "constructs" were said to portray as much about their users as they do about the "realities" they make an effort to describe. Similarly, Han's Vaihinger's (1924) philosophy of "as if" influenced Kelly in his *construction of alternativism* and Jakob Moreno's psychodrama successfully aided Kelly in determining role-play strategies that form an integral part in personal construct therapy (Fransella & Neimeyer, 2005, p. 7). While there is only one objective reality, Kelly's idea of *constructive alternativism* highlighted that reality can be experienced from different perspectives, therefore giving alternative constructions. It was without doubt the thoughts and ideas behind these great men that shaped Kelly's unique approach to psychology (Neimeyer & Stewart, 2000).

Fransella (1983) has suggested that it was Kelly's degree in physics and mathematics that played an integral part in the development of his theory of PCP and indeed his formation of the method of measurement – the repertory grid. Kelly requested each individual to look at themselves "as if" they were a scientist, whereby we each have a theory about what is happening at any given time, making a prediction based on our theory and then testing that theory through our actions and behaviour. Kelly's love of mathematics as "pure instances of construct functioning" and his reference to it as "the model of human behaviour" are clear indications of his theory to all those who study it (Kelly, 1970, p. 91).

Mair, Epting and Landfield (1985) have debated that Kelly's theory represents a counterpoint to his childhood and the religious ideology upon which he grew up in with conservative Christian parents. Mair suggests that Kelly accentuates the human potential to live alternatively, through daring experimentation in every-day life due to his conservative up-bringing.

2.2.4 Prior Knowledge

When children learn, they, their teachers and parents and other interested parties come to understand that such learning has taken place by the results achieved once the desired-for 'learning' has ended, however often the importance of prior knowledge and it's structure is over looked. Kelly (1992, p.5) states that "all thinking is based in part on prior convictions" and it is this very statement that acts as a basis for constructivist thinking in science education.

Brook *et al.*, (1989, p. 63) discuss the way in which human beings make sense of the world, describing the learner as someone who is constructing internal models and ideas and using those ideas to make sense of personal experience. Before formal science education begins, the author, along with many theorists, holds the view that children have been constructing their own ideas of how the world around us works. Duschl, Schweingruber and Shouse (2007), state that upon reaching school, young children already possess a rich implicit knowledge of the natural world. Alternative explanations to that given in formal science may already be constructed by a child long before they come to learning in a formal manner (Driver *et al.*, 1985). Driver *et al.*, (1985) and Brook *et al.*, (1989) similarly speak of making sense of physical experience while Kelly was concerned with social experience (Kelly, 1992), however connections can be made between these ideas.

- Prior experience holds some significance to the learner
- Experience can be symbolized

This area held a huge emphasis in science education in the late 1980's until research in problem-based learning moved forward. In a study in trends of science education research conducted by Chang, Chang and Tseng (2010), it was found that the topic *Conceptual Change & Concept Mapping* was the most studied topic, despite the decline in research publications in the 2000's. De Jong (2007) observed that cognitive psychology in the early years had a sufficient impact on the study of conceptual change in science education, which later included social-cultural and science technology domains. The adoption of the notion of pedagogical content knowledge (Shulman 1986, 1987) and its impact on science education (Gess-Newsome and Lederman 2001) is an example of a developmental trend in recent years. De Jong (2007) describes the shift in research interest from "content knowledge" to "pedagogical content knowledge" by teachers between 1995 and 2005.

2.2.5 Personal Meaning

> *But how can one spend his whole life, the one and only life that is given us, taking notes on things as they are, without once using his pencil to make a little sketch in the margin depicting things as they might be?*
>
> Kelly (1978, p.225)

Kelly argued that "education should be about personal meaning" (Stringer & Bannister, 1979) and it is this dispute that inextricably links Kelly to modern constructivist approaches in education. Pope (2005) has provided a comprehensive outlook of the ways in which Kelly's ideas have been used within education. Kelly explicitly describes the "perspective of the personal" in his writings stating that "we start with a person. Organisms, lower animals and societies can wait" (Kelly, 2003, p.7).

Thomas and Harri-Augstein (1985) have disputed the meanings that emerge from learning must be personally 'significant' in some part of the person's life. The practicality of these meanings depends on how abundantly the person or individual includes or builds them into personal experience. In order to become self-organised as a learner, Thomas and Harri-Augstein firstly encouraged learners, teachers and teacher trainers to recognise their own potential and reflect on their own learning process (Pope, 2005, p. 196). Learning-to-learn becomes an essential duty for the learner. Kelly saw learning as a personal exploration, a personal journey and the teacher's role to implement each child's own undertakings, each child's personal journey (Pope, 2005, p. 196) and "gain some sense of what is being seen through the child's eyes" (Kelly, 1970, p.262).

2.2.6 Teacher's Role & Teacher Education Worldwide

Through the process of education, Kelly aimed to encourage learners to acknowledge and articulate their world views but also to recognise that their views were open to potential invalidation, potential alternatives. Kelly hoped that through opening their minds to alternatives, he was helping people to reconstruct their lives in order to build a brighter future so they were no longer victims of their pasts. Kelly identified learning as a personal exploration, one that a teacher must journey with their student in order to fully carry out their role (Pope, 2005, p.197). According to Kelly, the teacher's role was to "implement each child's own undertakings", to support the interpretation of the outcomes and aid in creating more logical behavioural inquiries (Kelly, 1970, p.262).

Within the teaching world, news means and ways of professional development are incessantly being introduced year on year (Pope, 2005, p. 197). In 2012, the National Induction Programme for Teachers (NIPT) was introduced as a continual development for Newly Qualified Teachers upon graduation with an education degree, in their first year teaching. Teachers are encouraged each year to continue to develop and up-skill through summer courses, offering from three days off fully paid throughout the school year as a reward and an incentive for continual professional development.

Ju-Ling Shih *et al.,* (2010), writes of the way in which digital learning has been converting from e-learning to m-learning with mobile devices. Using Kelly's repertory grid technique to design learning content, Ju-Ling Shih *et al.*, found that "the environment is capable of enhancing students' motivation and learning effectiveness" while in turn reducing a teacher's work load.

As a nation, a world of people, the world is undoubtedly viewed through a variety of lenses each minute of every day and there are times when those images may not be easily altered. It is for this reason that teachers are continually being encouraged to rethink or redesign the metaphors by which they live (Lakoff & Johnson, 1980).

2.3 Personal Construct Psychology

> *We are the actors in life, if we do not like what we find as a result of our experiments, although it is not easy, we* ***can*** *change.*
>
> Centrepcp (2009)[4]

This chapter is concerned with George Kelly's theory of Personal Construct Psychology (PCP) and his famously stated reference to man as a scientist. Mischel (1980) has described PCP has "ahead of its time".

2.3.1 Background and context

What is it that springs to mind when one hears the word scientist? Kelly (1992) believed that people are "personal scientists" in anticipating the world, while Driver (1983) referred to "the pupil as a scientist". George Kelly pioneered the mathematical approach to psychology, which resulted in his opus magnus: 'The Psychology of Personal Constructs' Kelly (1992). In it, he investigated the structure of particular types of concept that he labelled as 'constructs' highlighting the bipolarity of concepts, and their position in a cognitive structure of the mind (Kelly, 1992). Tyler (1981) describes the publication of Kelly's book as a "landmark event in the opening toward individuality".

Raskin (2002) discusses Kelly's theory of personal construct psychology (PCP) as a knowing individual who continually puts his or her constructions to the test. PCP envisions people as adventurers, explorers capable of pushing the boundaries of their very own lives as

[4] Quote taken from http://www.centrepcp.co.uk/whatis.htm last accessed 31st May 2015.

they experiment with alternative interpretations of their ever-changing worlds in an effort to increase predictability (Walker & Winter, 2007). Raskin (2002) uses Kelly's concept of "hostility" to describe those who try to force the world to fit their preferred constructions rather than altering their constructions to fit a better world.

2.3.2 Man as a scientist

Kelly proposed the metaphor of "man as a scientist" whereby a scientist is someone who attempts to form theories about how something may work or what something is. As human beings, we actively make predictions daily and endeavour to test those predictions in order to see if they are correct. A positive prediction provides validation whereas a negative prediction is regarded as invalidation and creates a response, where-by the problem must be re-examined (Dalton & Dunnett, 2005, p.5). Bannister and Fransella (2013) emphasise that man is not a "victim of his biography" but "self-invented and shaped" by his enquiries.

2.3.3 Levels of Awareness

Kelly's theory includes unsullied understandings of "the unconscious". He stated that human beings are not inert substances that need energy to move them; instead they are living matter embracing the crucial property of movement. He suggested the idea of levels of awareness. 'Conscious' construing was placed at the highest level of awareness whereas 'pre-verbal' construing was at the lowest level.

Although a baby and young child do not hold a verbal label attached to their experiences, verbal attachments are found as they develop throughout the years (Fransella & Neimeyer, 2005, p. 11). It is in this respect that Kelly foreshadowed more contemporary cognitive theories, taking into account the point at which a baby or young child is construing, without attaching a verbal label. People 'know' more than they can tell – Kelly sought to include all that we construe as a human being, as many events in our lives can only be inferred (Fransella & Neimeyer, 2005, p. 11).

2.3.4 Human Development

Dalton and Dunnett (2005) posed the question, how do we come to be as we are? A common criticism against Kelly's theory of personal construct psychology is that he did not draw human development, from birth to adulthood, into his theory. Macnamara (1982) stated that our first concepts were acquired throughout the ages from birth to three years old, upon recognition of symbols and languages around us. Novak and Cañas (2008) refer to this as *discovery learning*, while after the age of three, much of a child's conceptual knowledge is founded in language and becomes known as *reception learning,* whereby a child has the ability to question and develop conceptions.

Fransella (1995) argued that the oversight was deliberate as human beings are seen as forms of motion, constantly developing, despite our age. Kelly was seen to be sceptical of theorists such as Piaget, who shared some of his constructivist leanings as Kelly's theory eliminates all attempts to place people into categories or boxes (Fransella & Neimeyer, 2005, p. 12). Like Werner, Kelly preferred to view human 'becoming' as an individual process by which both children and adults are consistently extending, revising, and reorganising their own system of meaning that they construct (Mascolo, Craig-Bay, & Neimeyer, 1997).

2.3.5 Skills for Personal Construct Users

Fransella (2005) states that there are some skills necessary for personal construct users in order to be a successful practitioner. The ability to subsume another's construing is essential, that is, employing the ability to see the world through another's "unique pair of spectacles" (Kelly, 1955). Although Kelly did not discuss suspension, it became evident that personal values must be suspended by the interviewer or practitioner (Fransella, 2005, p. 42). The idea of listening unquestioningly to another, taking on a "credulous attitude" (Kelly, 1955/1991, p.174/Vol. 1, p. 121) when listening to another (Fransella, 2005, pp. 42-43). One final skill that Fransella (2005) found to be essential in the application of personal construct psychology is reflexivity. Reflexivity refers to the attitude of the researcher towards their chosen area of study and the research process. Alvesson and Sköldberg (2009) describe reflexivity as the "interpretation of interpretation" however it is important to mention that according to Malterud (2001), "preconceptions are not the same as bias, unless the researcher fails to mention them".

2.3.6 Elicitation methods associated with PCP

Although the repertory grid technique is one of the most frequently engaged methods of elicitation, there are many examples of techniques and methods of elicitation associated with PCP. Kelly's version of self-characterization sketches involves asking the individual to write a character sketch of himself or herself as if they were a main protagonist in a play, from a friend's perspective, written in the third person. This enables the individual to portray not only how they view themselves but also how they recognise the world in which they live (Denicolo, P. 2005, p. 59).

Bright (1985) reflected on lying as a human activity and considered how it might be employed within a person construct framework to aid people to recognise potential change. Without any intention to deceive another person, Bright formulated a game based on lying whereby a participant was asked to write down lies about themselves within a chosen consideration, for example as a parent. When the participant is unable to produce any more relevant lies, two columns are inserted on the side of the page in which the respondent must replied yes or no (Y or N) to these questions:

1. Would you like this lie to be true?

2. Would you like other people to believe this lie?

An NN response suggests no wish for change, a YY response indicates a wish for change at a high level of awareness, a YN response signposts a wish for the lie to be true without wanting others to believe it and finally a NY response conveys a concern for what others think without actually wishing for change.

Osborne and Gilbert (1980) generated a technique involving a series of cards showing a stick figure (a player) involved in an activity (kicking a football), which were used as a stimulus for conversation. This technique explored students' views of the world in relation to scientific concepts. The simple drawings created an emphasis on the action portrayed, which in turn created situations whereby the understanding process of the action is the focus upon analysis of the conversation.

Although there are many elicitation methods fashioned by a number of theorists, the main elicitation method for the purpose of this study will involve the use of the repertory grid technique to elicit students' pre-existing and new knowledge structures centred on photosynthesis in plants. Kelly created the repertory grid in an effort to "get beyond the words" following the Repertory Test, the first of his creations focusing on studying the individual. Inspired by Kelly's view that our construing can only ever be limited by our imagination (Denicolo, 2005, p. 65), the author wishes to combine the use of the repertory grid with Joseph Novak's concept mapping idea in order to gain a broader understanding of the conceptual structures created by the learner.

2.3.7 The future of PCP

Many as a form of expression, a way of manifesting that which we cannot say aloud can perceive music. In relation to this, Davies (1976) carried out a study to identify what brass and string players' thought of each other, and how they viewed themselves as part of an orchestra. Eric Button (1988) spoke of music's predictability and indeed its undeniable unpredictability. Butler (1995) studied music students themselves, those with successful experiences towards music and their peers. For many, music is an essential part of life, and it is that vital aspect of construing music to suggest that Kelly's personal construct theory may be applied in the future (Fransella, 2005, pp.245-246).

John Lee (2000) highlighted the importance of using personal construct psychology as a basis for literary critics in order to understand the various characters in literature. In his book, *Shakespeare's 'Hamlet' and the Controversies of Self*, upon praising Kelly's approach to free oneself from enslavery in a sense, Lee (2000, p. 183) referred to literature as a "personality... a philosophical representation of the world".

This study is concerned with the application of Kelly's personal construct theory and repertory grid system in the constructions of photosynthesis in plants in primary science education.

2.4 Piaget and childhood

Our understanding of the experience of childhood is deepened by the study of Piaget (Schwebel & Raph, 1973, p.3). Piaget sought to examine the school system and found that it was a case of seemingly mindless mastery of techniques such as reading and writing arithmetic (Schwebel & Raph, 1973, p.6). Piaget believed that both the aim and the process of education was the freedom to act upon the world and to construct reality (Schwebel & Raph, 1973, p.22).

The principles of Piaget's theory are based on social interactions between children themselves in school and intellectual activity based on real experiences rather than on language (Schwebel & Raph, 1973, p. 201). Similarly to Kelly's idea of "personal meaning", Piaget believed that knowledge is "construction from within" (Schewbel & Raph, 1973, p.199) and it is through the principles of Piaget's theory that our understanding of a child's need to continue their discovery and construction of the real world is heightened. In order to do so, "turned on teachers" are necessary for the developing intelligence amongst "turned on kids" (Schwebel & Raph 1973, p.7).

2.5 The Repertory Grid Technique

> *The answers to such questions...may give us an understanding of the interweaving of the client's terminology and provide us with an understanding of his outlook which no dictionary could offer.*
>
> Kelly (1995/1991, .267/Vol.1 p.189)

This chapter outlines and defines the use of George Kelly's method of analysis – The repertory grid technique (RGT).

2.5.1 What is a repertory grid?

According to Jankowicz (2004), 'grid' is a basic term for a number of simple rating-scale procedures. Originally known as the 'role construct repertory test', the 'repertory grid' is the most widely known aspect of the work of George Kelly. The repertory grid is not merely a technique that is independent of personal construct theory (Bell, 1988). Kelly's fundamental hypothesis suggests that *a person's processes are psychologically channelized by the ways in which he anticipates events.*

Jankowicz (2004, p. 9) discussed the vast range of applications of a repertory grid. From basic applications such as forming a fast impression of a person's likes and dislikes, to educational applications whereby a repertory grid can be used as an assessment tool to identify children's learning. Every grid is made up of four components:

- Topics
- Elements
- Constructs
- Ratings

A repertory grid may contain both qualitative and quantitative data. The information in a grid depends on the elements and constructs that have been incorporated into the repertory grid. The identity of the elements and the nature of the constructs may supply qualitative information. The relationships between the constructs and elements may be read as quantitative data (Bell, 2005, p.68).

It is important to remember that the constructs elicited for a grid only provide a very small glance of how a person construes the world (Fransella, Bell *et al.*, 2004, p.17) as from the study of Kelly and his works, it is evident that a person's imagination and perception of the world is ever changing, so too are the ways in which a person construes the world around us.

The repertory grid provides a concise representation of the way in which a person construes his/her world or some aspect of it. It is a device used for measurement with a solid conceptual basic for its structure. It allows for both individualized and normative types of assessment. It can be applied in almost an inexhaustible range of contexts and can be used to supply many different kinds of information (Bell, 2005, p. 75).

	Element 1:	Element 2:	Element 3:	Element 4:	Element 5:
Construct 1:					
Construct 2:					
Construct 3:					
Construct 4:					
Construct 5:					

Figure 2.1 An empty repertory grid

2.5.2 A particular topic

A grid is always piloted based on a particular topic, with an intention of eliciting particular constructs in an effort to make sense of a particular area with reference to a person's share of experience (Jankowicz, 2004, p. 12). Through the unfolding of the constructs one discovers how a person thinks and what meanings he/she holds in relation to a particular topic. For the purpose of this study, the author has chosen photosynthesis in plants as a particular topic to gain an insight into the structure of children's own personal experience of the topic. However, it is important to note that like Kelly, Jankowicz states that in doing a grid on a particular topic, only a part of a person's collection or experience can be discovered (Jankowicz, 2004, p. 12).

2.5.3 Ratings

Each element is *rated* on each construct. Jankowicz (2004, pp.13-14) discusses the powerful nature of grids, enabling people to express their own personal views based on a particular topic by means of their own constructs. Through the combination of elements, constructs and ratings, a "kind of mental map" is provided conveying the way in which an individual construes the particular topic in question. (Jankowicz, 2004, p. 14)

2.5.4 What is an element?

Elements are described by Kelly as 'the things or events which are abstracted by a construct', one of the 'formal aspects of a construct' (Kelly, 1955/1991, p.137/Vol.1, p.95). Jankowicz (2004, p. 13) explains an element simply as a sampling of or an occurrence within a particular topic. In order to discover a person's constructs, one must compare a set of elements. The repertory grid's technique aims to define a set of elements, bringing forth a set of constructs that differentiate among these elements and relate elements to constructs (Bell, 2005, p.67).

2.5.5 Choosing elements

Elements are firstly determined in the standard grid elicitation process. Both Kelly and Mitsos (1958) defined a set of elements as 'acquaintances' by 'role titles' as an origin for choosing elements. Adams-Webber (1997) employed both real and 'nonsense' elements in his study into the ratio of assignment to positive or negatively valued poles, finding differences in the ratio of assignment to poles. Consequently, Bell *et al.,* (2002) proved the need for more research into the choice of elements as he analysed sources of variation in grid data. He discovered that elements usually made up four times as much variance as constructs. Bell (2005, p. 69) discussed the opportunity for more process-oriented research with the technique when choosing elements.

2.5.6 What is a construct?

The constructs of a repertory grid are the *ways*, the elements, the *events* (Bell, 2005, p.67). Kelly gave the name constructs to those arrangements that are used as a way of construing the world. Humans are continuously seeking to develop and increase their understanding of the world, increasing their repertoire of constructs by altering certain constructs to provide better fits and more accurate outlooks on the world (Kelly, 1992, p. 7). Like Kelly, Jankowicz (2004, p.10) describes the way in which we *construe*, we make sense of something, we find meaning in it, all by means of constructs themselves.

The most significant property of a construct is described in the Dichotomy Corollary – it is bipolar (Fransella, Bell *et al.,* 2004, p.15). Through a single interpretation of one's experiences, bipolar dimensions are formed. Through these interpretations, the bipolarity of a construct is distinguished from a single concept expressed previously (Fransella, Bell *et al.*, 2004, p.16). A construct represents a contrast. Jankowicz provides an example that we are a people can each relate to and may have had experience with both – A good teacher as opposed to an ineffective teacher (Jankowicz, 2004, pp. 10-11). According to Husain and Adams-Webber (1983), any single construct is part of a complex system of constructs. Therefore not all constructs have only one opposite.

The universe is essentially a collection of events whereby a person's experiences and recollections are testes and challenged. A construct, which is more worthwhile than others, holds a higher predictive efficiency (Kelly, 1992, p.9). However, it is the fear of the outcome that often instils hesitation in one to experiment and challenge their constructs.

2.5.7 Eliciting constructs

Bell (2005, p. 69) states the most basic concern for use of personal constructs in a repertory grid surrounds the issue of how constructs should be elicited or supplied. From a Kellyian viewpoint, the technique seems to demand constructs to be drew from the person themselves, hence the name *personal* constructs. Much research demands data to be accumulated and with this, there is need of a certain amount of camaraderie and commonality between the data. Adams-Webber (1970) carried out a study focused on whether or not supplied or elicited constructs produce similar results and found that it was dependant on the context in which the grid was based or in use (Bell, 2005, p. 69).

2.5.8 Relating elements to constructs

In both research and educational settings, there is an interest in relating elements to constructs. Kelly's original grid allowed for three natures of elements with reference to a construct. An element was seen to have the ability to be related to one pole, or another pole, or be labelled as not being related to the construct (Bell, 2005, p. 70). Fransella and Bannister (1977) discussed the original method of ranking elements on each construct, imposing a distribution of elements along a single construct which in turn restricted the free allocation of elements (Bell, 2005, p. 70).

2.5.9 Analysing the data of repertory grids

Grid data requires comprehensive evaluation and analysis. If one had ten elements rated on ten constructs, that individual grid would require one hundred judgements of a respondent (Bell, 2005, p. 71). The repertory grid analysis will be discussed in detail in chapter 5.

2.5.10 Comparing repertory grids

No two grids are identical, therefore it is necessary to compare the grids to gain a group overview and identify a standard at which students can be compared in the general educational context of teaching and learning. Grids will be analysed in detail and compared in both class 1 and class 2 in chapters 5 and 6.

2.5.11 Slater's repertory grid method

Patrick Slater published a monograph entitled "The Principal Components of a Repertory Grid" in 1964. Fransella *et al.*, (2004, p. 93) discuss the way in which they found Slater's title 'principal components' misleading as a generic term and stated that it is more precisely called 'Singular-Value Decomposition', otherwise known as 'Eckart-Young decomposition'.

It is important to discuss Slater as he firstly recognised that this procedure could be applied to Kelly's repertory grid data and his method of 'principal component' analysis in 1964 became the standard at which all repertory grids were used following his research, despite his further research and versions of the computer programme (Fransella *et al.*, 2004, p. 94).

Following Slater's acceptance of a financial grant from the British Medical Research Council, he went on to provide a grid analysis service which ran until 1973 at which time 10,000 grids per year were being processed (Slater, 1976). As a result, a two-dimensional spatial representation of constructs and elements suited a way of viewing the grid and it remains the accepted way of the viewing the grid today (Fransella *et al.*, 2004, p. 94). Multidimensional unfolding is a different approach, which also provides a spatial representation of a repertory grid. It originates from non-metric multidimensional scaling, finding a pattern of points representing elements and constructs through the rank order of distances between points representing such elements and constructs. A point indicating a construct is the same as the rank order of the grid data for the elements on that construct (Fransella et al., 2004, p. 97).

Whereas Kelly employed the use of binary data (ticks and blanks), using the number of matching ticks as his index of association in his original repertory grid method (Fransella *et al.*, 2004, p. 84). Correlations for ranking and rating can be interpreted however it provides the user with large amounts of information. Clearer relationships between constructs can be represented by principal-component analysis (with varimax rotation), which focus on association between constructs such as correlations and distances (Fransella *et al.*, 2004, pp. 86-88).

2.5.12 Study samples using Kelly's repertory grid technique

George Kelly's repertory grid technique has been employed by many as a form of analysis for a broad range of particular topics, emphasising the sheer diversity of application for this highly inventive technique. Through the repertory grid technique and an interview inspired by Kelly's Personal Construct Theory, Oscar Tomico *et al.*, (2009) carried out a study exploring cross-cultural differences. They discovered the way in which17 Dutch and 16 Japanese industrial designers valued a set of pens. Oscar Tomico *et al.*, (2009) discuss culture, according to Kluckhohn (1951) as values that pervade history and ideas that are passed down through generations, which in turn create a pattern of ways of thinking, feeling and reacting. Using triads, they found that the Japanese designers were more concerned with comfort relating to their choice of pens, while the Dutch displayed a greater concern for durability and symbolic qualities of the product in their choice through measures of 'dominance, importance and descriptive richness' of their constructs. Culture was found to play a role in products that a designer may consider important.

Björklund (2008) aimed to assess creative work and problem solving skills using the repertory grid technique. In a Swedish city, a class of 15-16 year olds working on a project in technology and design were interviewed to discover and analyse their level of level of creativeness and ability to problem solve. Wilson and Tagg (2010) employed the use of repertory grid technique and Kelly's personal construct theory to examine the constructs related to male and female business owners and the role of sex and gender in a business in

Britain. It was found that few differences existed in the way male and female business owners are construed and view each other.

Gracey *et al.*, (2008) employed Kelly's theory and technique to address the 'personal construction of self after brain injury'. Thirty-two participants who had acquired brain injury were involved in the study of construing oneself. Comparisons were made of pre-injury, current state and ideal selves of each participant in small groups. Through this study, it was found that people construe themselves in terms of the values and felt experiences of social and practical activity.

2.5.13 Limitations in repertory grid analysis

Limitations exist concerning the validity of the repertory grid technique and its ability to enable researchers and theorists to elaborate their construing. Fransella *et al.*, (2004) discuss the capacity to increase the *range of convenience* of a construct, taking more elements into account. Those wishing to apply a 'theory' or measurement instrument such as the repertory grid technique can widen the research area. Fransella *et al.*, (2004) refers to validity as the way in which a means of understanding empower one to take effective action. Kelly compared validity with usefulness and saw understanding as the most useful of initiatives.

2.6 Conclusion

The repertory grid technique has been the most widely known and indeed most widely used trait of George Kelly's personal construct theory. It is a flexible measurement device that provides a coherent representation of the way an individual construes his or her world or some part of it. It can be applied in a vast range of contexts and provides an array of information (Bell, 2005, p. 75). To conclude, although the author presents only a small insight into the vast range of studies, Kelly's personal construct theory and repertory grid technique hold the key to unlocking a world of knowledge, yet to be discovered. In the next chapter, Joseph Novak's method of concept mapping will be outlined and discussed in detail.

Chapter 3: Concept mapping

Concepts embody our knowledge of the kinds of things there are in the world.

Murphy (2002)[5]

This chapter will explore Joseph Novak's method of concept mapping, the idea and function of a concept, how and why concepts are formed and provide an insight into conceptual frameworks. The author will also outline methods of concept map construction and limitations associated with concept mapping.

3.1 Idea of a concept

Duit and Treagust (2003) discussed the investigations into the notion of conceptual change and students' preconceptions on a number of science content domains. Research by Gilbert, Osborne and Fensham (1982) highlighted the way children make sense of their experiences. Gilbert, Osborne and Fensham (1982, p. 623) described children's intuitive knowledge as being called "children's science". This study aims to identify children's structural pre-conceptions and pre-instructional knowledge or beliefs about the concepts surrounding photosynthesis in plants and indeed the structure of their alternative conceptions surrounding the topic also. Over the past three decades, studies have been conducted which indicate that students do not meet with science concepts without any pre-existing knowledge or conceptual knowledge. (Gilbert, Osborne & Fensham, 1982, p. 3)

[5] Murphy, G. (2002) *The Big Book of Concepts*. Massachusetts Institute of Technology, United States of America.

3.1.1 What is a concept?

Concepts enable humans to go beyond what is essentially presented, the information given, forming new ideas and thinking around what we experience and build upon what we already know (Murphy, 2002). Murphy (2002, p.1) so rightly stated, "concepts are the glue that hold our mental world together".

3.1.2 Functions of a concept

Murphy (2002) describes the way in which concepts give us the knowledge and indeed the courage, to build upon what is already known and to understand what is happening in the world around us. This raises the question, what would the world be like without concepts? Smith and Medin expressed their view of the world without concepts, describing the chaotic and overwhelming nature of it all. "Concepts [...] give our world stability" (Smith & Medin, 1981, p. 1). Humans would be lost in the once simple process of identifying similar or familiar objects, places, and people around them and this in its essence, the function of a concept.

3.1.3 How is a concept formed?

Keil and Wilson (2000, p.1) speak of the way children question things from an early age in order to develop their thinking and learning, suggesting that the possession or concepts indicates an understanding through explanation (2000, p.4). Thus, implying that one can possess explanatory understanding without linguistic ability even, highlighting a level of understanding in infants especially.

3.1.4 Why is a concept formed?

Why, from an early age, do we seek explanations? Why do we continuously pose the question "why?" Keil and Wilson (2000, p. 8) believe that we do so to make sense of what has happened around us, and indeed what is continuously happening around us each and every day of our lives. There is a sense of recognition and "guessing right" (Peirce 1960-1966)[6]. It is in our nature, as human beings to question things around us, in order to gain some sort of an understanding into how the world works.

3.2 Concept mapping

> *Knowledge structures are built primarily through meaningful learning, and by contrast, rote learning or simple memorizing information contributes little to building a person's knowledge structure.*
>
> Joseph D. Novak (2004)[7]

3.2.1 Introduction to conceptual frameworks

The term "conceptual framework" is often used to describe graphic images that present relational information about concepts (McCloughlin, 2008). Although there are a number of conceptual frameworks, the most relevant to this study are concept maps. Lawson (1997) referred to the concept map as a system for externalising internal memory representation. It is impossible to discuss concept mapping without mentioning the true man behind the advances associated with the term, Joseph D. Novak. Fisher *et al.*, (2000) has described concept

[6] Peirce, C. S. CS 1960-1966. *Collected Papers.*

[7] Novak & Cañas (2004) 'Building on New Constructivist Ideas and CmapTools to Create a New Model for Education. http://www.ihmc.us/users/acanas/Publications/NewModelEducation/NewModelforEducation.pdf last accessed 11th June 2015.

mapping as one of the many types of knowledge mapping. Concept maps facilitate learning, creating and indeed using knowledge. A concept map enables a teacher to view the understanding of a child's learning structurally, indicating those students with only an overall grasp of the subject, and those with a more deep and meaningful understanding of the topic (Novak, 2010, p. 21).

They are, in the words of Novak (2006, p. 1), "graphical tools for organizing and representing knowledge". Concepts are enclosed in boxes usually with the relationship between concepts shown by a connecting line. Linking words, words written on the line between the two linking boxes, indicate what type of a relationship the two concepts have (Novak & Cañas, 2006). Ruiz-Primo *et al.,* (2001) also described concept maps as a graphic in which the nodes represent concepts, relations are represented through the lines between nodes and the labels on the lines denote the nature of the relations.

Providing more scientific facts and principles for students or increasing "hands on" activities will not increase students' understanding of science alone. A "minds on" emphasis in the learning of science (Pines, 1985) can be carried out through techniques such as concept mapping whereby the developments and structures in students' learning can be traced (Cakir, 2008).

3.2.2 Classifying concept maps

Concept maps may be classified into types or forms. Novak and co-workers initially classified students into those who possessed 'notions of understanding' (Nussbaum & Novak, 1976) or 'categories of understanding' (Novak & Hibbard, 1975). In an effort to attain more explicit descriptions of concept meanings, they turned to Ausubel's (1968) 'assimilation theory of cognitive learning'.

Ausubel's theory describes the way in which meaningful information is stored through connected facts or concepts referred to as schemata. New information is more easily understood, learned and retained when it fits into an existing schema whereby new concepts will be more readily learned and anchored to existing schemata. As a result, Novak and co-worker's borrowed the idea that cognitive structure is organized hierarchically from Ausubel's theory which has been retained by some researchers today (Novak & Gowin 1984).

3.2.3 Types of concept maps

Many types of concept maps and indeed representations of concept maps have been explored in science education. The author presents a small selection of concept map techniques that apply to the purpose of this study. Cluster maps, 'skeleton' maps and 'construct-a-map' techniques will be discussed below.

Cluster maps or 'webs' are practices or techniques that capture connections between ideas, displaying links and associations between concepts freely. This technique forms the basis for this overall study. Buzan (2013) created a MindMaps (™) tool that allows the creation of cluster maps.

Schau and Mattern (1997) argued that too high a cognitive demand is placed on a student when asked to create a concept map from a start to finish. As a result, 'skeleton' maps or 'expert skeleton' maps were proposed to aid the student in completion of a concept map. 'Skeleton' map or 'fill in the map' as they were also known, are often used for difficult topics and have been prepared by an expert on the topic of study, providing students with some concepts or links, to scaffold or aid learning in the specific topic area (Novak & Cañas, 2008).

Finally, the 'construct-a-map' technique can be completed on a blank sheet of paper and possesses a variety of complexity, according to the researcher and the scoring system employed. Although scoring can be difficult (Schau & Mattern, 1997; Schau, Mattern, Zeilik, Teague, & Weber, 2001), this type of concept map may be scored according to the number of ideas represented, the links between ideas and their level of hierarchy portraying an "observable phenomenon" (Evans, Hay & Kinchin, 2008) of ideas expressed.

According to Kinchin *et al.,* (2000), concept maps may also take 'shapes' such as a 'chains' or linear (Figure 3.1), a 'radical' or 'spoke' (Figure 3.2) and 'nets' or webs' (Figure 3.3) concept map shape. Learners may be encouraged to produce a specific form of concept map, due to a common assumption that concept map complexity is associated with depth of understanding, which is not always the case. The author wishes to employ the use of such methods of construction of a concept map, without compromising the methodology, when examining the concept maps constructed by the participants.

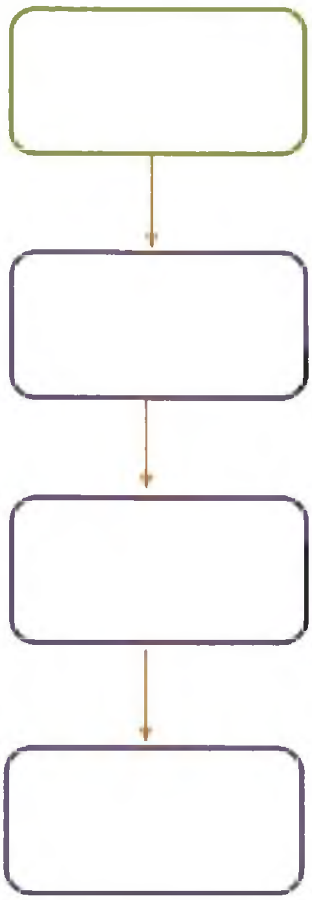


Figure 3.1 A chain or linear concept map shape

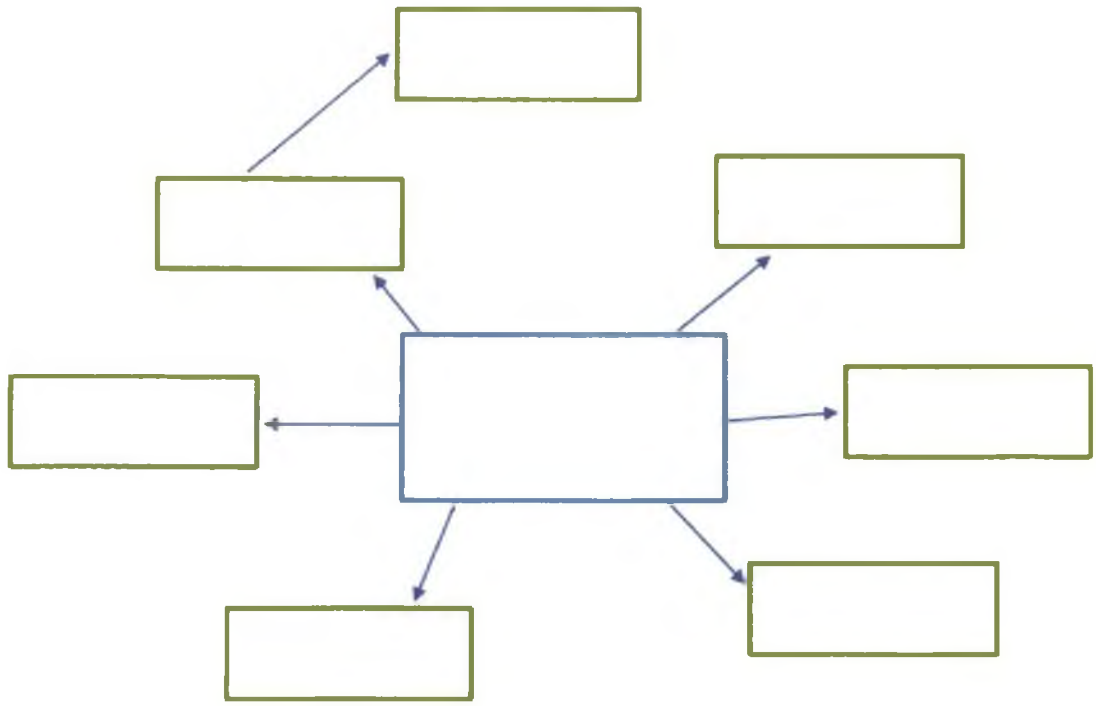


Figure 3.2 A radical or spoke concept map shape

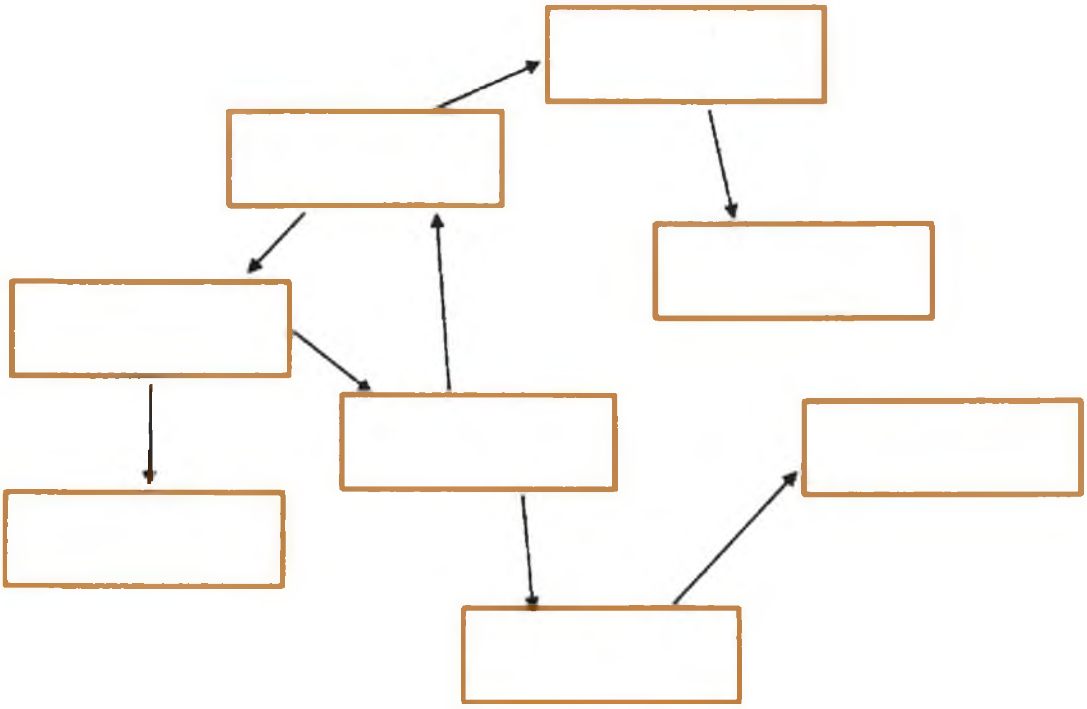


Figure 3.3 A net or web concept map shape

3.2.4 Constructing concept maps

The hierarchical structure (Figure 3.4) is the central feature of the Novakian concept map, which is founded in the theory of subsumption, assimilation or incorporation. Ausubel (1963, 1968) referred to concept mapping as a process of knowledge formation and organisation, whereby patterns were established among concepts. Vanides *et al.*, (2005) outline a number of steps in order to effectively use concept maps in the classroom:

I. select key terms

II. identify what area of the curriculum the map will be rooted

III. create the activity in a construct-a-map style

Novak and Cañas (2008) speak of a *focus question* as an integral part of a concept map in order to heighten the level of concept maps produced, the focus question must provide the student with a specific reasoning based on the topic of study. Concept maps can be produced by hand or through the use of the software CmapTools (Cañas *et al.*, 2004b) whereby images, graphs and more resources from the Internet can be employed.

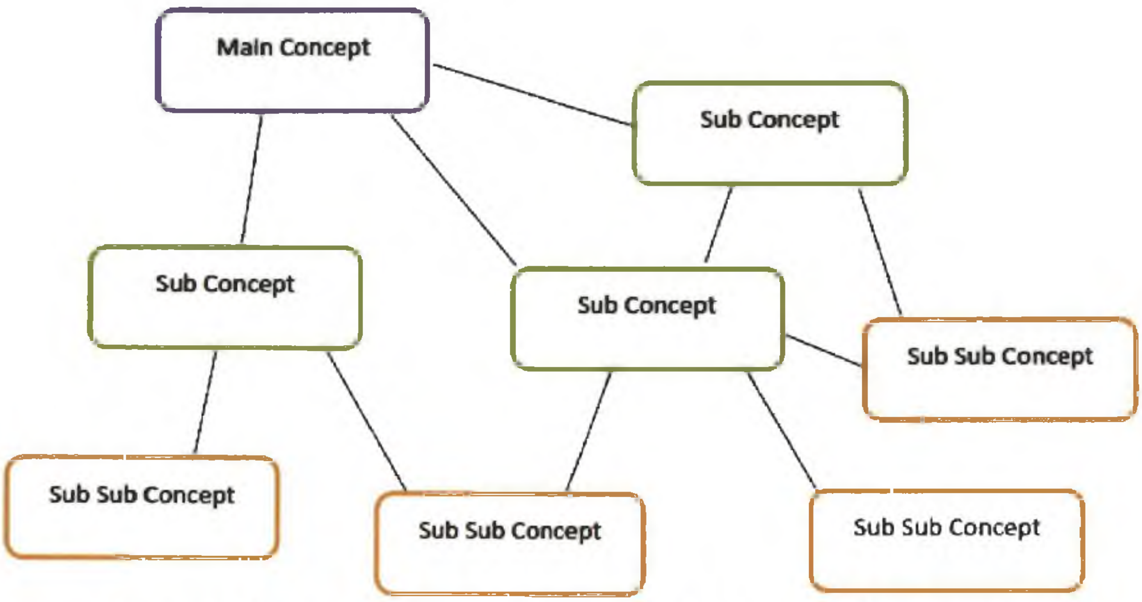


Figure 3.4 A generalised concept map displaying hierarchical arrangement

3.2.5 Scoring concept maps and validity

Scoring concept maps employ an element of summative assessment. On applying a summative approach (Novak & Gowin, 1984) the overall score reflects the sum of individual scores awarded to:

1. the number of general links: score of 1 mark per link
2. the number of levels in a hierarchy: score of 5 per level
3. the number of cross links: score of 2 per cross-link
4. the number of worded examples: score of 1 per example

This summative assessment approach, although simple to apply, highlights a limitation or cause for concern in its application. Although the concept map in question may appear complex in structure with a deep understanding of the content displayed, the score of a concept map purely represents the complexity of the structure itself and disregards the quality of information conveyed. The structures of the ideas expressed by the student are no longer important in terms of this scoring method.

A second limitation or concern is evident when discussing this scoring method. Students who have been taught or trained to construct concept maps within the levels of scoring would be enabled to exploit the scoring system and achieve maximum scores through cross-links in their concept maps. The author wishes to step away from the limitations of traditional scoring and develop a scoring technique which would allow the structure of concept maps to be analysed through repertory grid analysis.

Martin *et al.,* (2000) developed another scoring procedure for scoring structural change (Pearsall *et al.,* 1997). This method of scoring possesses similarity to the idea behind Kinchin's method of describing the structure of concept maps (Kinchin *et al.,* 2000). Three structural changes are recognised in Martin *et al.,*'s (2000) method of scoring:

1. *Restructuring* – a concept label is restructured, added or deleted, from the first level of a hierarchical concept map.
2. *Accretion* – ten or more concept labels or tags are added to a pre-existing concept
3. *Tuning* – change to a pre-existing concept results in a modification or change in its meaning by the addition of limiting variables.

Each map is compared to a following map (map 1 v map 2; map 2 v map 3) and a score of 1 or 0 is recorded for each occurrence or non-occurrence of a structural change. A set of scores is produced for each student. However, the issue of validity remains due to the nature of a practitioner choosing certain links and/or cross-links to score. As a result, *item response* *theory* (IRT) models were used for scoring concept maps (Liu, 1994) without holding a need to sit the same test (Hambleton, 1991). Samejima (1969) discusses the replacement of traditional IRT models with graded IRT which allow a student's response to be graded categorically as opposed to simple right or wrong. Four aspects of a concept map are taking into account in the scoring of a concept map using IRT:

- Links
- Hierarchies
- Cross-links
- Examples

The overall structure of a concept map is emphasized through IRT scoring contrary to the black and white, right or wrong, nature of a specific concept map. Liu (1994) stated that IRT scoring was generally valid and reliable in nature and a correlation exists between IRT and total concept mapping scores based on the Novakian scoring method, therefore taking the Novakian method to be a reliable gauge of 'ability'.

3.2.6 Uses of concept mapping

Novak and Gowin (1984) found that concept maps helped students "learn how to learn" (Novak, 2010, p. 23). Concept maps were not just a tool that could be used for students in primary school, concept mapping made new studies of human learning possible in any context. Heinze-Fry and Novak (1990) identify one of education's most commendable goals – "to move students away from rote mode learning toward meaningful learning", and a worthy goal it is.

Vanides *et al.*, (2005) discussed the way in which concept maps benefit students by giving them the opportunity to (1) recognise connections between science terms being learned (2) organizing their thoughts into a visual representation of the relationships between concepts and (3) reflect on their understanding of the science concepts at hand.

A number of studies with secondary school science students highlighted the effectiveness of concept maps during learning (Okebukola, 1990). Furthermore, studies by Wilerman and MacHarg (1991) found that concept maps used as an advance organiser for 8th grade science students proved to produce higher post-test results than the group who did not employ the use of concept maps in their learning. However, Lehman *et al.*, (1985) found no differences in results using concept maps and a control group in biology, while the use of concept maps in chemistry was found to produce lower scores in more able students (Stensvold & Wilson, 1990).

Studies by Miandoab *et al.*, (2012) examine the effects of concept mapping instruction on academic achievement in areas outside science in a history course in which the experimental group tested significantly better than the control group.

Udeani and Okafor (2012) examined the effect of concept mapping instructional strategy on the achievement of secondary school slow learners in biology. The 131 slow learners were selected based on past examination results, teachers' observations and student inter-ratings. The researcher then observed this selected group of slow learners for two weeks in their individual biology classes. The students were randomly assigned to an expository group and a concept mapping group and each group was taught the concept of photosynthesis. A post-test was carried out and it was evident that the group exposed to concept mapping instructional strategy performed considerably better than their counterparts. Another interesting result concluded that female slow learners taught using the concept mapping instructional strategy performed significantly better than their male counterparts taught using the same method.

Nesbit and Adescope (2006) carried out meta-analysis reviews both experimental and quasi-experimental studies whereby students learned by 'constructing, modifying, or viewing node-link diagrams'. Fifty-five studies involving 5,818 participants were carried out with students at levels ranging from grade 4 to postsecondary school. The participants used concept maps to learn in a number of domains including science, psychology, statistics and nursing. Post-tests were employed to measure recall and transfer and interestingly across numerous instructional conditions, settings and organisational features, the use of concept maps in learning was linked with increased knowledge retention.

Concept maps can also be used as an evaluation device (Novak & Gowin, 1984) (Novak & Cañas, 2008). Vanides *et al.,* (2005) identified the concept map as a valuable tool for teachers that provide information about the students' understanding of a science concept. Using concept maps, teachers can examine how well a student understands a science concept by observing the complexity of their concept map. Students' levels of understanding are highlighted on a concept map upon taking a closer look. Links made between unrelated concepts uncover students' alternative conceptions in science. Similarity, the absence of a link between two closely related concepts exposes a lack of understanding in the relationship between the concepts in question. Vanides *et al.,* (2005) also speaks of the clear development over time in a student's learning that can be visible in a concept map while the gaps in learning are also evident, helping an educator to modify lesson plans based on students' understanding of the science concepts taught.

Novak and Cañas (2008) discuss the usefulness of concept maps in curriculum planning. Key concepts and principles can be presented in an organised, concise manner through the use of concept mapping, which provide opportunity also for sequencing of curriculum material.

3.2.7 Limitations of concept maps

Considerable debate took place in the science education community, recalled by Novak (1990), based on the ability of young children to understand 'abstract' concepts intangible ideas such as 'energy' or 'evolution'. This limitation was grounded in their 'cognitive operational capacity' (Piaget, 1926/1959). However, Novak's early work proposed that this limitation may not exist, and instead the limitation to the ability of young children might be the quantity and quality of their relevant knowledge attained through both experience and instruction.

The reliability and validity of concept map scoring techniques have raised speculation amongst researchers. The scorer must determine what aspects of a concept map are 'valid' and Kinchin (2001) has expressed doubt whether one can be reliable in such determination. Caine and Caine (1994), and indeed White and Gunstone (1989), have criticised this quantitative approach to scoring concept maps.

3.3 Conclusion

There is room for change. As human beings, our understanding, our beliefs, our conceptions of the world are ever changing. Kelly (1955) offers a "unique pair of spectacles" that will be found to fit the reader. Every individual holds their own personal view of what the world is like and there is no doubt that some constructions are more accurate than others. Symington and Novak (1982) uncovered that primary school children are indeed capable of developing detailed concept maps and they hold the ability to explain the concept maps intelligently to others. As primary teachers, as science educators *"the challenge we face... is primarily how to organise better instructional material and how to help students learn this material"* (Novak, 1990). It is important to note that no one individual grips the complete construction, the perfect perspective of the world (McCloughlin, 2008). Each perspective is unique to the individual and encompasses value in the eyes of the beholder. In the next chapter, the author will present the methodology for this study.

Chapter 4: Methodology

A person who never made a mistake, never tried anything new.

Albert Einstein (1995)[8]

4.1 Introduction

This chapter aims to outline the methodology in use for the purpose of this study. Centred on the research idea, the structure of a concept, and enlightened by Kelly's theory Personal Construct Psychology, the author aims to use Joseph Novak's method of concept mapping and a questionnaire in order to gather information and prior-conceptions which will provide an insight into the learner's science conceptual knowledge through further analysis. The author embraces the goal to relate Novak's method of concept mapping to Kelly's repertory grid technique in order to examine and evaluate the various structures of concepts in photosynthesis and observe any changes in structure and knowledge from pre-test to post-test concept maps.

4.2 Populations, Sample and Setting

The population for this study were primary school students aged 11-12 years old. Participation in the study was both voluntary and confidential in nature. The research encompasses a (i) quasi-experimental aspect and involve a (ii) small-scale case study. Two groups or classes of approximately twenty students involved in the study are referred to as the 'experimental' group, whereby one group, class 2, with act as a controlling 'non-experimental' group. An interactive intervention lesson was taught to one group, while the control group was taught in a rote learning fashion.

[8] Einstein, A. (1995) Weak attribution of the motto to Einstein in Syracuse Hearld-Journal, New York.

A pre-test questionnaire and concept map was carried out with both classes within the primary school setting. A simple intervention was done with the 'experimental' group. A post-test concept map was carried out post-intervention lesson. The following steps to obtain research data are outlined in table 4.1 below. This type of technique will enable the researcher to gain an insight into the children's pre-conceived knowledge of the proposed strand in the primary science curriculum, in order to investigate how their existing schemata effects their ability to gain new knowledge. Thus, attempting to prove the research statement.

Table 4.1 *Research steps for both experimental and non-experimental groups*

Research Steps	**Experimental Group**	**Non-experimental Group**
Step 1	Complete a free-concept map on plants	Complete a free-concept map on plants
Step 2	Participate in a questionnaire based on core concept	Participate in a questionnaire based on core concept
Step 3	Intervention lesson – "hands on" active lesson based on photosynthesis in plants & use of ICT	Textbook style lesson with little opportunity for active learning
Step 4	Create a closed concept map on plants and their relating concepts after learning has taken place	Create a closed concept map on plants and their relating concepts after learning has taken place

4.3 Ethical considerations

This study, prior to implementation, was submitted to the University review board for approval and the author acted ethically at all times. This study does not involve any potential risk or harm to the participants beyond common, everyday classroom risk. As previously stated, participation in the study was both voluntary and confidential in nature in spite of involving normal teaching classes. Each student was assigned an alphanumeric code to ensure that the pre-test and post-test results can be compared while maintaining the anonymity of each of the students.

4.4 Research design

This study aims to relate Novak's method of concept maps to George Kelly's repertory grid technique. Although both concept mapping and the repertory grid technique are well known to researchers across a range of study areas, there has been little or no research to suggest that both methods have been combined in the area of photosynthesis in primary science education. The study practises a quasi-experimental, pre-test-post-test design with a 'non-experimental' group to determine if students are taught using a more "hands on" approach, will their concept maps be more structurally complex in nature, showing a greater understanding of the science concepts in question.

This work aims to investigate the structure of children's preconceptions and alternative conceptions of scientific concepts and investigate if these conceptions have an effect on the gaining of new knowledge in a positive or negative manner. As a result, this design allows the researcher to acquire qualitative and semi-quantitative data for a comparison analysis.

4.5 Instrumentation

A questionnaire created by the researcher was used in this study. The questionnaire consists of a concept map whereby the participant may construct-a-map on the front page of the questionnaire, highlighting the structure of their existing knowledge around the chosen science concept based on plants. The participants were asked to create a concept map based on a plant before any further discussion on the topic took place.

A total of four carefully selected questions based on the specific area of photosynthesis in plants were then presented to the participant whereby they chose '*strongly disagree, disagree, neutral, agree, strongly agree*' from the Likert scale (1932)[9] as their answer. The questions were presented in both a positive and negative formation shown in the example below (Figure 4.1).

1. **All plants photosynthesize.**

Strongly Disagree Disagree Neutral Agree Strongly Agree

2. **Chlorophyll is not needed for photosynthesis to occur.**

Strongly Disagree Disagree Neutral Agree Strongly Agree

Figure 4.1 Example of questions using the Likert scale in the study

A further four carefully selected questions and corresponding images were presented to the participant whereby they continued to use the same Likert scale (1932) as in previous questions, excluding images shown in the example below. Images were included in

[9] Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology*, 140, 1–55.

connection with the questions in order to examine a change, if any, in their perception and indeed 'misconceptions' (Helm, 1980) based on photosynthesis in plants (Figure 4.2).

1. This is an example of a plant making its own food.

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

Figure 4.2 Example of question and image using Likert scale in the study

Following this questionnaire, the participants in class 1, the experimental group, and class 2, the non-experimental group, took place in an intervention lesson taught by the researcher. The lesson involved a "hands on" approach to learning in science in class 1. Both lessons can be examined in the appendix. The participants were then asked to construct a concept map based on their learning when given four branches in the concept map in order to encourage richer understanding and complexity. An example of this concept map will be presented in chapter 5, research findings.

4.6 Procedure

Students were split into two groups, an experimental group in class 1, and a non-experimental group in class 2. The students in the experimental group were taught in a "hands on" interactive learning method, based on the child-centred science primary curriculum 1999. Students in the non-experimental group, class 2, experienced traditional teaching methods based on photosynthesis in plants from a science book in preparation for their post-test concept map.

Both groups were given an opportunity to construct a free concept map and participate in a questionnaire in order to gather their pre-existing knowledge and structural thoughts based on the scientific concept, photosynthesis in plants. A post-test, closed concept map was then distributed to both groups following an intervention lesson based on photosynthesis in plants. Data was collected through both the free concept map and the questionnaire during pre-test and the closed concept map in the post-test. The author aims to combine and relate Novak's method of concept mapping with Kelly's RGA technique, as a method of structural observation, through a scoring system that will be further outlined and discussed in chapter 5.

4.7 Data processing and Analysis

In this study, data collected through the instrumentation, concept mapping, will be processed and analysed through the use of George Kelly's repertory grid analysis technique. This form of analysis produce graphs which represent a person's set of constructs with co-ordinates of the constructs plotted in two or more dimensions. (Jankowicz, 2004; McCloughlin & Matthews, 2002; Slater, 1977).

The relationships among constructs will be represented by principal component analysis (Fransella *et al.,* 2004, p. 86) and co-ordinate grid analysis. Both pre-test and post-test concept maps will be scored by the author and data will be inserted into Idiogrid (Grice, 2004) and analysed with Kelly's repertory grid technique, thus combining Novak's concept mapping method with Kelly's method of analysis. The researcher used only the first two principal axis loadings as variance when creating graphs. Most of a graphs variance is accounted for by the first two loadings, therefore, it is safe to use a selected two if the first two axis loadings combined are great than 75% of the variance. The graphs produced will be further analysed by the author in chapter 5, with respect to the research question previously outlined, will examine the structure of concepts relating to photosynthesis.

4.8 Summary

The purpose of this methodology chapter was to describe the research methodology of this study, outlining the instrumentation in use, the procedure followed, and define the process for data analysis. Data analysis will be further discussed in chapter 6. In the next chapter, results from the research findings will be outlined in detail.

Chapter 5: Research Findings

The principle goal of education is to create men who are capable of doing new things, not simply of repeating what other generations have done – men who are creative, inventive and discoverers.

Jean Piaget (1964)[10]

This chapter will present the research findings, including tables and figures, to illustrate the patterns presented in the data. In the individual results, being printed in block-capitals denotes the conceptual mapping concepts. The use of capital letters will be employed to distinguish the four main concepts as follows – PHOTOSYNTHESIS, GROWTH, REPRODUCTION and ANIMALS. The concepts listed above were selected based on their opulent association with the core concept and main idea, plants. The central concept PLANTS will also be represented in block-capitals.

Results of pre-test and post-test concept mapping and RGA under both principal component analysis (PCA) and co-ordinate grid analysis (CGA) will be presented in both tables and figures in this chapter.

5.1 Concept maps

This section will outline findings in relation to the pre-test and post-test concept maps produced by both class 1, the experimental group, and class 2, the non-experimental group, prior to analysis under RGA and CGA.

[10] Credited with the remark in 1964 in The Arithmetic Teacher, Vol. 11, No. 7. Piaget rediscovered by Eleanor Duckworth. Re-printed in 1968 in *The New York Times* in an article titled "Giant in the Nursery – Jean Piaget"

5.1.1 Concept map coding

Two 6th class groups were asked to participate in this study. Class 1 will be referred to as P6 and class 2, the non-experimental group, will be referred to as P62 for the duration of this study. Each student was assigned a number co-existing with their class group and their pre-test and post-test concept map. A pre-test concept map will consist of the digits 01 at the end of the code, whereas a post-test concept map will be assigned 02 at the end of the code. Each student's work will be assigned a varying code to ensure their work is unidentifiable, e.g., SP601 and KP6202.

5.1.2 Results of concept map analysis

Both class groups, P6 and P62 were asked to complete a concept map based on PLANTS. The pre-test concept map consisted only of the requested concept PLANTS to be placed in the centre of the page (Figure 5.1). Each student in both class groups were then asked to create a concept map based on their existing knowledge and prior understanding of PLANTS. The students were given time to complete their concept maps based on the core concept without influence or further instruction from the author, providing an opportunity for each student to portray a natural thought process in their individual concept maps.

Concept maps were interpreted and marked by the author relative to a striking link between the core idea, PLANTS, and four chosen associated concepts PHOTOSYNTHESIS, GROWTH, ANIMALS and REPRODUCTION. A striking link embodies a direct related aspect of each concept, e.g., Sunlight would be considered a striking link between PLANTS and PHOTOSYNTHESIS and awarded one point by the author when marking. The four identified concepts will become an important feature subsequent to the intervention lesson in the closed post-test concept map.

PLEASE NOTE: Your completion of this questionnaire confirms that you understand the purpose of this study and that you freely consent to participate in it.

Create a concept map based on a plant.

Figure 5.1 Blank free pre-test concept maps with notice of consent.

5.1.3 General overview of pre-test concept maps

Students in both 6^{th} class groups created a concept map based on their existing knowledge constructed through a natural thought process of plants and the way in which plants grow. Each concept map highlighted aspects of GROWTH in relation to PLANTS, however omissions were predominant involving the other concept areas REPRODUCTION, ANIMALS and PHOTOSYNTHESIS.

5.1.4 General overview of post-test concept maps

Post-test concept maps consisted of the central concept PLANTS and four branches of the relating concepts ANIMALS, REPRODUCTION, GROWTH and PHOTOSYNTHESIS. The branches were presented as shown in Figure 5.2 below.

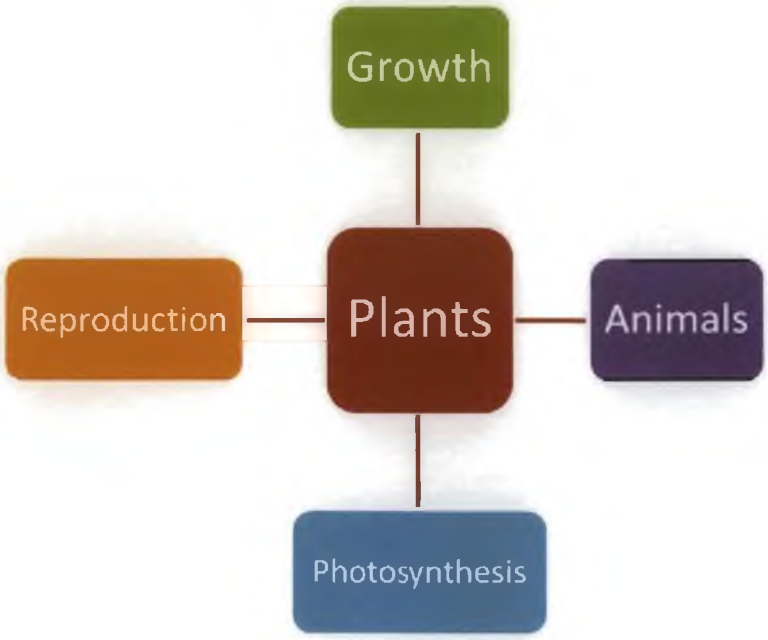


Figure 5.2 Blank closed post-test concept map

In the closed post-test concept map, the students in both class 1 and class 2 were asked to consider each of the four concepts listed above in relation to the core concept PLANTS.

A closed post-test concept map was employed by the author in order to structure participant's thoughts and ideas, and identify concepts that were perceived and listed as closely related to the principal idea. A closed post-test concept map was arranged as shown above, reproduction opposite animals and growth opposite photosynthesis, as a result of the coupled nature of opposing concepts. Growth is inextricably linked with photosynthesis, for growth would not continue to take place without the process of photosynthesis. Animals and reproduction hold an indivisible connection whereby animals provide a platform for reproduction to take place. The structure of the closed post-test concept map also provided a clear outline of related concepts and links made by the participant which created a sharp method of marking for the author.

5.1.5 Individual results of pre-test and post-test concept maps

KP601 (Figure 5.3) displays a clearer understanding of the inter-dependent relationship between PHOTOSYNTHESIS and GROWTH, linking the two concepts frequently on the concept map created. Concepts related to PLANTS such as ANIMALS and REPRODUCTION are omitted from this concept map.

KP602 (Figure 5.4) presents a complex and detailed post-test concept map. Ideas surrounding GROWTH and PHOTOSYNTHESIS were undeniable linked, listing aspects of both concepts branching from either concept. A clear understanding of the process of PHOTOSYNTHESIS is displayed, stating that it is the process by which plants make their own food. Although only features of REPRODUCTION stem from the branch marked as so, traits of REPRODUCTION also feature reaching from the branch marked ANIMALS, highlighting a vibrant understanding of links between both concepts.

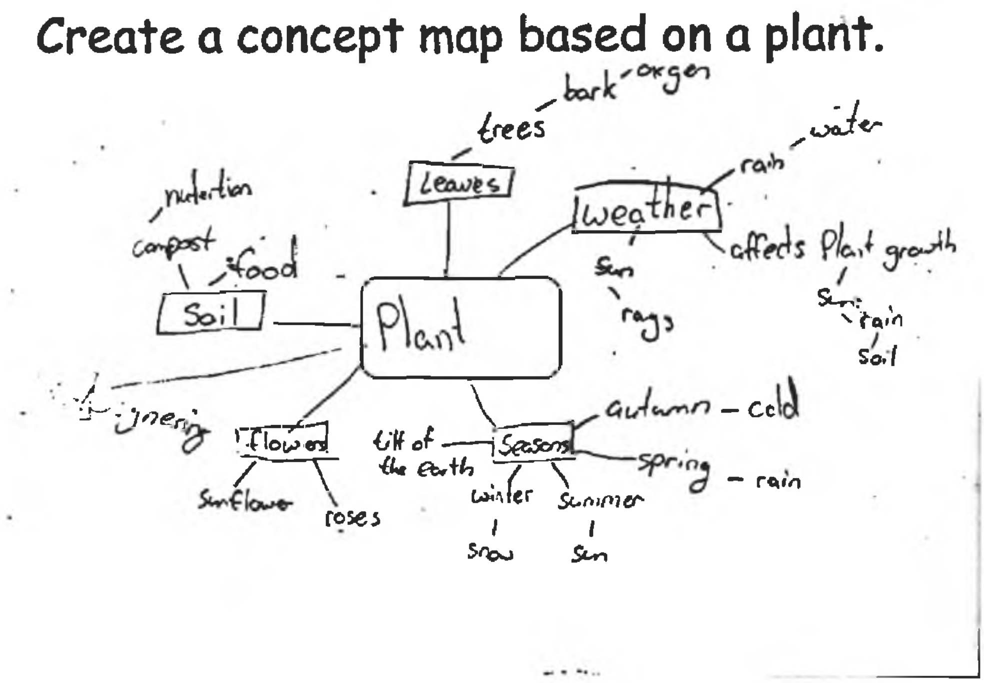


Figure 5.3 Free concept map of PLANTS for KP601

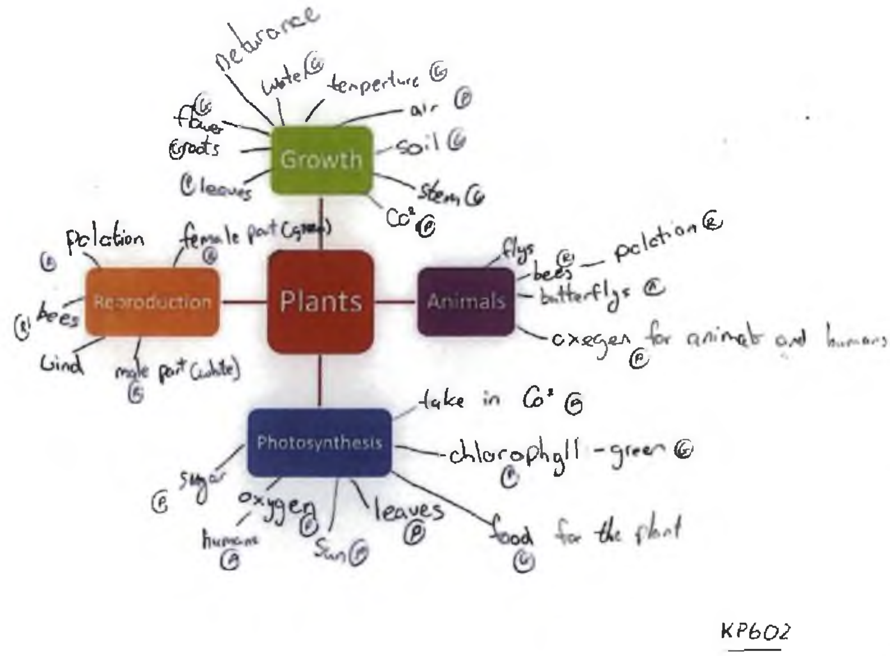


Figure 5.4 Closed concept map of PLANTS for KP602

GP601 (Figure 5.5) created a free concept map portraying a natural thought process in relation to PLANTS, conveying ideas surrounding the earth's landscape and issues that affect PLANTS on Earth such as deforestation and pollution. The many uses of PLANTS are conveyed in this concept map such as paper and wood. The link between PLANTS and ANIMALS is made in the form of a connection from medicine to living things, highlighting the human's need for PLANTS.

Although the four branches, ANIMALS, REPRODUCTION, GROWTH and PHOTOSYNTHESIS are present in each of the closed concept maps, GP602 (Figure 5.6) often links thoughts and ideas from the central concept PLANTS. Many connections are made between PHOTOSYNTHESIS and GROWTH however both REPRODUCTION and ANIMALS stand as individual concepts. A clear understanding of PLANTS and their link to ANIMALS is not yet prevalent. This map also draws in notions of global warming and planet Earth in space.

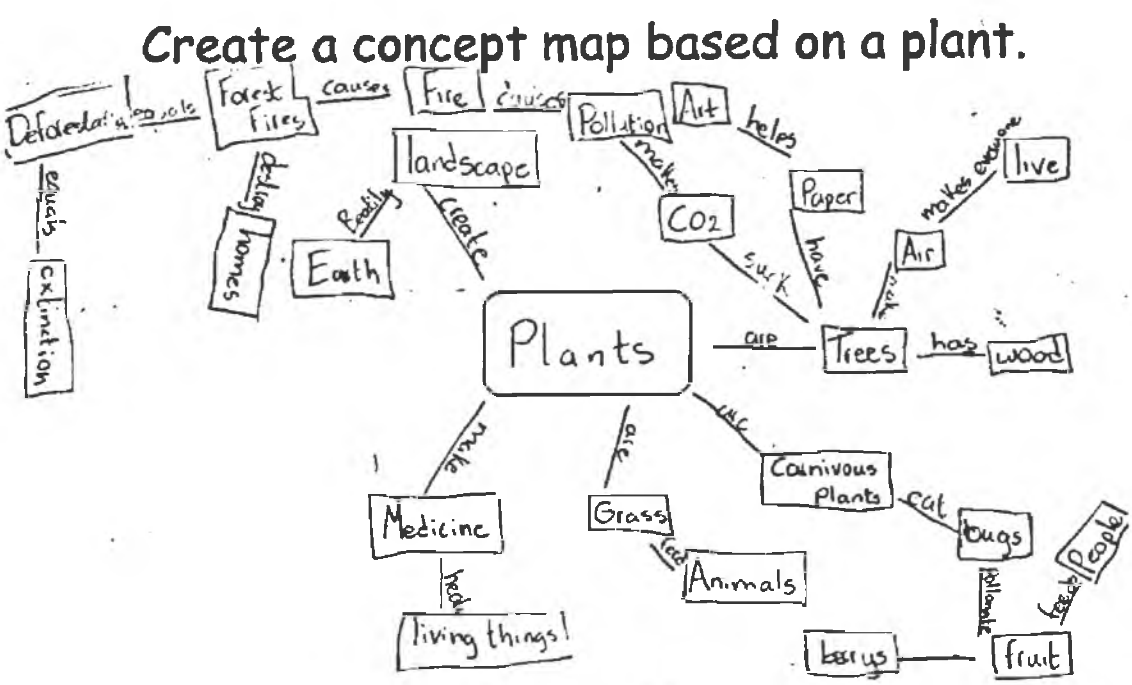


Figure 5.5 Free concept map of PLANTS for GP601

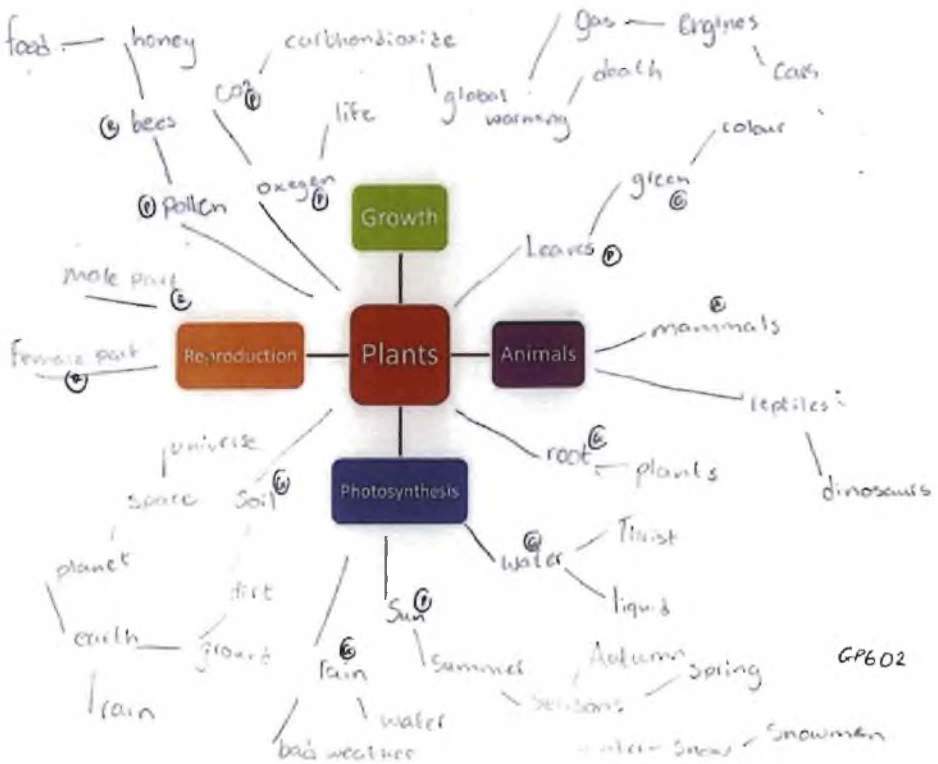


Figure 5.6 Closed concept map of PLANTS for GP602

Regarding RP601 (Figure 5.7), all four concepts are presented in this concept map. Links are made between GROWTH, REPRODUCTION and ANIMALS whereas PHOTOSYNTHESIS regularly stands as an individual group of branches stemming from the central concept PLANTS. Clear associations are made between REPRODUCTION and ANIMALS, linking pollen distribution to animals, highlight the concept reliance on each other. The dependence of ANIMALS on PLANTS for oxygen is also noted in this concept map.

In RP602 (Figure 5.8), all four concepts are represented however the thought process has moved from the relation of specific concepts to PLANTS into a broader relationship of each link. In this concept map, it is recognised that PHOTOSYNTHESIS enables a plant to make its own food and the necessary settings for this process to occur are stated. Links from both REPRODUCTION and GROWTH resemble ideas around the central concept however when the student attempts to create branches from the concept ANIMALS, an overflow of ideas is presented with little or no relation to the main concept PLANTS.

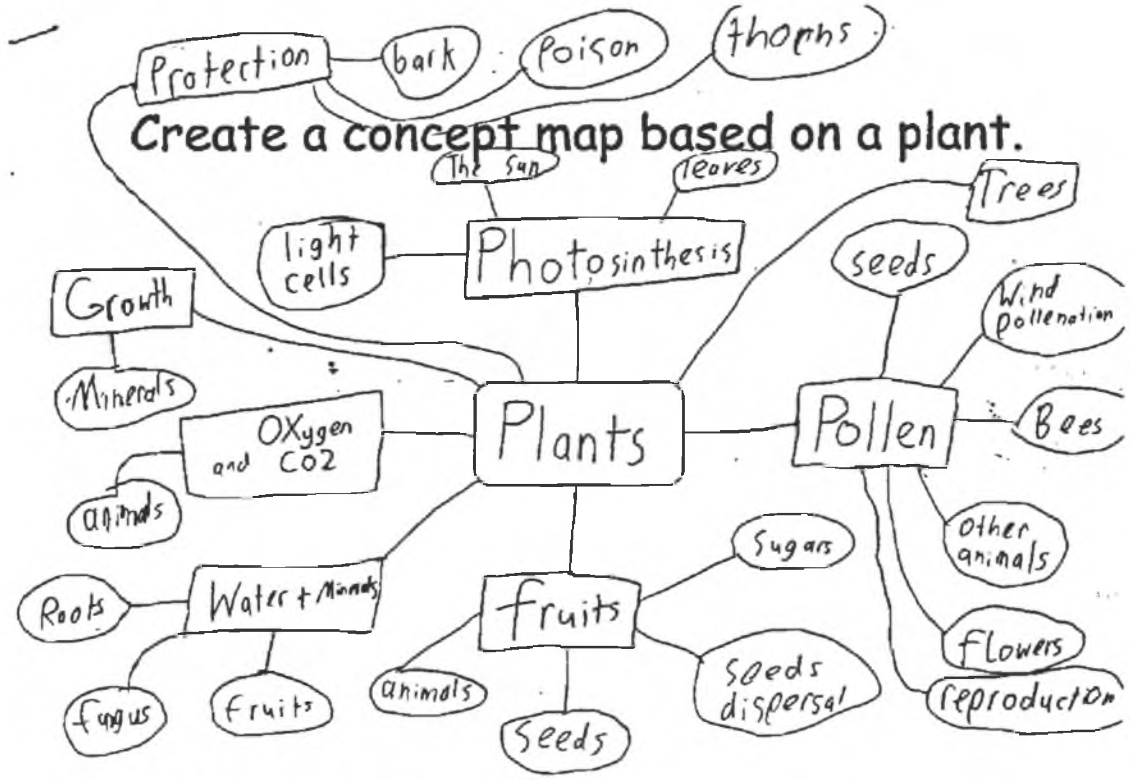


Figure 5.7 Free concept map of PLANTS for RP601

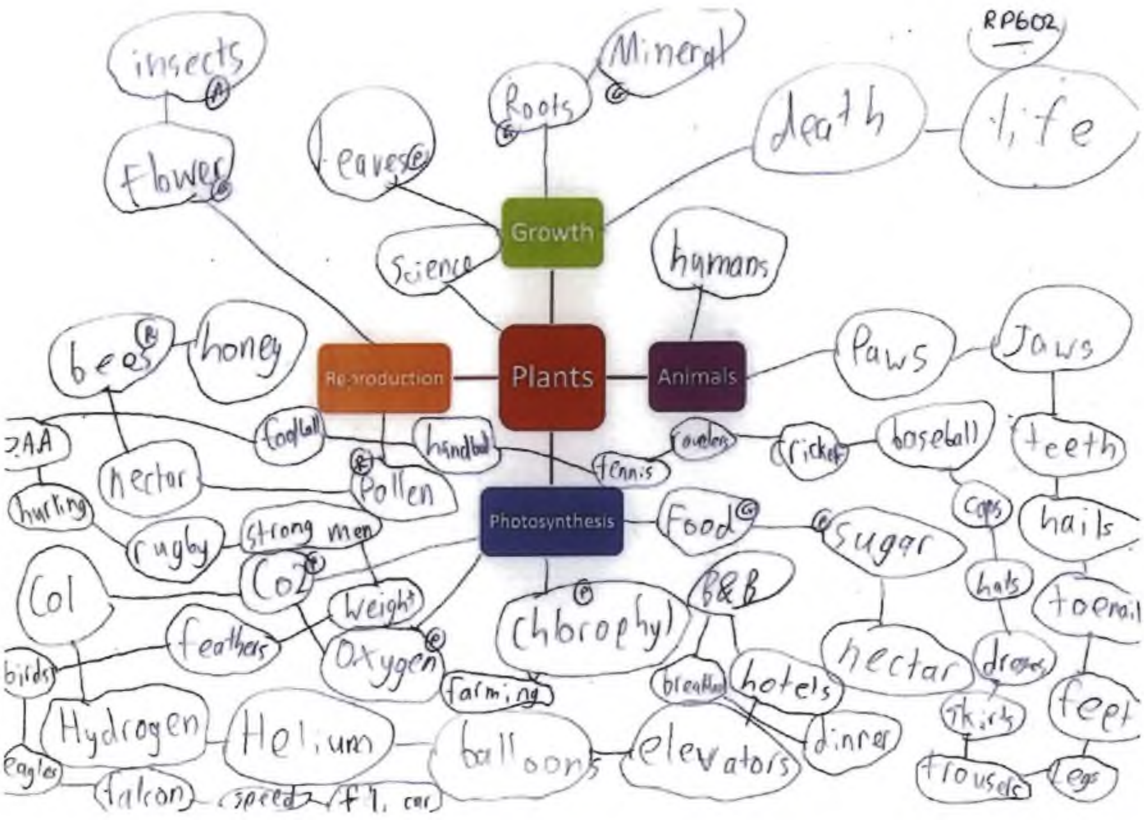


Figure 5.8 Closed concept map of PLANTS for RP602

Clear branches are formulated and present in TP601 (Figure 5.9). Similar to RP601 (Figure 5.7), all four concepts are presented in this concept map, highlighting distinctive connections between GROWTH and PHOTOSYNTHESIS and likewise, ANIMALS and REPRODUCTION. Bees contribute to reproduction and therefore a link is made between ANIMALS and REPRODUCTION in the form of pollen distribution. The need for PHOTOSYNTHESIS to occur in order for GROWTH in plants is recognised through the connection of flowers, sunlight and water and indeed the link between trees and leaves necessary for PHOTOSYNTHESIS in this concept map.

TP602 (Figure 5.10) displays a strong connection between the concepts GROWTH and PHOTOSYNTHESIS, presenting a detailed understanding of the conditions necessary for GROWTH and the process of PHOTOSYNTHESIS. Links exist between ANIMALS and

REPRODUCTION, which derive from the ANIMALS branch, however notions surrounding REPRODUCTION are plant based only and bear no relation to ANIMALS.

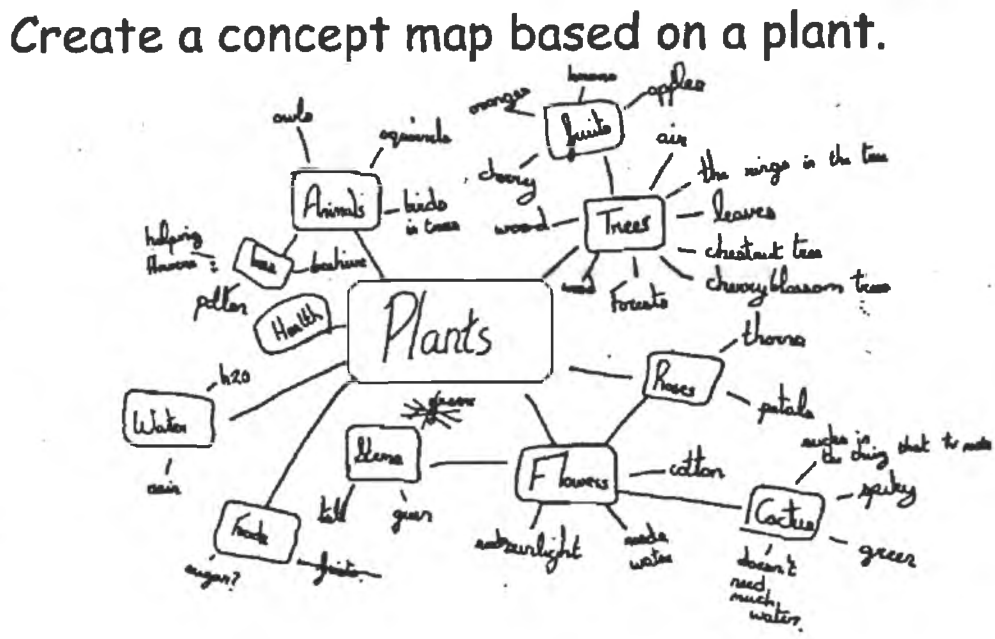


Figure 5.9 Free concept map of PLANTS for TP601

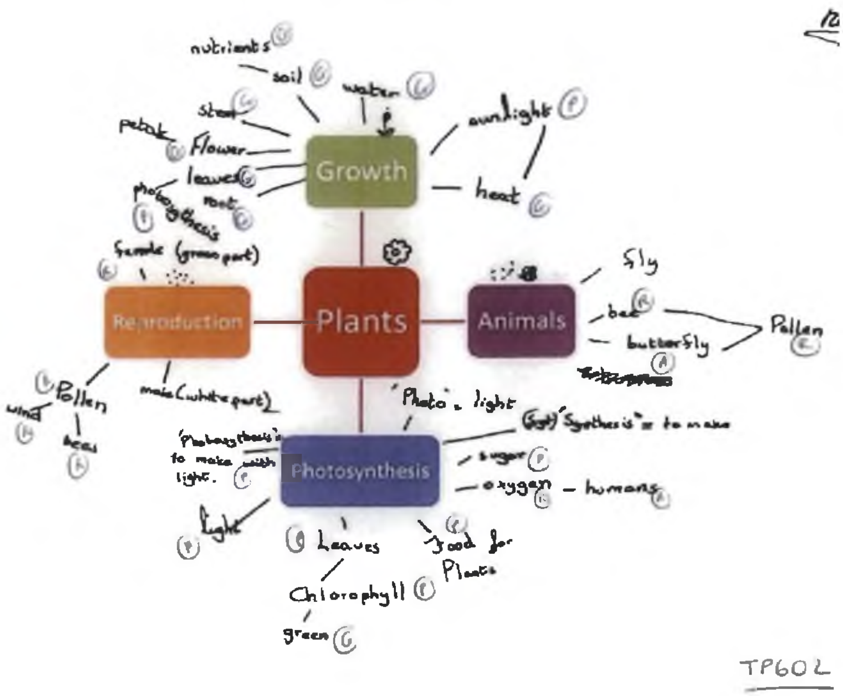


Figure 5.10 Closed concept map of PLANTS for TP602

In LP601 (Figure 5.11) all concepts stemmed from the core concept, PLANTS. Connections failed to be made between concepts creating a cluster form of concept map with the concepts PHOTOSYNTHESIS, GROWTH and REPRODUCTION mentioned briefly only. The concept ANIMALS and their connection with PLANTS was omitted from this pre-test concept map.

Similar to GP602 (Figure 5.6), the concept map LP602 (Figure 5.12) chooses to create links stretching from the principal concept idea PLANTS only. In this concept map, no connections are made between PLANTS and ANIMALS. The conditions necessary for GROWTH are present and associated with PLANTS. Bees and pollen are the only ideas mentioned linking to the concept REPRODUCTION.

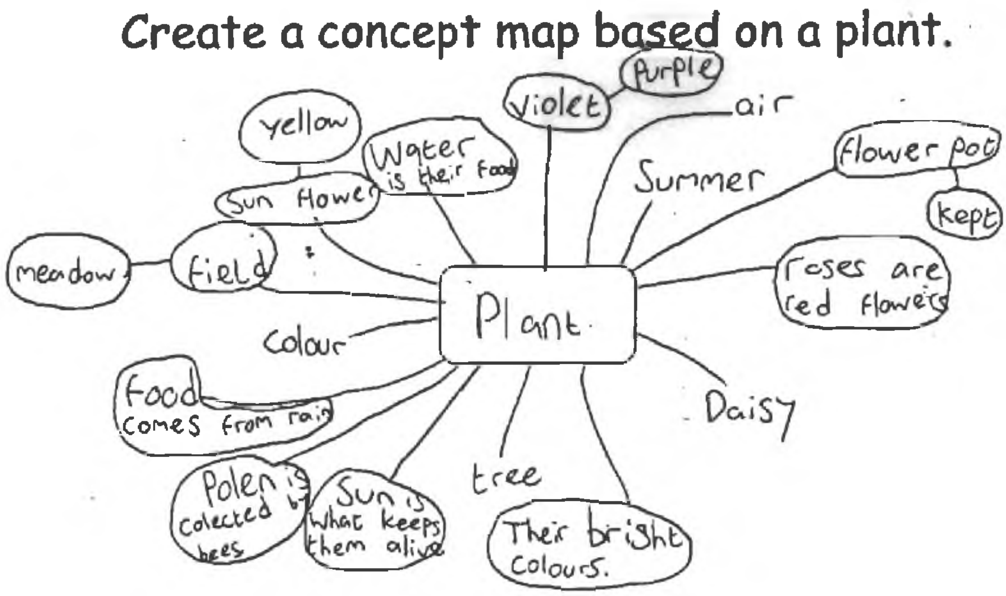


Figure 5.11 Free concept map of PLANTS for LP601

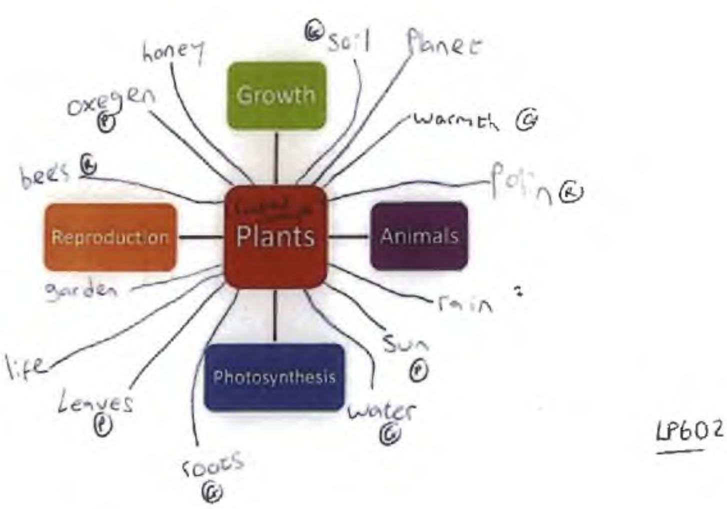


Figure 5.12 Closed concept map of PLANTS for LP602

ISP601 (Figure 5.13) demonstrates a clear understanding of the necessary rudiments for GROWTH and REPRODUCTION. The stem gives support and water to a plant system. Both aspects mentioned derive from the word flower on this concept map, which in turn is linked to REPRODUCTION in the form of pollen and bees. GROWTH and the processes necessary for PHOTOSYNTHESIS to occur are noted in the bond between trees and air, leaves and oxygen. In this concept map, the way in which PLANTS act as a form of shelter for ANIMALS is noted. ISP602 (Figure 5.14) offers a strong overlap of ideas between the concepts GROWTH and PHOTOSYNTHESIS, symbolising their need for each other. Bees are listed on this concept map as both an animal and an important part of plant REPRODUCTION.

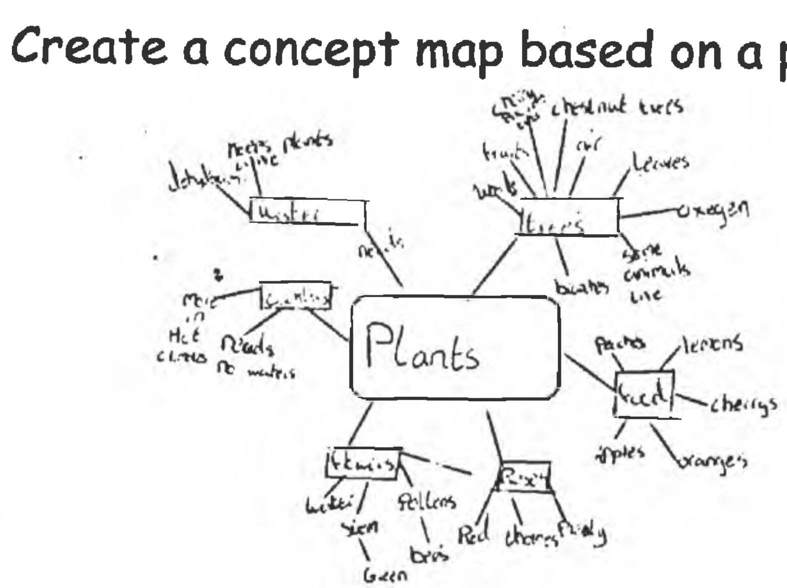


Figure 5.13 Free concept map of PLANTS for ISP601

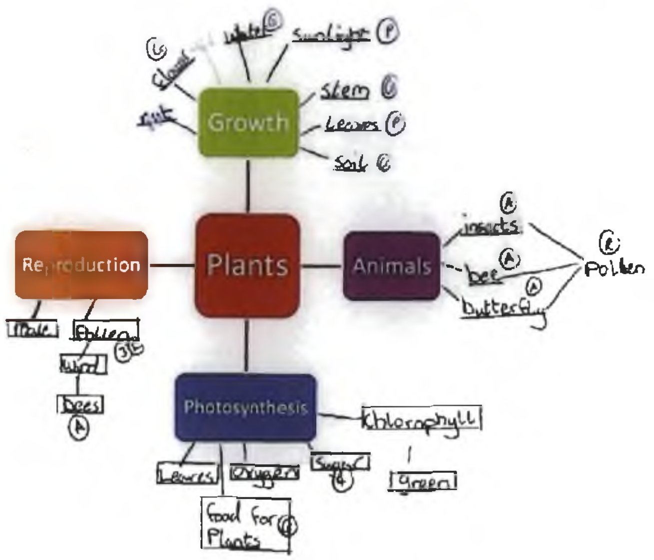


Figure 5.14 Closed concept map of PLANTS for ISP602

Plant REPRODUCTION is absent from the concept map KDP601 (Figure 5.15) however all other concepts feature briefly. The need for water, air and sun in order for GROWTH to occur is clearly stated in this concept map. GROWTH is linked with PHOTOSYNTHESIS and ANIMALS underlining the importance of PLANTS for ANIMALS in the form of food and edible fruits. The process of PHOTOSYNTHESIS is also noted to take in carbon dioxide and emit oxygen-enabling ANIMALS to breathe and survive.

KDP602 (Figure 5.16) presents a rich understanding of GROWTH, REPRODUCTION and PHOTOSYNTHESIS in PLANTS with many connections made between GROWTH and PHOTOSYNTHESIS. Although a thought process branching from ANIMALS is shown, the links made bare little or no relation to the central concept PLANTS.

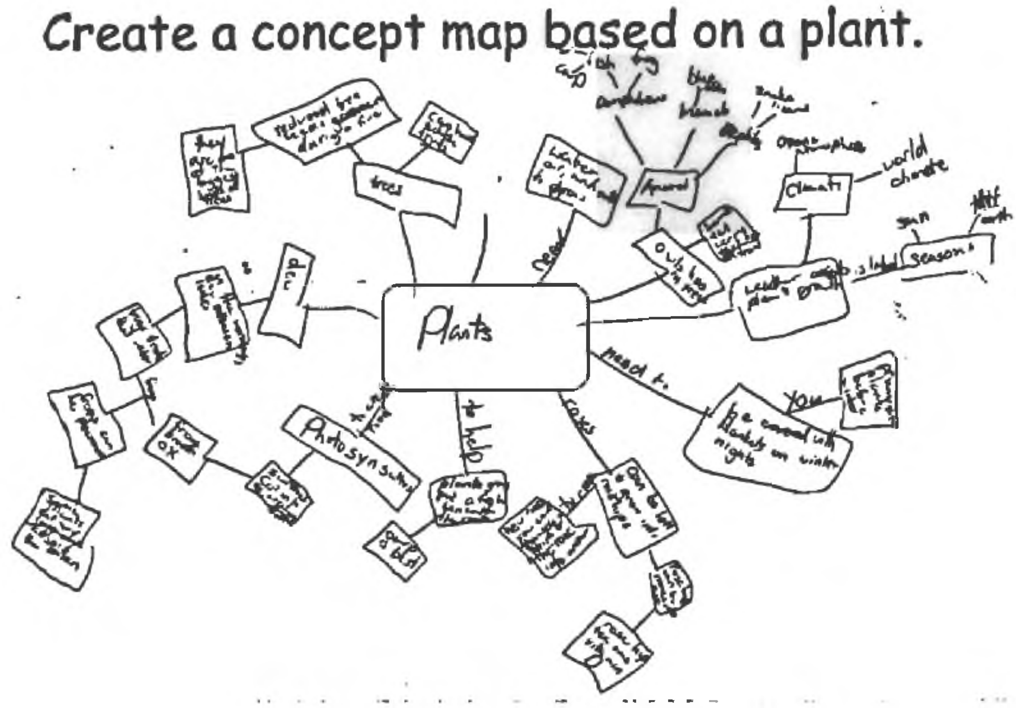


Figure 5.15 Free concept map of PLANTS for KDP601

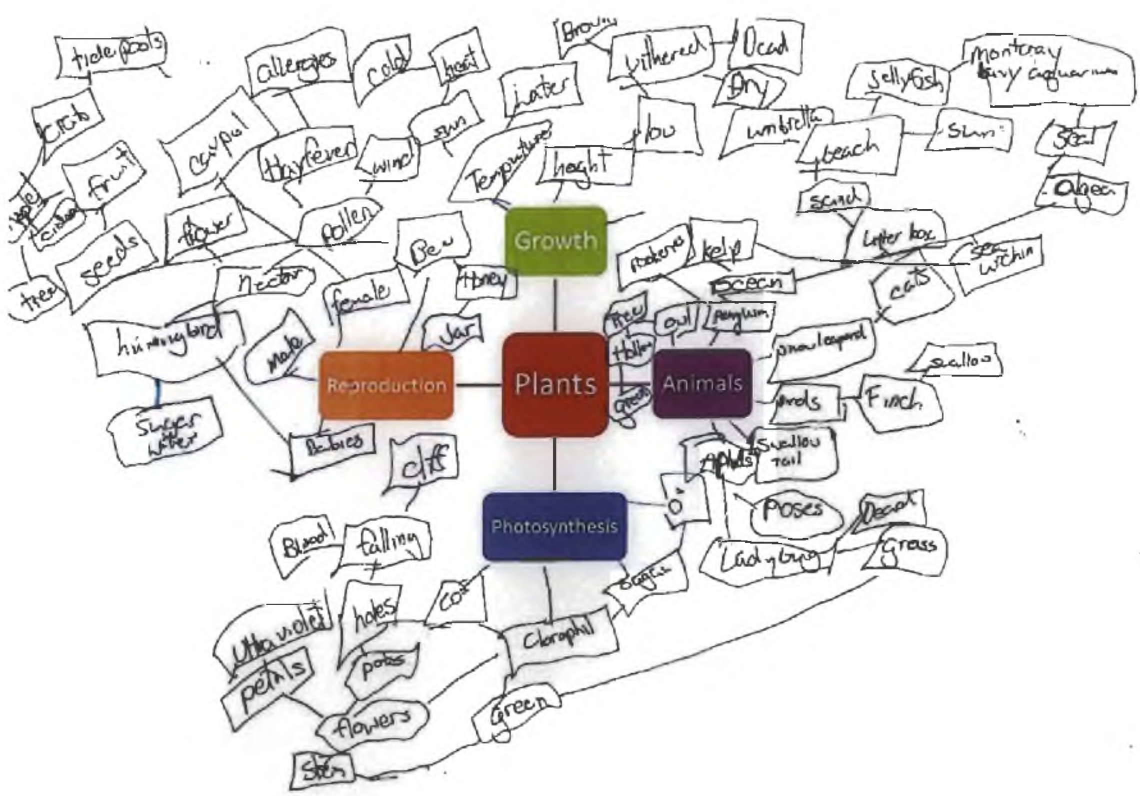


Figure 5.16 Closed concept map of PLANTS for KDP602

IP601 (Figure 5.17) exhibits all four concepts linking GROWTH from the central concept PLANTS to ANIMALS and REPRODUCTION. The notion of PHOTOSYNTHESIS however stands separate to the other concepts, linking only to the core concept PLANTS. The idea that PLANTS provide food for ANIMALS is prominent and the flower linking to bees shows an understanding of the way in which PLANTS reproduce.

In the concept map named IP602 (Figure 5.18), again rich links are made between the concepts PHOTOSYNTHESIS and GROWTH. An understanding of PLANTS ability to self-reproduce is shown declaring the female and male part of a flower, linking to REPRODUCTION. A connection is made between PLANTS and ANIMALS as the core idea is listed as a food source for ANIMALS.

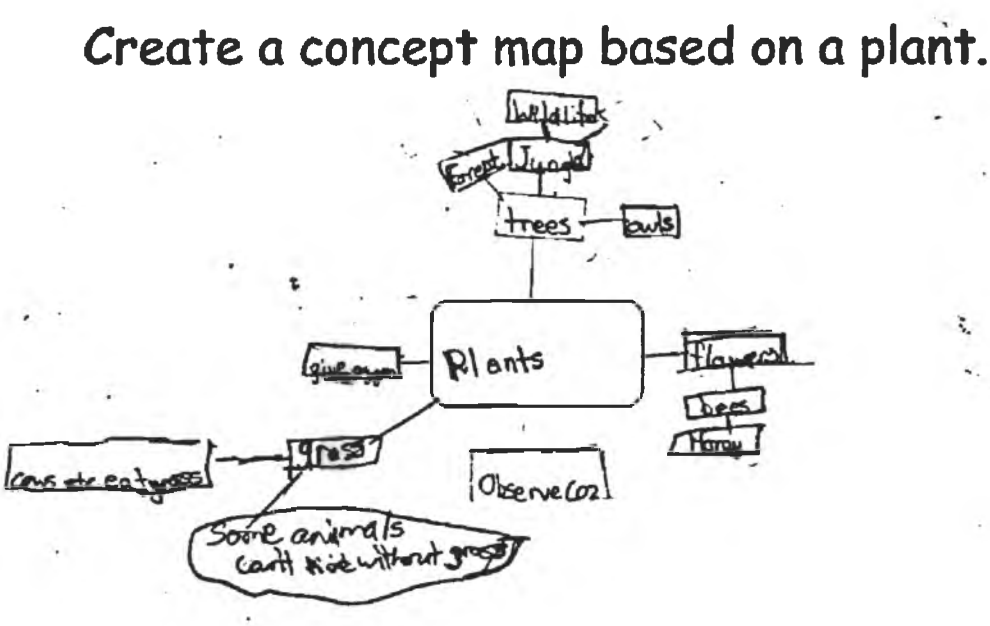


Figure 5.17 Free concept map of PLANTS for IP601

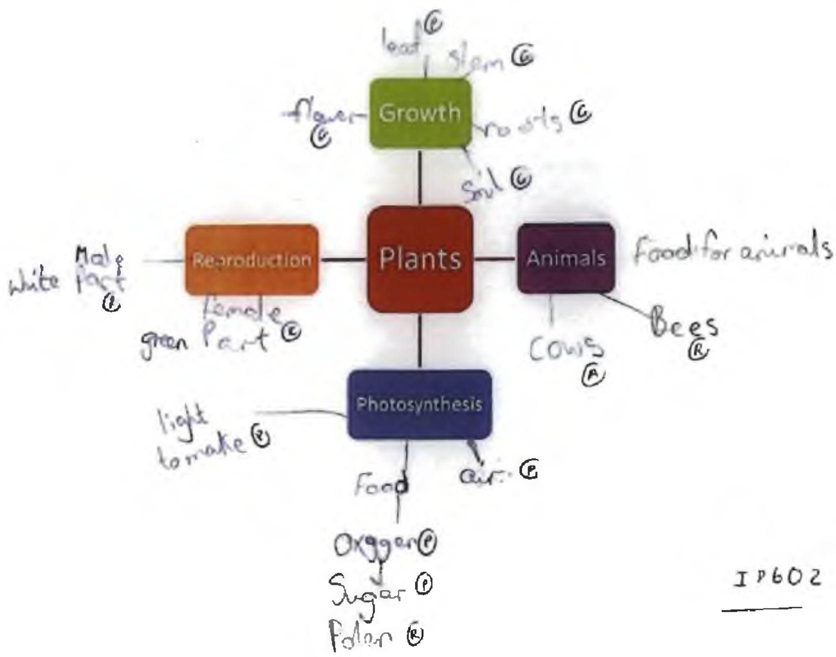


Figure 5.18 Closed concept map of PLANTS for IP602

Although GROWTH features strongly in the concept map produced for RAP601 (Figure 5.19), there is no reference to PHOTOSYNTHESIS showing an alternative conception of the way in which plants grow. A need for PLANTS to act as housing and food for ANIMALS is declared. The creation of pollen by PLANTS that in turn is collected and distributed by bees is also cited in this concept map while the various locations and kinds of plants are briefly mentioned also.

Branching from PHOTOSYNTHESIS, RAP602 (Figure 5.20) links exist for GROWTH, ANIMALS as well as PHOTOSYNTHESIS itself. Wind pollination, insect pollination and self-pollination are presented in this concept map as forms of REPRODUCTION. The support systems of a plant are clearly recognised through the ideas roots and stems and the conditions necessary for GROWTH are also visibly stated. Although the idea of ANIMALS is linked to REPRODUCTION, REPRODUCTION is indicated to stand separate on the opposite side of the closed concept map.

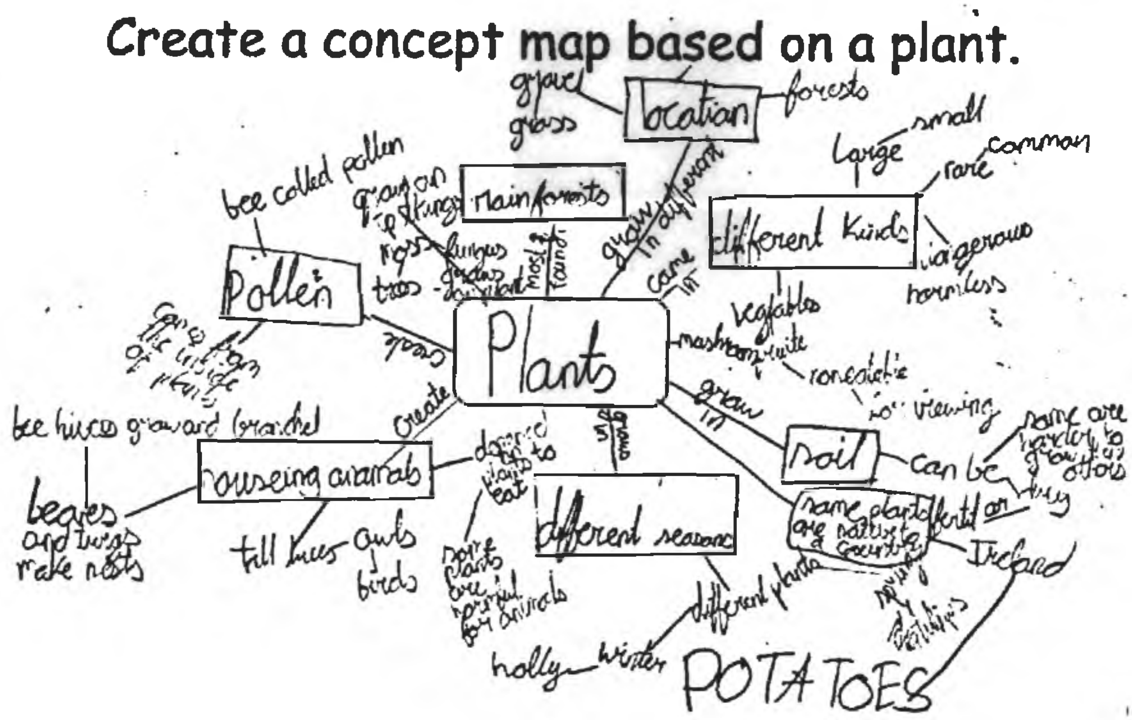


Figure 5.19 Free concept map of PLANTS for RAP601

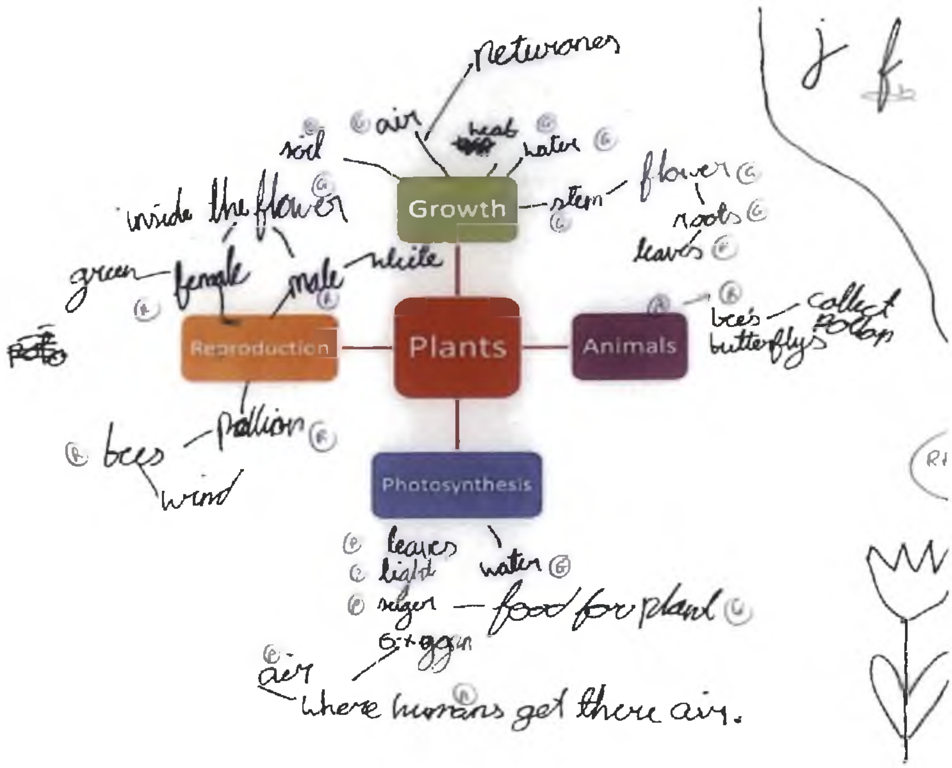


Figure 5.20 Closed concept map of PLANTS for RAP602

In EP601 (Figure 5.21), the concept map displays a thought process moving from the core concept PLANTS ranging to areas such as natural disasters and climate change. REPRODUCTION has not been included in this concept map however the process of PHOTOSYNTHESIS emitting oxygen has been linked to ANIMALS. GROWTH has also been associated twice with ANIMALS in the form of food. The absorption of carbon dioxide is mentioned on this concept map and therefore PHOTOSYNTHESIS is connected as a process in order for GROWTH to occur.

EP602 (Figure 5.22) is concerned with notions relating to life outside of the central idea PLANTS itself. The laws of gravity, the brain and nerve cells and the idea of science being linked to smartphones and the Internet is presented in this concept map. PHOTOSYNTHESIS is recognised as an essential relation to ANIMALS as oxygen is linked to life, animals and in turn human beings. Again, the features of GROWTH are present in this concept map with an understanding of REPRODUCTION in a plant.

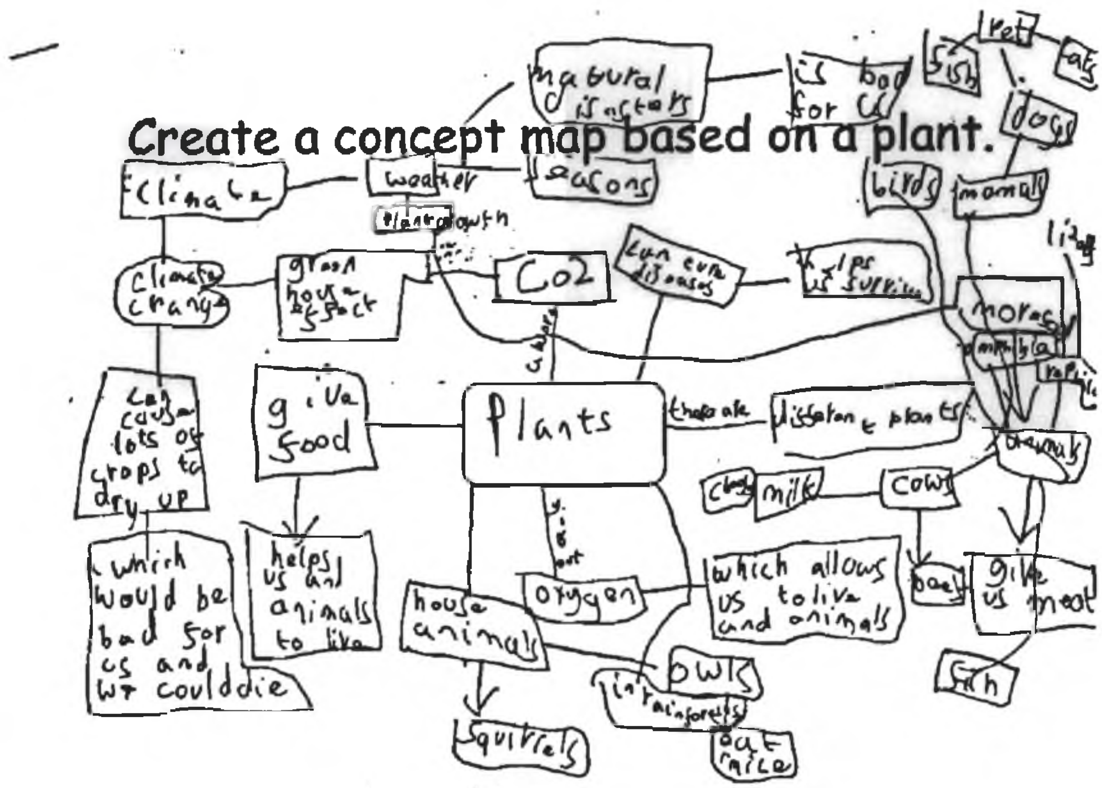


Figure 5.21 Free concept map of PLANTS for EP601

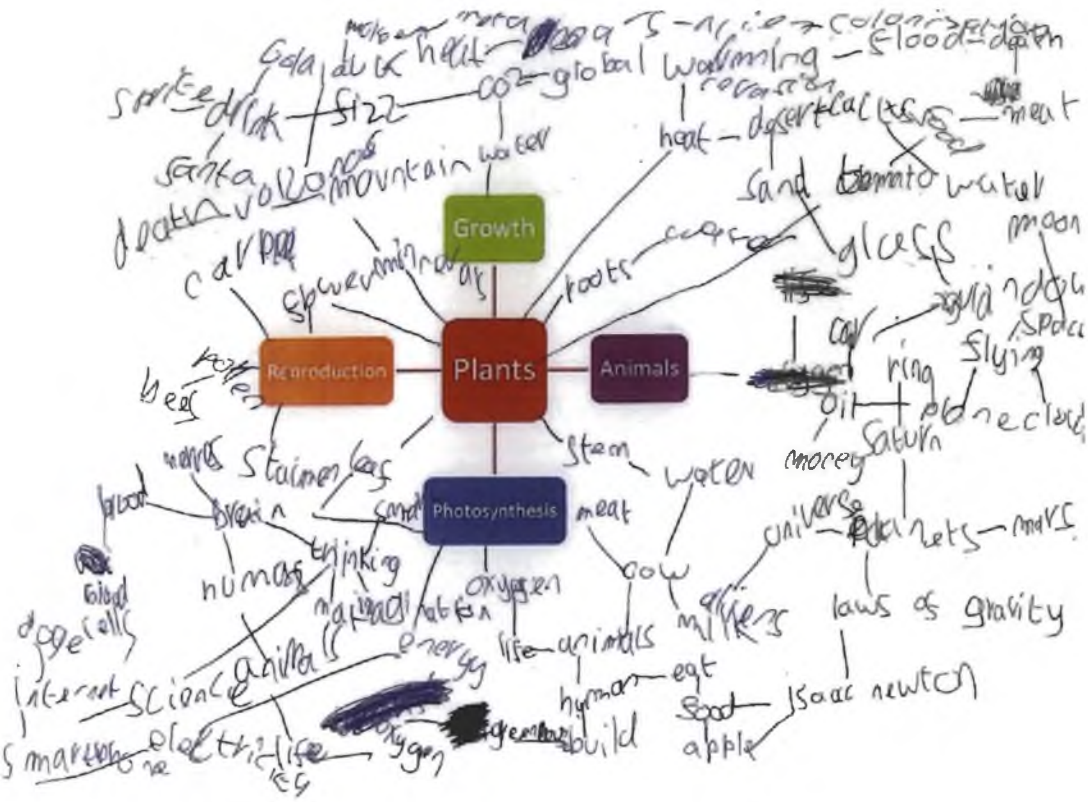


Figure 5.22 Closed concept map of PLANTS for EP602

Concerning the concept map NP601 (Figure 5.23), the process of PHOTOSYNTHESIS features strongly with reference to the way in which carbon dioxide is taken in and oxygen is released and how plants get their minerals from the soil. The fear of reduction to oxygen production is recognised through the link to rainforest and deforestation. REPRODUCTION is also presented in the form of pollination and bees. The final concept, ANIMALS, does not feature in this pre-test concept map.

The link between PHOTOSYNTHESIS, the production of oxygen, and survival for humans is recognised in the concept map produced by NP602 (Figure 5.24). PHOTOSYNTHESIS and GROWTH are clearly associated while REPRODUCTION and ANIMALS stand as separate concepts, failing to be connected to any other concept.

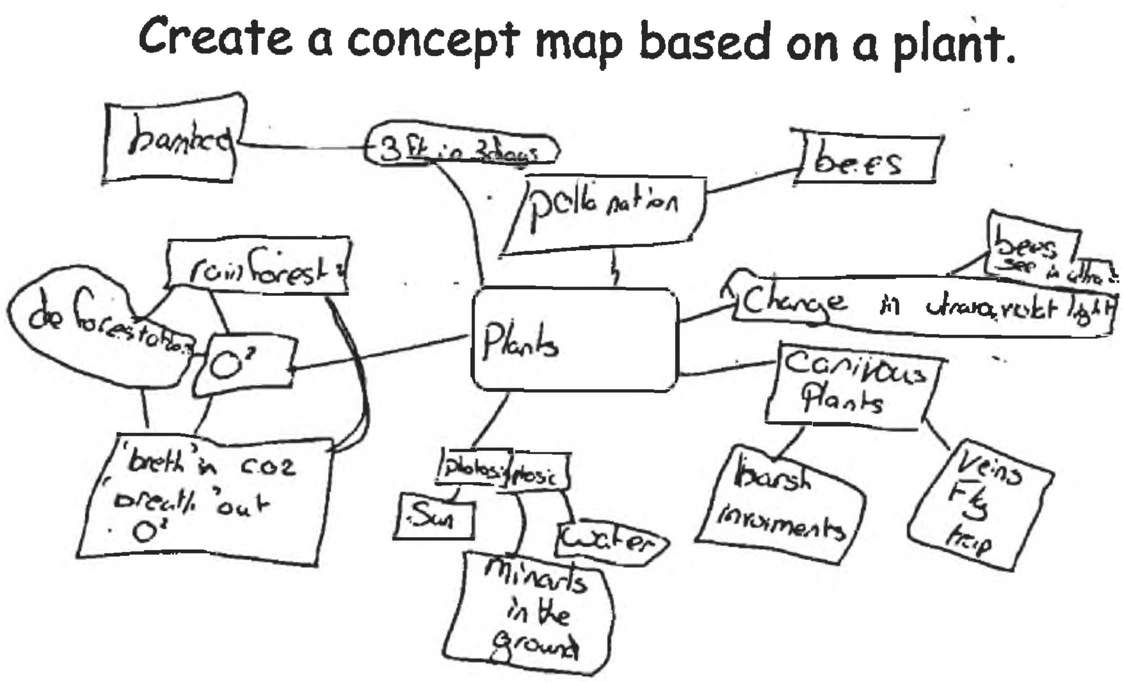


Figure 5.23 Free concept map of PLANTS for NP601

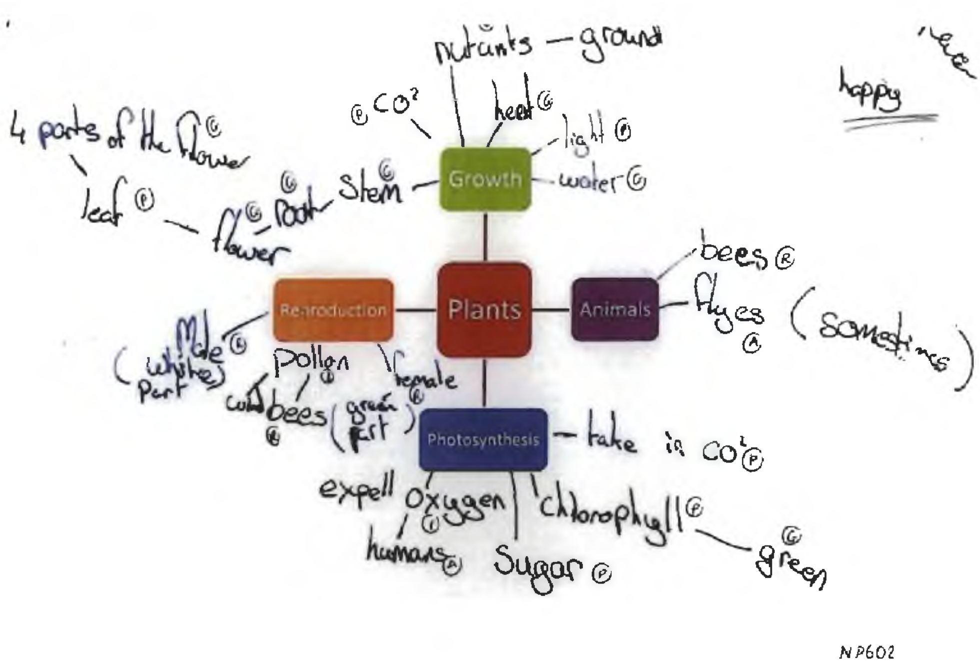


Figure 5.24 Closed concept map of PLANTS for NP602

CP601 (Figure 5.25) excludes the concept ANIMALS from the concept map. GROWTH and REPRODUCTION are closely linked while flowers and stem are placed on the same main branch as bees and pollen. The process of carbon dioxide been taken in and converted to oxygen has been linked to the main platform trees, linking PHOTOSYNTHESIS to ideas of GROWTH. PLANTS act as a source of food for ANIMALS and this is emphasised on the concept map.

In contrast to NP602 (Figure 5.24), CP602 (Figure 5.26) associates ANIMALS with REPRODUCTION highlighting an animal's ability to take part in the plant REPRODUCTION process. In this concept map, the meaning of PHOTOSYNTHESIS is showcased; however the notion of a plant making its own food is not yet discussed. PHOTOSYNTHESIS and GROWTH are again linked displaying their inter-dependent nature.

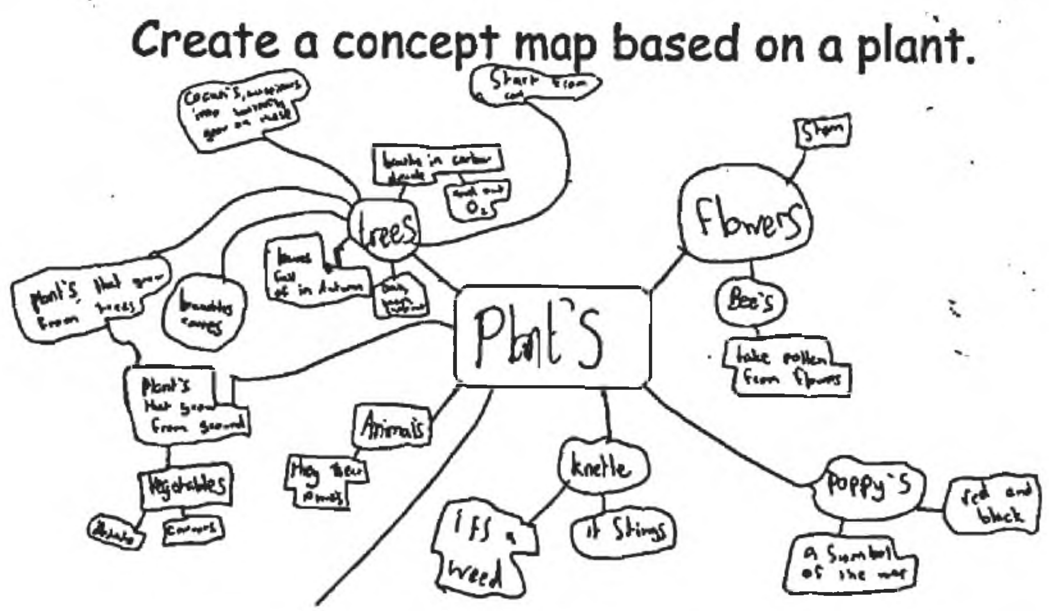


Figure 5.25 Free concept map of PLANTS for CP601

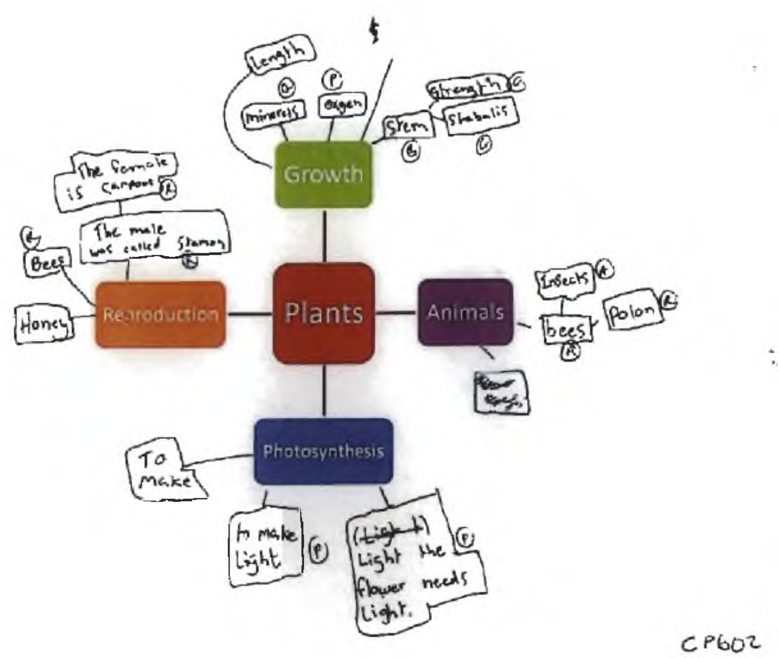


Figure 5.26 Closed concept map of PLANTS for CP602

AP601 (Figure 5.27) provides a very clear linkage between the primary concept PLANTS and GROWTH naming stem, buds, chlorophyll and tree all branching from the central concept. On this concept map, PHOTOSYNTHESIS is stated however the factors that are necessary for the process to occur are not present. There is no mention of plants and their relationship with ANIMALS.

AP602 (Figure 5.28) extends ideas from each of the four conceptual branches provided. Associations are often made between the concepts GROWTH, PHOTOSYNTHESIS and ANIMALS. Knowledge is displayed of a plant making its own food and in turn providing humans with food. REPRODUCTION includes an idea of the reliance on bees to pollinate however a flower's ability to self-reproduce is not recognised.

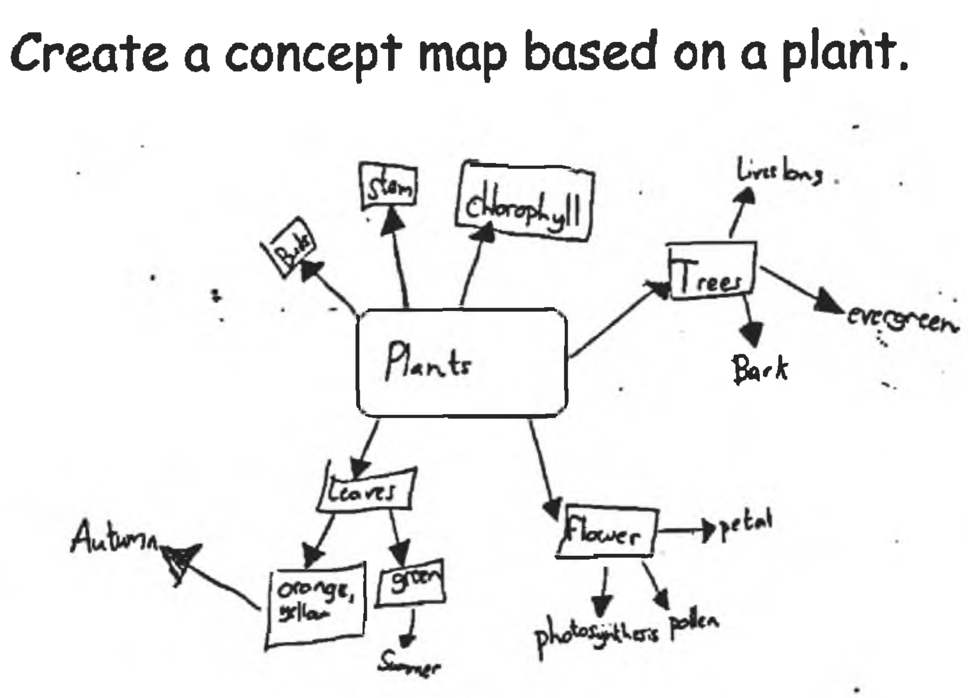


Figure 5.27 Free concept map of PLANTS for AP601

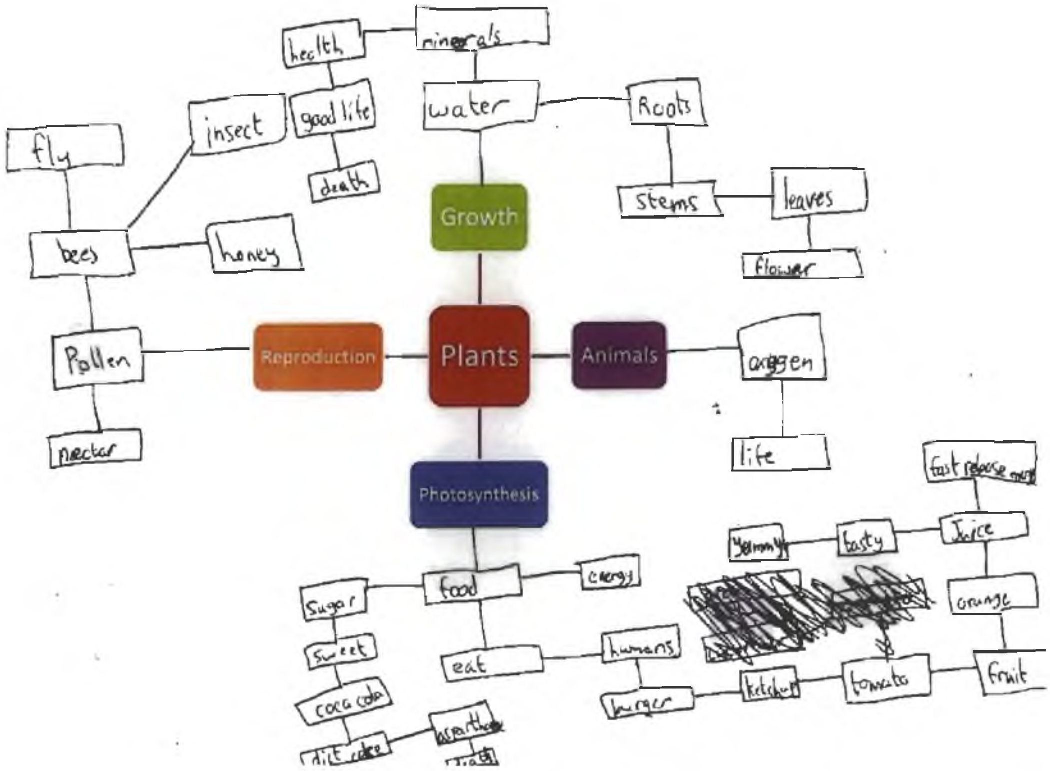


Figure 5.28 Closed concept map of PLANTS for AP602

Various types of flowers and insects exist in the concept map SOHP601 (Figure 5.29) however few links were made throughout concepts. Links occur between GROWTH and PHOTOSYNTHESIS as warmth and sun, and trees and oxygen are mentioned. Bees are also presented in relation to flowers, GROWTH and PLANTS.

SOHP602 (Figure 5.30) acknowledges the way in which some ANIMALS and insects feed off PLANTS, while also linking the concept ANIMALS to REPRODUCTION and pollination. GROWTH and PHOTOSYNTHESIS are once again inter-linked, exhibiting an understanding of the way in which a plant makes its food. REPRODUCTION expresses knowledge of pollination and is also linked to GROWTH through the production of more plants.

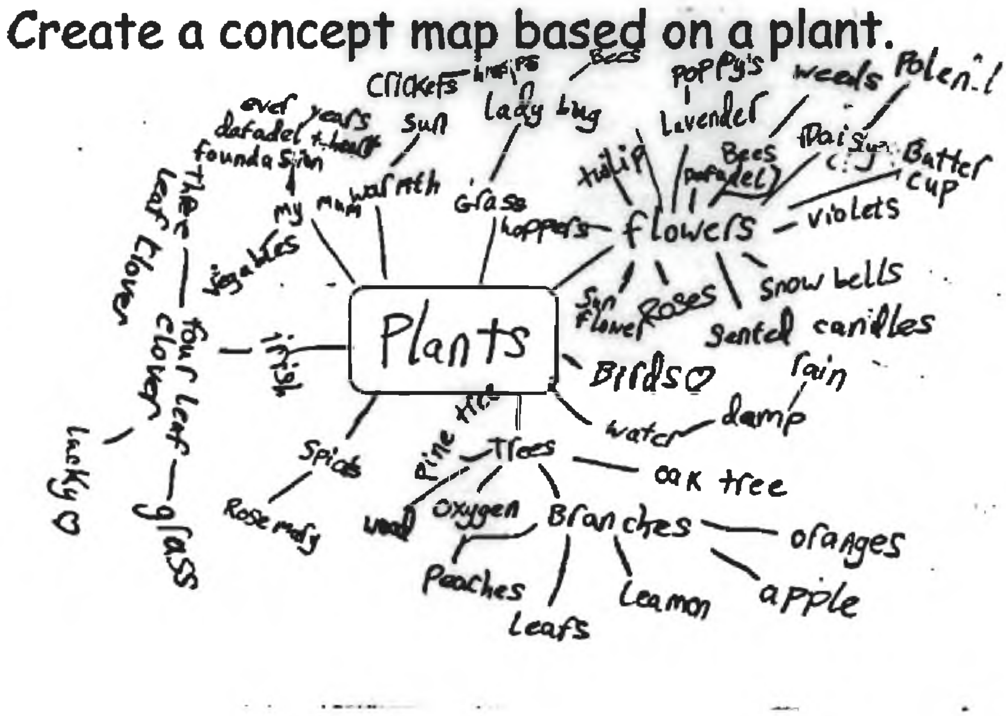


Figure 5.29 Free concept map of PLANTS for SOHP601

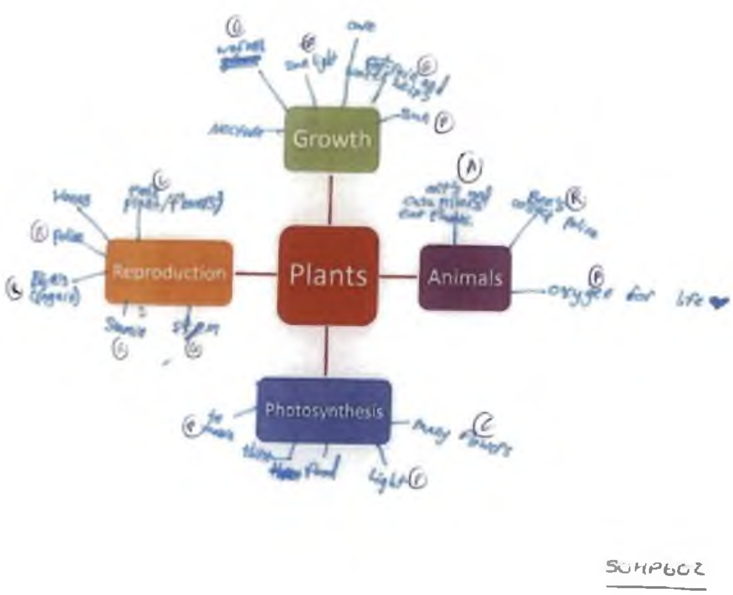


Figure 5.30 Closed concept map of PLANTS for SOHP602

A clear concept map of all four concepts is presented in SAP601 (Figure 5.31) whereby strong links are made GROWTH and each of other concepts, ANIMALS, REPRODUCTION and PHOTOSYNTHESIS. The process of making food is expressed in the link between trees and the mention of oxygen and carbon dioxide and leaves. The need for the sun for this process to occur is also recognised. In this concept map, trees are shown to provide shelter for ANIMALS and PLANTS also act as a food source. Similarly to several concepts map present in the results, the progression of thought and connection of GROWTH and REPRODUCTION follows the link flowers, pollen and bees.

Only one link between ANIMALS and PHOTOSYNTHESIS is made on this concept map, SAP602 (Figure 5.32), connecting animals in the form of oxygen need for survival. Concepts have little relationships created between each other and only the basic ideas surrounding GROWTH and PHOTOSYNTHESIS are expressed on this concept map. REPRODUCTION reveals an understanding of self -pollination through the male and female reproductive organs in the flower and pollination through the aid of bees.

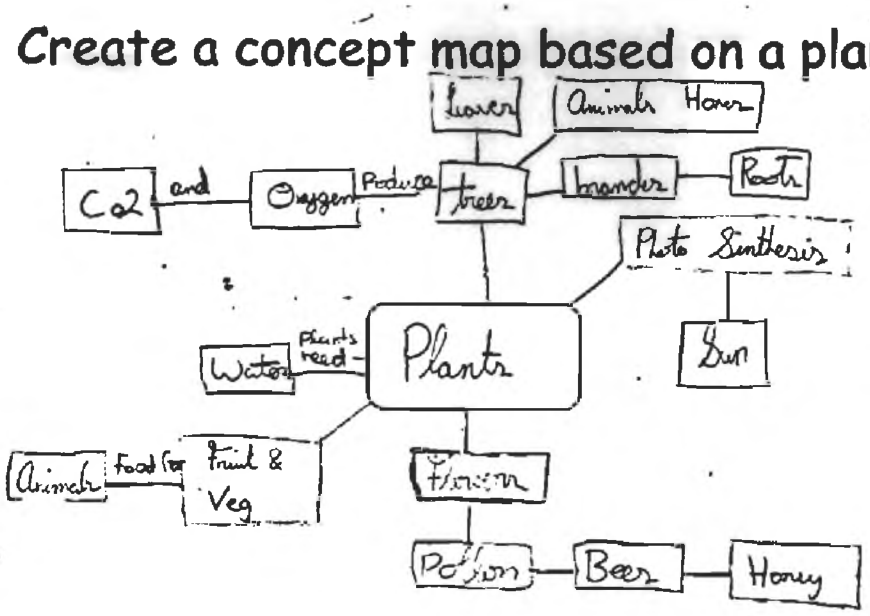


Figure 5.31 Free concept map of PLANTS for SAP601

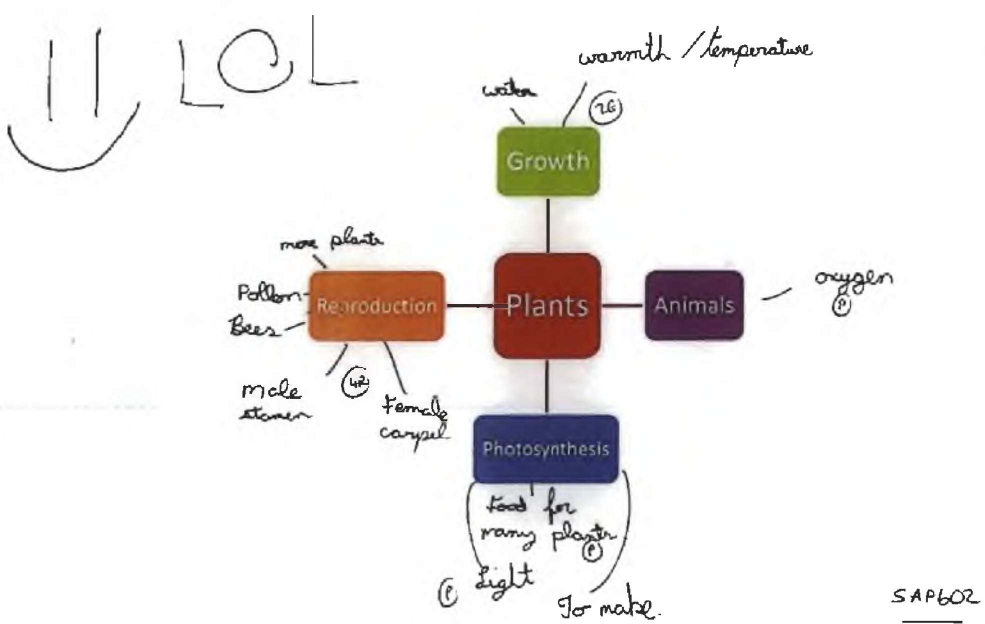


Figure 5.32 Closed concept map of PLANTS for SAP602

EP6201 (Figure 5.33) demonstrates a visual concept map, using images of each of the ideas presented. All four concepts are represented in this pictorial, the sun, rain, leaves and roots are seen to link directly to the main concept PLANTS, connecting both GROWTH and PHOTOSYNTHESIS to this principal concept. Although not directly linked in the image, REPRODUCTION and ANIMALS are clearly seen to stand closely on the concept map, the tree bares both fruit and provides shelter for ANIMALS.

EP6202 (Figure 5.34) identifies the need for water and sunlight in order for GROWTH to occur. Leaves are recognised as taking in sunlight, which is linked through the use of an arrow to PHOTOSYNTHESIS also. Although the female and male organs of a flower are mentioned in this concept map, alternative conceptions lie in how plant REPRODUCTION occurs. PLANTS as a food source for ANIMALS are recognised in this concept map.

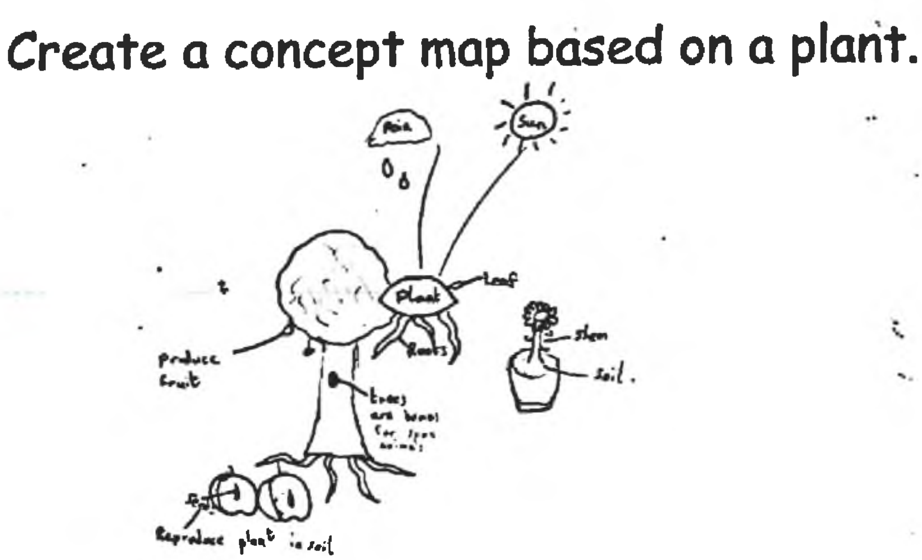


Figure 5.33 Free concept map of PLANTS for EP6201

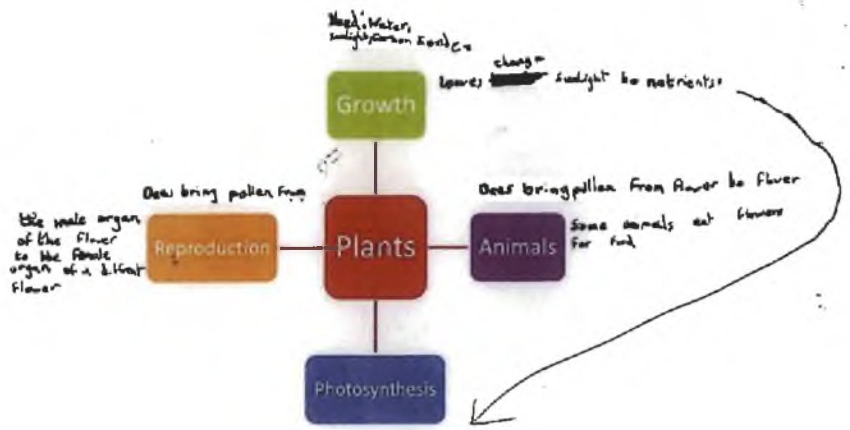


Figure 5.34 Closed concept map of PLANTS for EP6202

In a concept map by PP6201 (Figure 5.35) REPRODUCTION of plants is omitted and the process of PHOTOSYNTHESIS is featured most prevalently. The essentials for GROWTH and PHOTOSYNTHESIS are recognised in the presentation of sun and water and the realisation that PLANTS provide food for humans and animals is evident.

In PP6202 (Figure 5.36), although REPRODUCTION is linked to the concept ANIMALS in the form of bee pollination, there are no connections made to the REPRODUCTION branch itself. Again, like EP6202, the environmental conditions necessary for GROWTH are recognised and links exist between GROWTH and PHOTOSYNTHESIS.

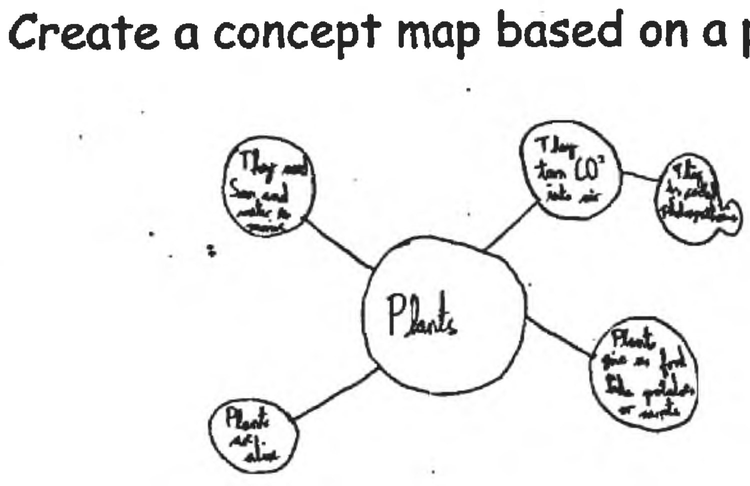


Figure 5.35 Free concept map of PLANTS for PP6201

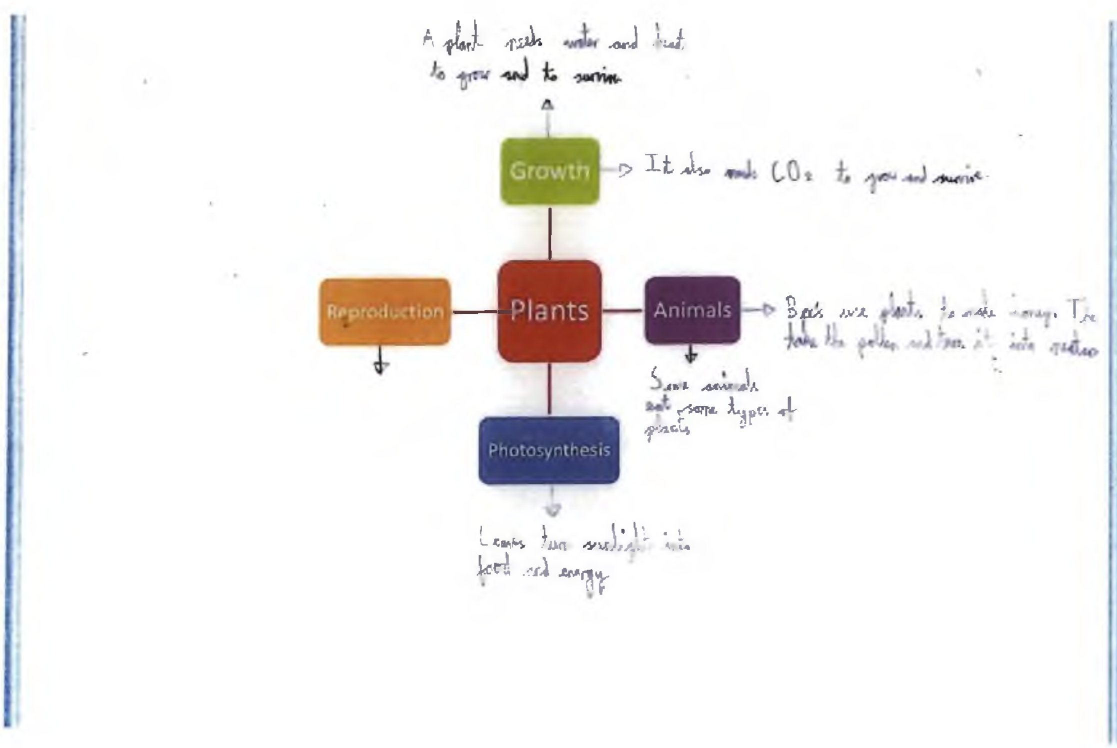


Figure 5.36 Closed concept map of PLANTS for PP6202

ABP6201 (Figure 5.37) ignores any relationship PLANTS may have with ANIMALS, however the need for sun and water are interlinked, connecting GROWTH and PHOTOSYNTHESIS. Plants baring fruit is also revealed in this concept map, highlighting the aspect of REPRODUCTION. In ABP6202 (Figure 5.38) GROWTH and PHOTOSYNTHESIS are inextricably linked. The reproductive parts of a flower are listed in REPRODUCTION and bee's pollination is linked to ANIMALS in this concept map.

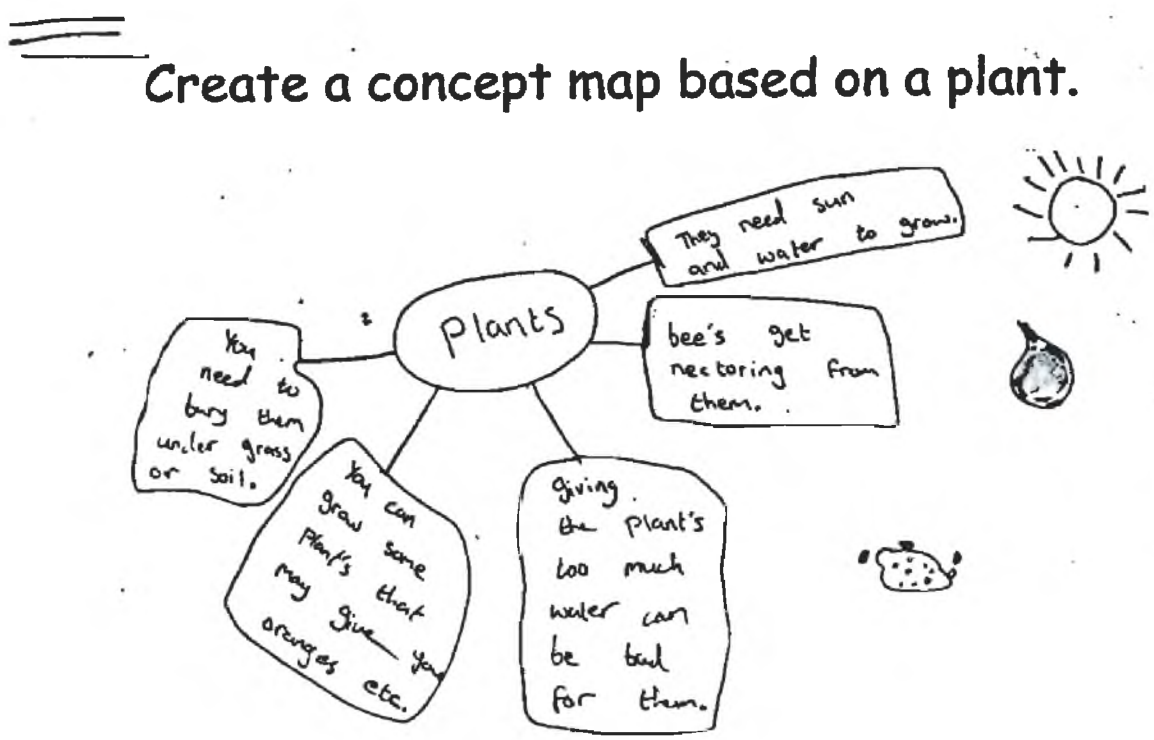


Figure 5.37 Free concept map of PLANTS for ABP6201

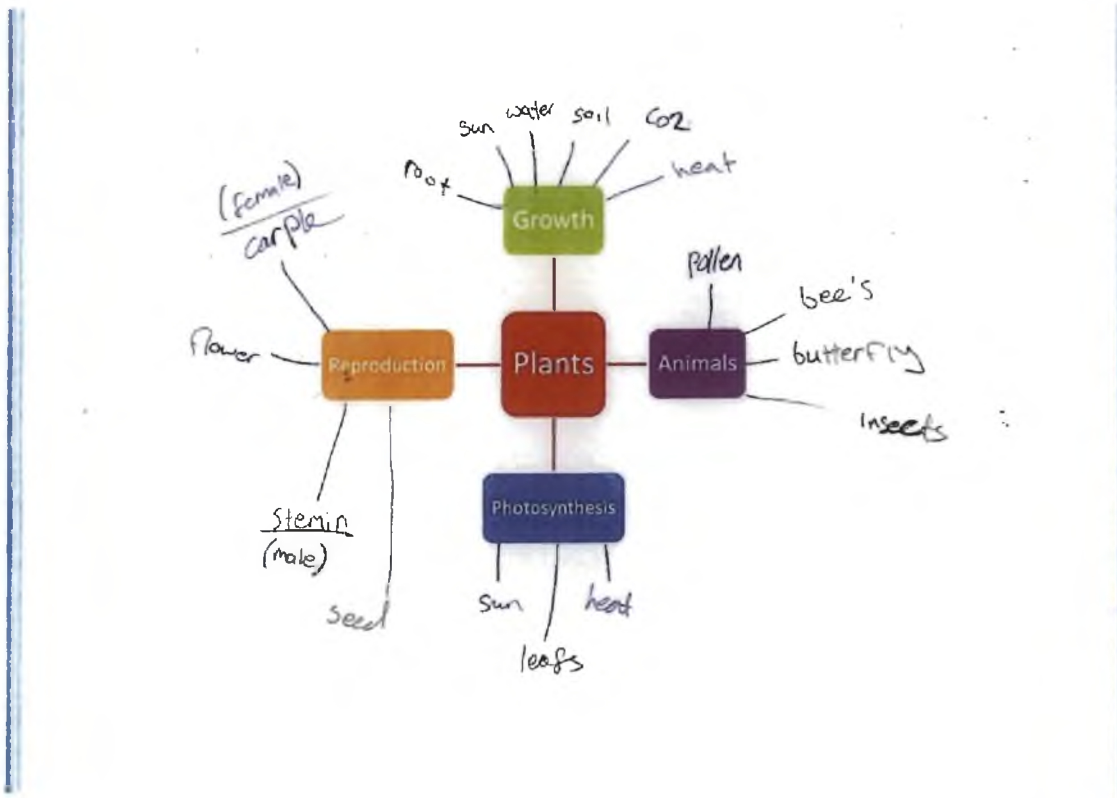


Figure 5.38 Closed concept map of PLANTS for ABP6202

The conditions necessary for GROWTH are presented in this concept map named LP6201 (Figure 5.39), water, sun and minerals from the soil. Although PHOTOSYNTHESIS is touched on, there is no indication that this process is understood as necessary to make a plants food. The concepts ANIMALS and REPRODUCTION are omitted from this concept map. LP202 (Figure 5.40) exhibits strong associations between GROWTH and PHOTOSYNTHESIS however these links are all clearly placed surrounding the GROWTH branch itself. PLANTS are seen as a food source for ANIMALS on this concept map, and there is no definite point mentioned for REPRODUCTION.

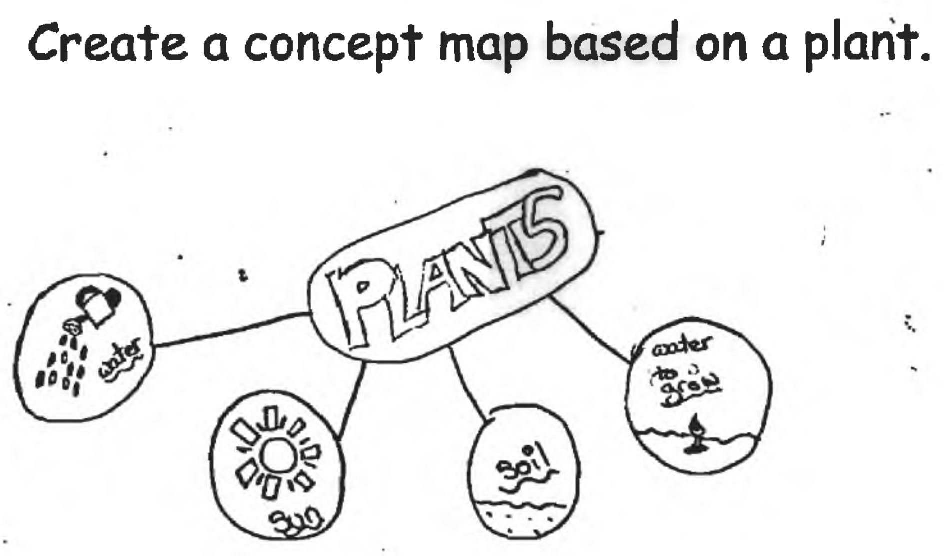


Figure 5.39 Free concept map of PLANTS for LP6201

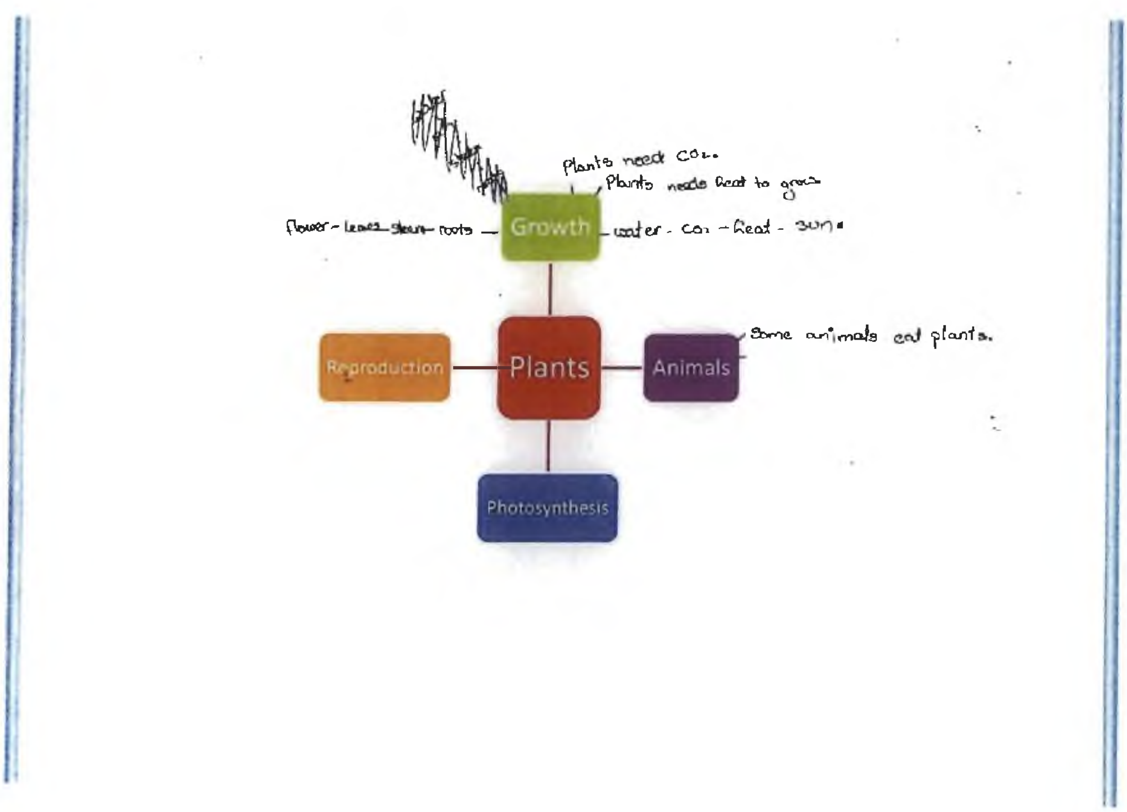


Figure 5.40 Closed concept map of PLANTS for LP6202

HP6201 (Figure 5.41) presents connections from the core concept PLANTS only. There are no links between concepts and GROWTH and PHOTOSYNTHESIS are the most commonly featured concepts. A clear understanding of the conditions necessary for GROWTH are displayed, however the way in which a plant makes its food is not detailed. Seeds are the only reference to REPRODUCTION in this concept map and ANIMALS failed to be connected to the original concept.

GROWTH, REPRODUCTION and PHOTOSYNTHESIS are intricately connected in HP6202 (Figure 5.42) whereby the reproductive parts of a flower continue to be linked to a stem which act as support for GROWTH and leaves which aid in PHOTOSYNTHESIS. The association with GROWTH and PHOTOSYNTHESIS is also clearly stated in the need for this process to occur in order for GROWTH to occur. REPRODUCTION and ANIMALS are undoubtedly link through bee pollination also.

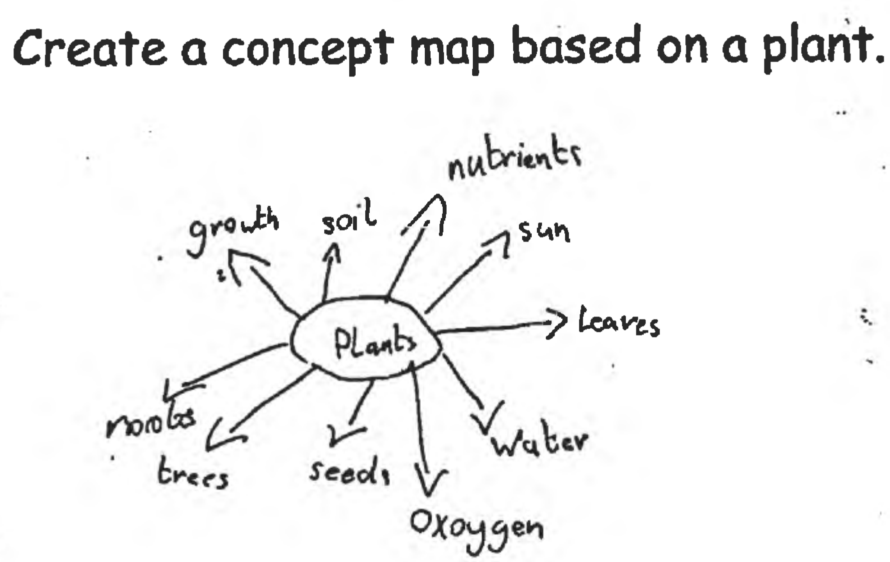


Figure 5.41 Free concept map of PLANTS for HP6201

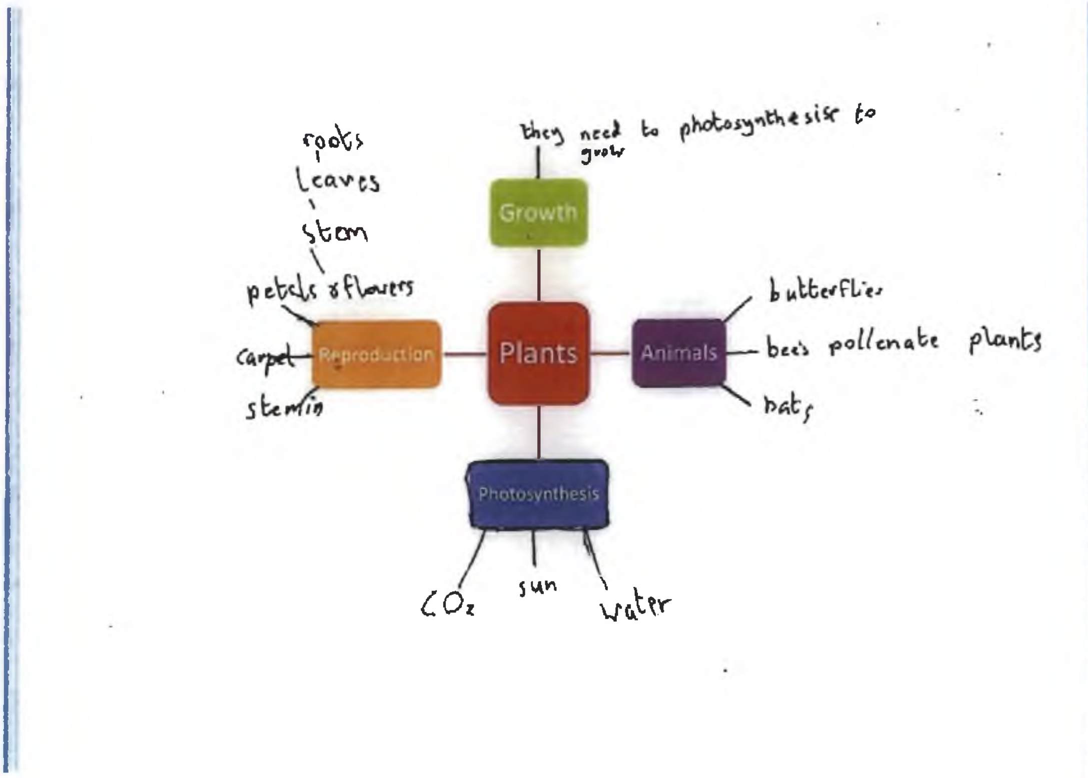


Figure 5.42 Closed concept map of PLANTS for HP6202

5.1.6 Conclusions drawn from pre-test and post-test concept maps

Conclusion were drawn from the pre-test and post-test concept maps through the close analysis of each, following an in-depth study of the current literature on concept mapping and the use of the marking system created and subsequently outlined by the author. The researcher focused on the four associated concepts, PHOTOSYNTHESIS, GROWTH, ANIMALS and REPRODUCTION when distinguishing conclusions.

Pre-test concept maps generally failed to recognise a plant's reliance on ANIMALS (e.g., for pollination, seed dispersal), and in turn their link with REPRODUCTION. A number of students failed to identify that PHOTOSYNTHESIS is an integral part of a plant's growth; however each concept map across both class groups highlighted areas relating GROWTH to PLANTS. When made, links between GROWTH and PHOTOSYNTHESIS were strong and closely related showing an understanding of the concepts dependency on each other. Furthermore, participant's thoughts seemed varied and in some cases scattered, however links were generally made from the core concept, PLANTS.

Through the close study of post-test concept maps in both class groups, strong links were presented between PHOTOSYNTHESIS and GROWTH upon the completion of this closed concept map, acknowledging their relationship and inter-dependent nature. Likewise, REPRODUCTION and ANIMALS were two concepts inextricably linked highlighting PLANTS reliance on animals for seed dispersal and pollination, as stated by the participants in post-test concept maps. Ideas stemming from the REPRODUCTION branch remained very individually related to PLANTS and bared little association to ANIMALS however. Clear links were made between the pairs of concepts, however little or no relation was made between the four concepts individually.

5.2 Scoring concept maps to insert into Repertory Grid Analysis

Both pre-test and post-test concept maps are scored based on 4 sub-headings/areas:

- Growth
- Animals
- Reproduction
- Photosynthesis

Therefore:

Score per mention in each area: 1 mark

Score per cross-link of two areas: 2 marks

Score per link between areas: 1 marks

Table 5.1 *Scoring example of concept map for SP602*

	Concept (Plants)	Growth	Animals	Reproduction	Photosynthesis
Concept (Plants)	0	5	1	1	4
Growth	5	1	2	0	6
Animals	1	2	0	0	0
Reproduction	1	0	0	0	0
Photosynthesis	4	6	0	0	0

One mark is awarded for each correct idea for a concept in each of the four areas listed. **Example:** 'Stem' is awarded one mark for GROWTH as a stem signifies support and growth in a plant, e.g., In KP602 (Figure 5.4).

Each notion is then crosschecked against a different conceptual idea, and two marks are awarded when two different areas are linked, or cross-linked.

Example: 'Sun' linked to 'water'. The sun is necessary for PHOTOSYNTHESIS to occur and water is a condition necessary for GROWTH, hence linking two concept areas and earning two marks, e.g., In TP602 (Figure 5.10). Novak and Cañas (2008) define cross-links as relationships or links between concepts, links one realm of knowledge represented on the concept map, with another domain displayed on the map.

One mark is awarded for links in one individual area, under the same overall concept.

5.2.1 Combining concept maps and RGA

As outlined above, a concept map scoring technique was used as a method of combining concept mapping and RGA under which two protocols were utilised, namely principal components analysis and coordinate grid analysis. Each concept map was scored an inserted into Idiogrid (Grice, 2004) where it was initially analysed under PCA.

In the PCAs produced by Idiogrid (Grice, 2004), structure coefficients, component correlations and component score coefficients are created in both unrotated PCA and Varimax rotated PCA. In this chapter, the author has chosen to compare Varimax rotated PCA graphs for both class 1 and 2. The author found that the Varimax rotated PCA bore a closer resemblance to the placement and linkage of ideas represented in the concept maps produced by class 1 and class 2.

The diagrams produced by Idiogrid (Grice, 2004) are characterised by their appearance of a Cartesian plane employed point plots and vectors in square border and colourful combination of constructs and elements. The constructs are written externally to the border in blue printing, which are usually symbolised by vectors, drawn in grey straight lines from the origin of the graph to the construct point. The elements are printed in black as points with a red dot. The axes of a graph produced in Idiogrid (Grice, 2004) are labelled 'comp 1' and 'comp 2' representing component 1 and component 2. These characteristics are displayed in Figure 5.43.

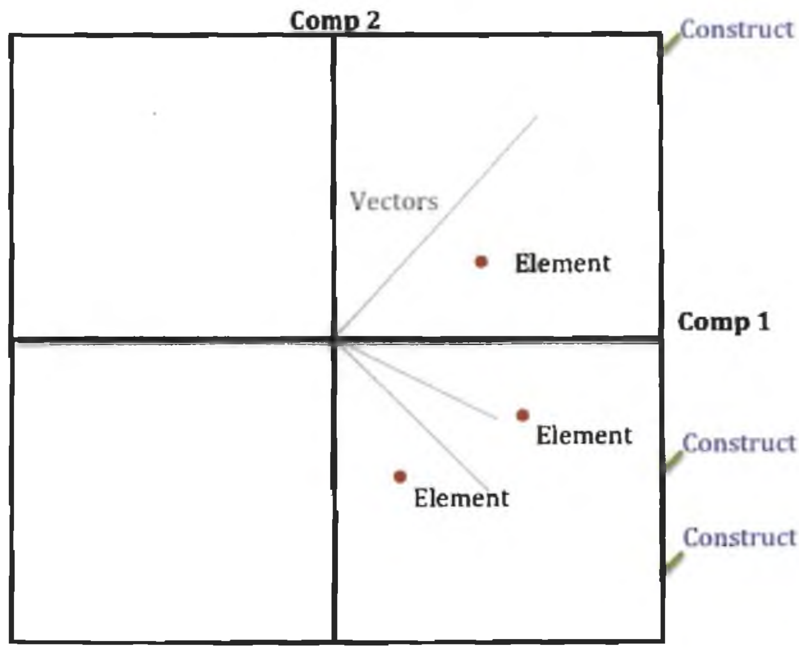


Figure 5.43 Example of a labelled graph produced in RGA

A graph produced by RGA under PCA for SP601 illustrates each of the characteristics discussed in use, wherein, as explained before, the concepts as constructs will be represented in block-capitals, e.g., PLANTS; and the concepts, as elements will be represented in italicised block-capitals, e.g., *PLANTS*. The diagrams appear counter-intuitive since the elements and constructs are the same in title, however the elements are the roles that are being investigated by the participant, and the constructs express how those roles are represented against certain events, and their relationship between one another.

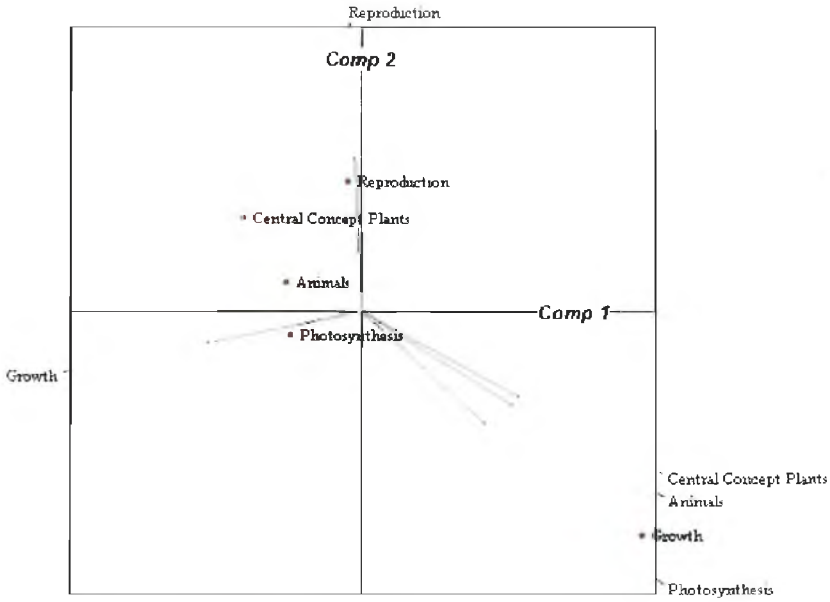


Figure 5.44 PCA varimax rotated graph of free concept map on PLANTS for SP601

In this graph, Figure 5.44, the central concept PLANTS is in fact aligned very close to ANIMALS strong influence by *GROWTH*. PHOTOSYNTHESIS too is close to GROWTH. It might be expected that GROWTH was aligned closely with *GROWTH,* but this is not the case in a score derived from a procedure involving more than three constructs and elements which would generate a reciprocal series of scores for each. When the number of constructs approaches six, five in this case, a more complex picture emerges. Connections between ideas and their attributes have a degree of commutativity, but not numerical reciprocity, owing to how learners construct ideas, which are not in a purely linear fashion. The closer the construct is to the origin the greater the confusion, or less certainty, concerning the construct, e.g., ANIMALS and how they relate to other constructs.

5.2.2 Individual results of RGA for pre-test and post-test concept maps under PCA

KP601 (Figure 5.45) shows strong links between *GROWTH* and PHOTOSYNTHESIS as the elements are plotted near the construct GROWTH. However, the need for *PHOTOSYNTHESIS* to occur in order for GROWTH to occur is not yet recognised and is plotted further from GROWTH on the graph. References to the concepts *ANIMALS* and *REPRODUCTION* are excluded from this graph. KP602 (Figure 5.46) displays *REPRODUCTION* placed almost central between the constructs ANIMALS and REPRODUCTION. Links are recognised between GROWTH and PHOTOSYNTHESIS reciprocally. The reliance between the two concepts has been recognised as they are indeed inextricably linked.

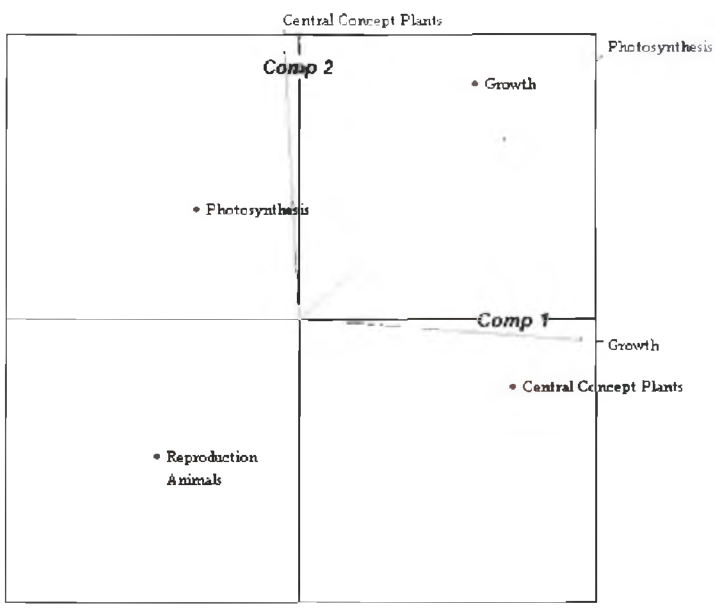


Figure 5.45 PCA varimax rotated graph of free concept map on PLANTS for KP601

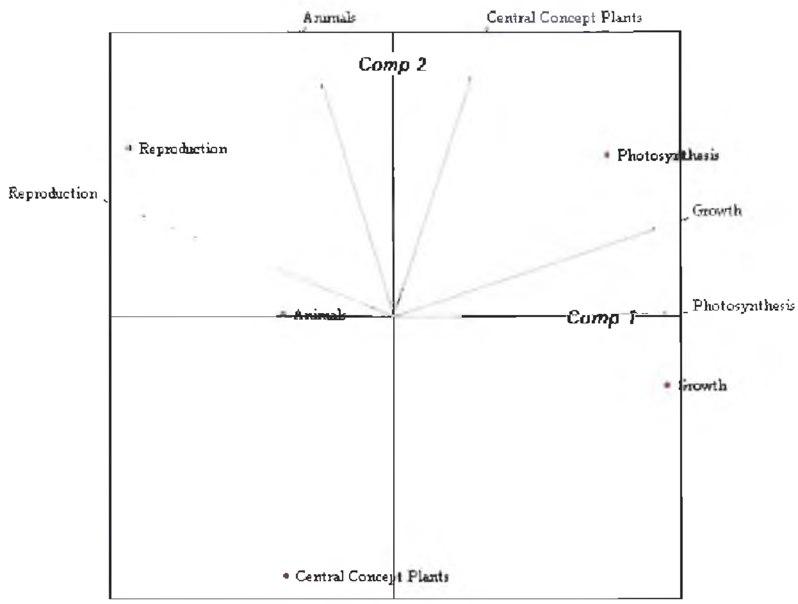


Figure 5.46 PCA varimax rotated graph of closed concept map on PLANTS for KP602

Regarding the graph produced for RP601 (Figure 5.47) *PLANTS*, *ANIMALS* and *PHOTOSYNTHESIS* all lie between the constructs PHOTOSYNTHESIS and GROWTH. *GROWTH* sits between REPRODUCTION and the central concept PLANTS showing a relationship between the 3 concepts on the graph formed. *PHOTOSYNTHESIS* and *REPRODUCTION* lie both sides of the central concept PLANTS and are the main links made on original concept map.

In RP602 (Figure 5.48) the three concepts *REPRODUCTION*, *GROWTH* and *ANIMALS* are all connected to the construct REPRODUCTION which is clearly shown on graph. A link between GROWTH and PHOTOSYNTHESIS is not visible and the graph suggests that the participant views each element as a standalone process. *ANIMALS* are closely linked to GROWTH showing a strong relationship between the two concepts for plant REPRODUCTION.

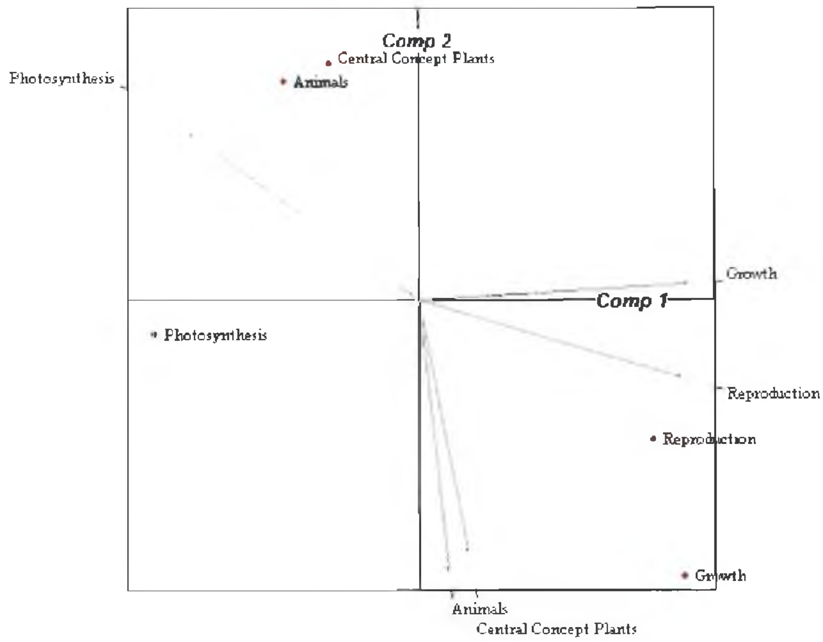


Figure 5.47 PCA varimax rotated graph of free concept map on PLANTS for RP601

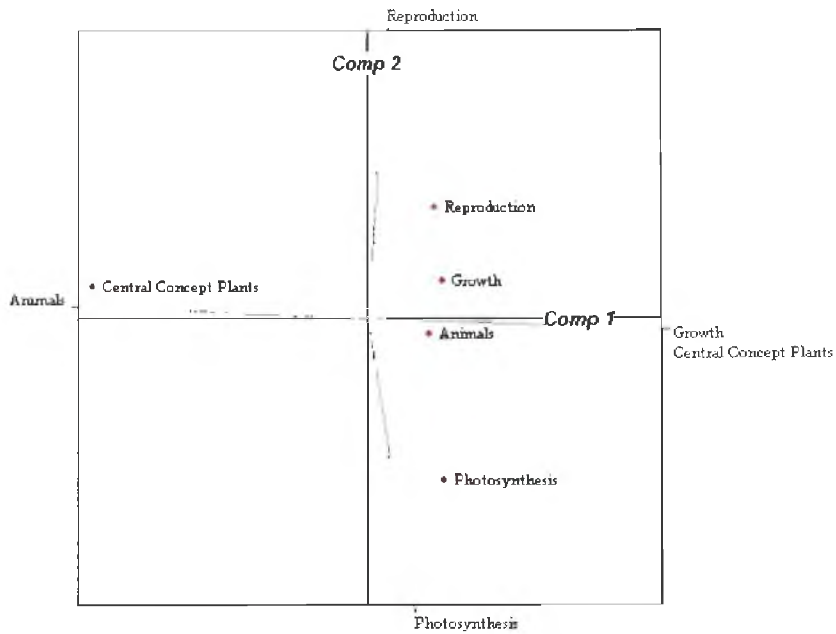


Figure 5.48 PCA varimax rotated graph of closed concept map on PLANTS for RP602

In TP601 (Figure 5.49) a strong connection is evident between ANIMALS and REPRODUCTION. No link between *GROWTH* and ANIMALS, or between *PHOTOSYNTHESIS* and REPRODUCTION has been made. PHOTOSYNTHESIS and GROWTH are closely related in both elements and constructs, as shown on graph and on concept map. GROWTH and PHOTOSYNTHESIS are strongly connected in both elements and constructs in TP602 (Figure 5.81), while REPRODUCTION is linked to ANIMALS reciprocally. The central concept *PLANTS* lies between all four concepts. Ideas based on PLANTS are evenly dispersed in each of the four conceptual areas.

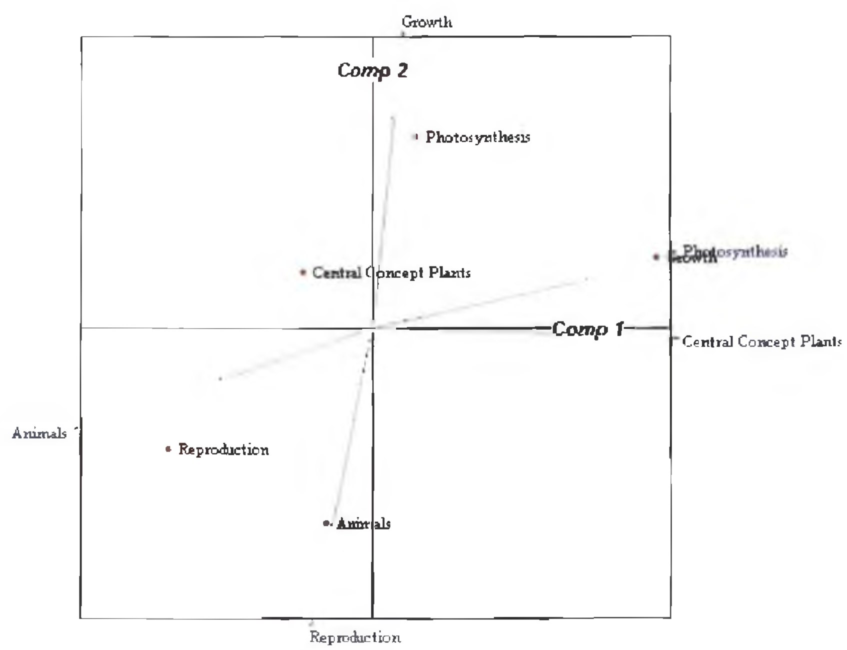


Figure 5.49 PCA varimax rotated graph of free concept map on PLANTS for TP601

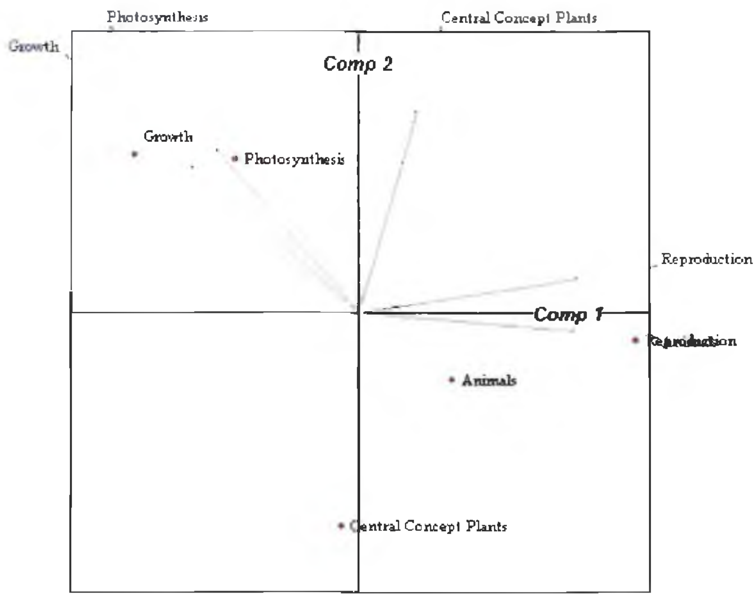


Figure 5.50 PCA varimax rotated graph of closed concept map on PLANTS for TP602

LP601 (Figure 5.51) does not consist of notions of the concept ANIMALS. All concepts branch from core concept. *PHOTOSYNTHESIS* and *GROWTH* are most commonly linked to the core concept PLANTS, while *REPRODUCTION* is plotted further away from this central idea. LP602 (Figure 5.52) chose to link their thoughts from the core concept only as all four concepts were presented and linked to the central concept however no connections were made between concepts.

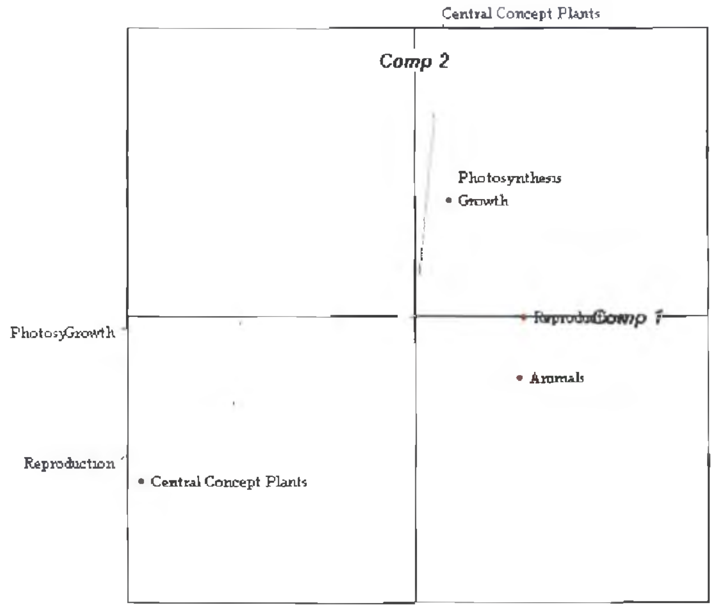


Figure 5.51 PCA varimax rotated graph of free concept map on PLANTS for LP601

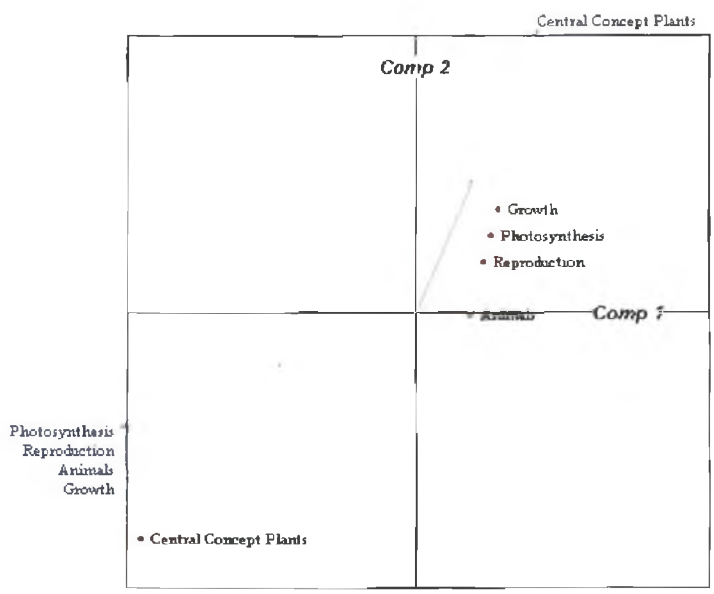


Figure 5.52 PCA varimax rotated graph of closed concept map on PLANTS for LP602

Although links across conceptual areas were structurally present in the pre-test concept map, those links were not as clearly identified under RGA for ISP601 (Figure 5.53). In the graph produced, a static outline of concepts was offered under RGA, showing only links between the core concept PLANTS and *GROWTH.*

Regarding the graph produced by ISP602 (Figure 5.54) PHOTOSYNTHESIS and GROWTH are undoubtedly linked. Similarly, REPRODUCTION and ANIMALS are linked strongly to each other building an awareness of their inter-dependent nature. Both pairs of concepts are plotted on opposite sides of the graph while core concept PLANTS holds a central position.

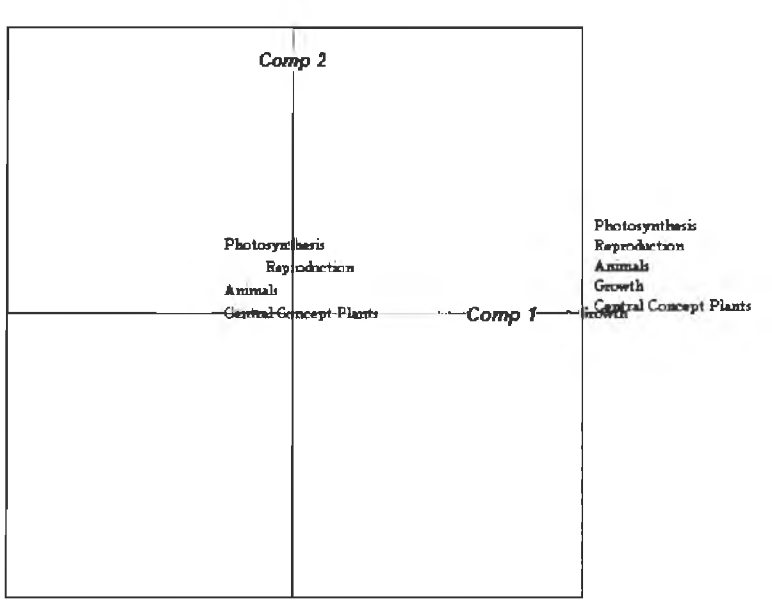


Figure 5.53 PCA varimax rotated graph of free concept map on PLANTS for ISP601

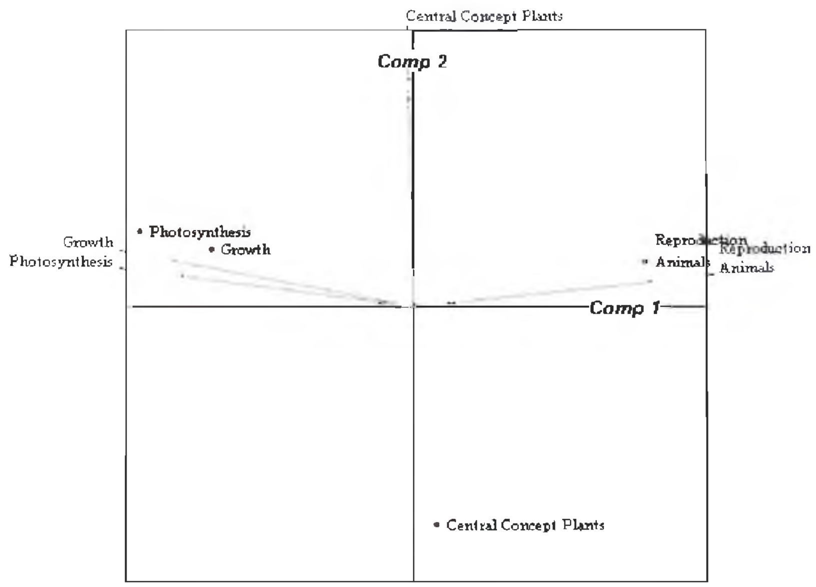


Figure 5.54 PCA varimax rotated graph of closed concept map on PLANTS for ISP602

REPRODUCTION is not expressed in graph under PCA for KDP601 (Figure 5.55). Uncertainty is present around the concept *ANIMALS* link to core concept and *PHOTOSYNTHESIS* and *PLANTS* bear links to GROWTH reciprocally. In KDP602 (Figure 5.56) each concept is individually linked in relation to PLANTS, however ANIMALS bare no relation to the central concept on this graph. Connections are made between *PHOTOSYNTHESIS* and *GROWTH* as they are plotted in close proximity.

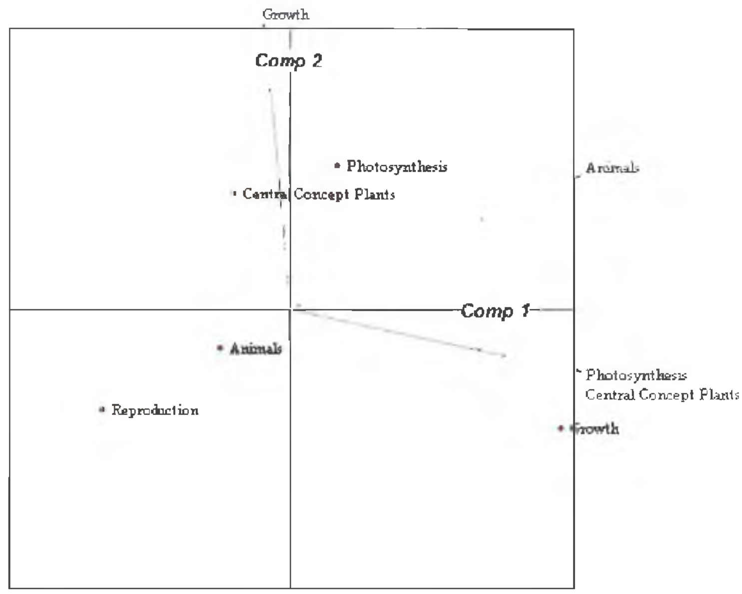


Figure 5.55 PCA varimax rotated graph of free concept map on PLANTS for KDP601

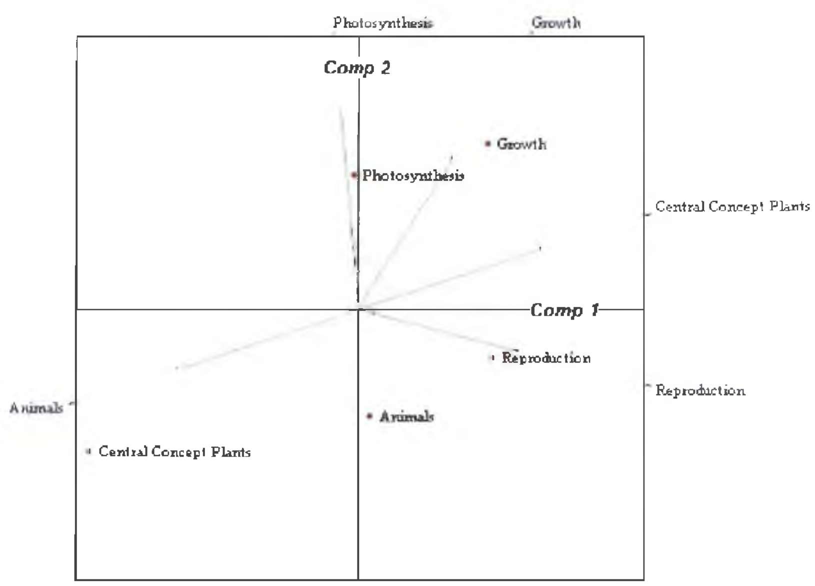


Figure 5.56 PCA varimax rotated graph of closed concept map on PLANTS for KDP602

In IP601 (Figure 5.57) the central concept lies between PHOTOSYNTHESIS and GROWTH. GROWTH and *REPRODUCTION* are linked at a distance on the graph, and *ANIMALS* is plotted at the furthest point from the core idea PLANTS. *REPRODUCTION* is positioned between the constructs ANIMALS and REPRODUCTION, showing link between the two concepts in IP602 (Figure 5.58). *PHOTOSYNTHESIS* and *GROWTH* are associated to the central concept however links between the two concepts are not as clear on the graph.

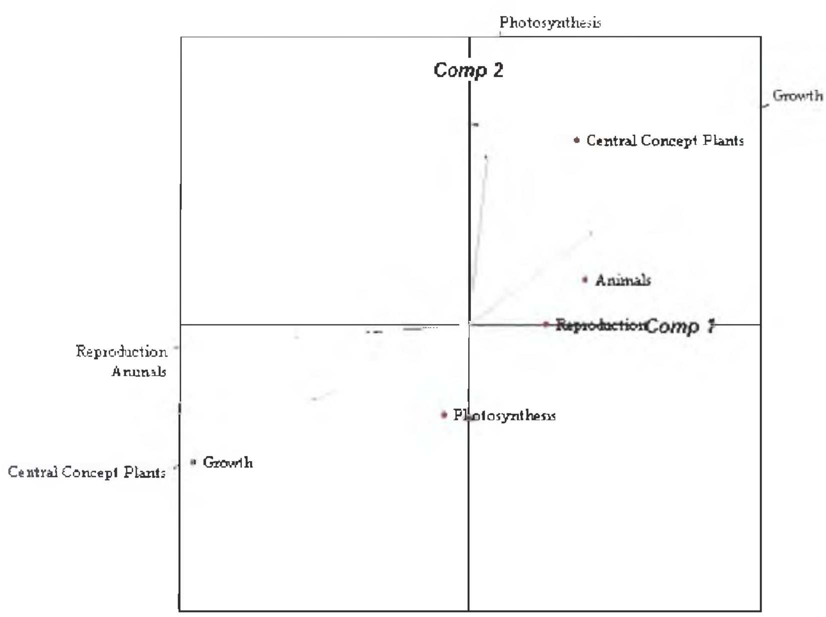


Figure 5.57 PCA varimax rotated graph of free concept map on PLANTS for IP601

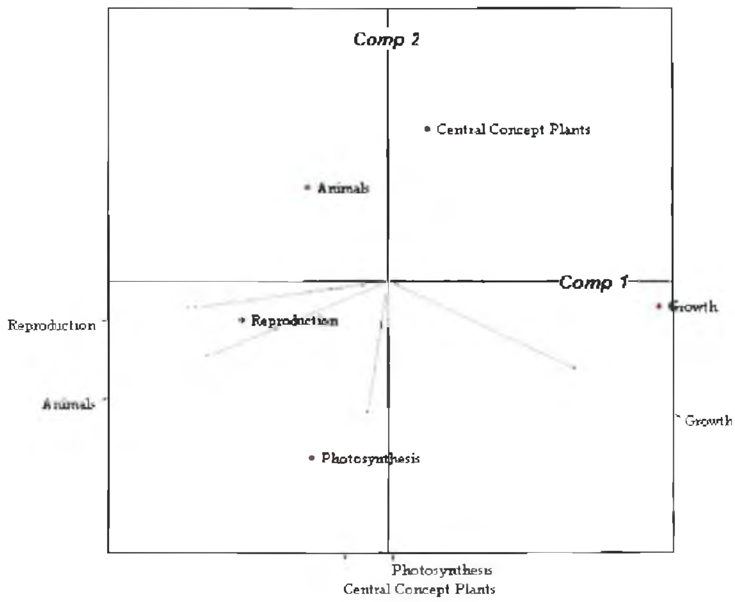


Figure 5.58 PCA varimax rotated graph of closed concept map on PLANTS for IP602

REPRODUCTION is not highlighted in the graph produced for EP601 (Figure 5.59). *GROWTH* is more closely linked to ANIMALS while the concept of *ANIMALS* is plotted further from the idea of GROWTH. PHOTOSYNTHESIS is connected to core concept *PLANTS*. PHOTOSYNTHESIS is also associated with *ANIMALS*, therefore *ANIMALS* is plotted between GROWTH and PHOTOSYNTHESIS on the graph. As presented in several graphs, in EP602 (Figure 5.60) *GROWTH* continues to be placed between the core concept PLANTS and GROWTH. The core concept lies between PHOTOSYNTHESIS and GROWTH, perhaps indicating that the concepts are reliant on each other. A link is made between *PHOTOSYNTHESIS* and ANIMALS as they are closely related on this graph.

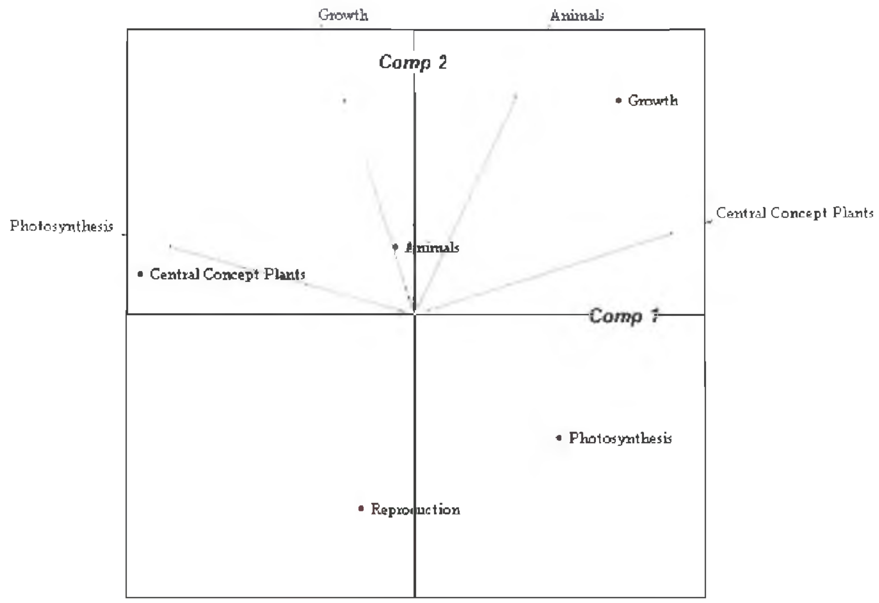


Figure 5.59 PCA varimax rotated graph of free concept map on PLANTS for EP601

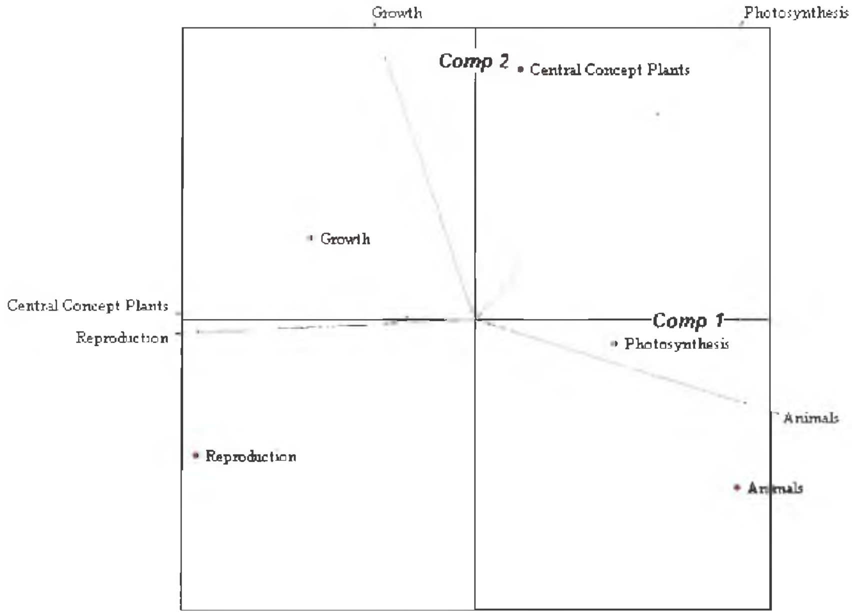


Figure 5.60 PCA varimax rotated graph of closed concept map on PLANTS for EP602

In class 2, the equivalent scoring system was employed to mark pre-test concept maps produced. EP6201 (Figure 5.61) displays the relationship of all four concept areas to the central idea PLANTS. *GROWTH* is plotted closely to the central concept PLANTS construct while *PHOTOSYNTHESIS*, *REPRODUCTION* and *ANIMALS* are all shown close-by. EP6202 (Figure 5.62) displays a closer relationship between *GROWTH* and PHOTOSYNTHESIS, while *PHOTOSYNTHESIS* is plotted near the constructs PLANTS and GROWTH. The element *PLANTS* holds a central locus while again, *ANIMALS* and *REPRODUCTION* are linked to their relative constructs.

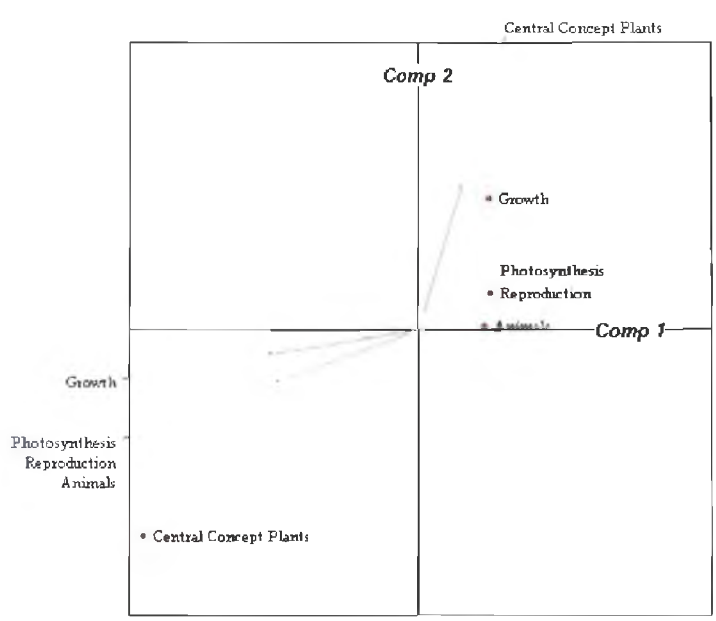


Figure 5.61 PCA varimax rotated graph of free concept map on PLANTS for EP6201

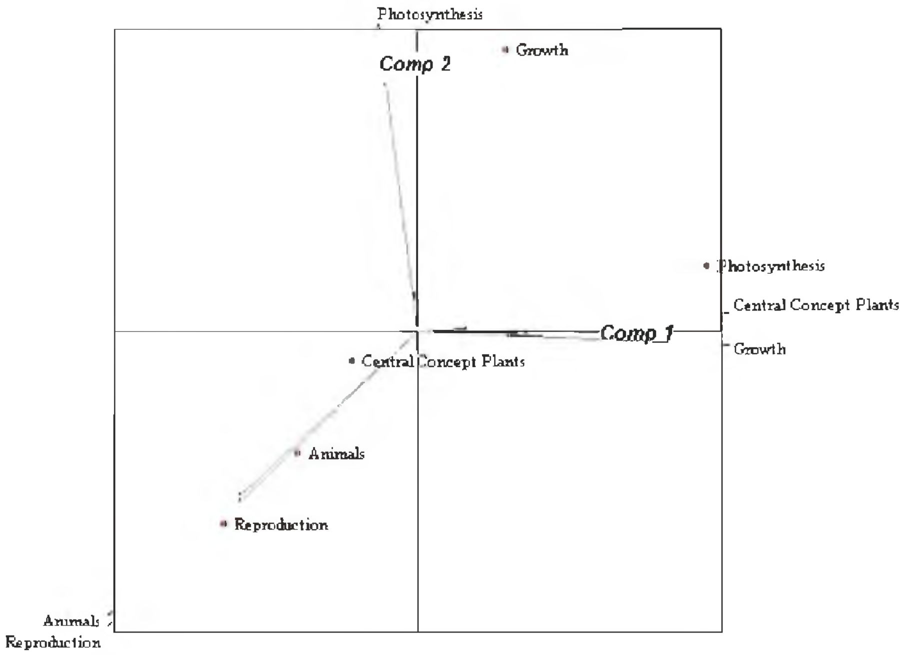


Figure 5.62 PCA varimax rotated graph of closed concept map on PLANTS for EP6202

PP6201 (Figure 5.63) presents *PHOTOSYNTHESIS* plotted between the constructs PLANTS and GROWTH, showing a relationship between all three concepts. ANIMALS is directly linked to the central concept *PLANTS* and *GROWTH* is placed on the vertex for PHOTOSYNTHESIS. REPRODUCTION is not represented as a construct on this graph. In both PP6202 (Figure 5.64) and MZP6202 (Figure 5.72), the central concept PLANTS holds a central position in the graphs produced. Both elements and constructs are reciprocally linked in pairs, ANIMALS and REPRODUCTION, and indeed GROWTH and PHOTOSYNTHESIS.

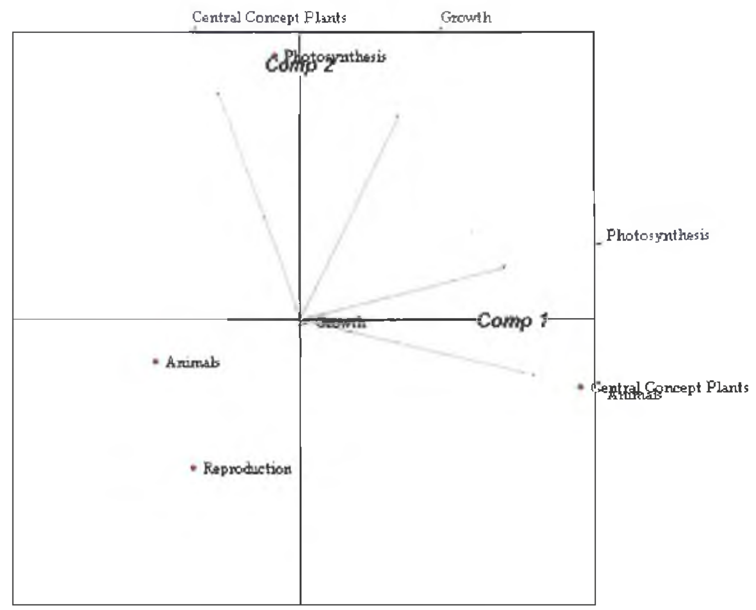


Figure 5.63 PCA varimax rotated graph of free concept map on PLANTS for PP6201

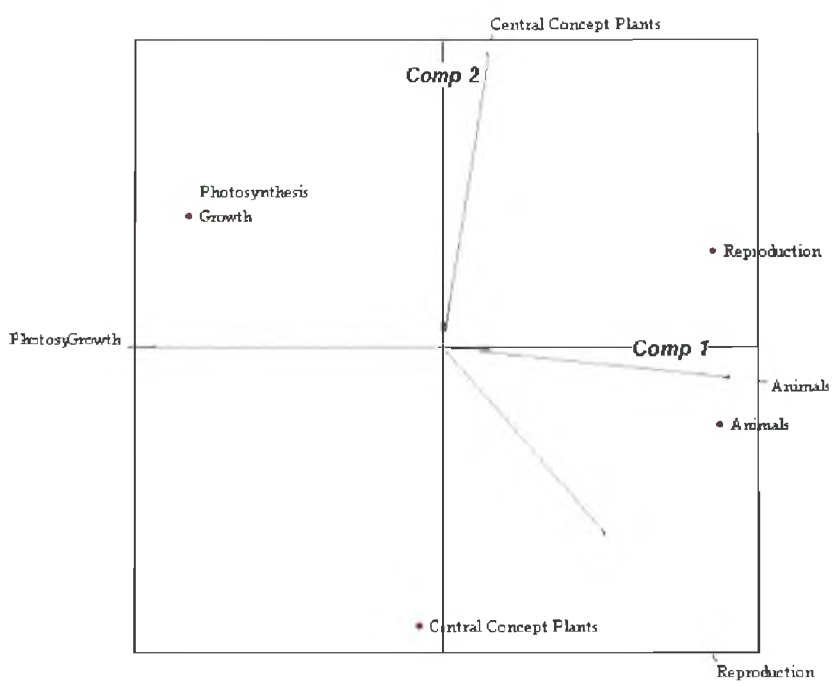


Figure 5.64 PCA varimax rotated graph of closed concept map on PLANTS for PP6202

ABP6201 (Figure 5.65) exhibits a strong inter-twined relationship between the core concept *PLANTS* and the constructs GROWTH and PHOTOSYNTHESIS. *REPRODUCTION* is graphed between the constructs GROWTH and PHOTOSYNTHESIS, however ANIMALS is not denoted on this graph. In AB6202 (Figure 5.66), the central concept PLANTS holds a central position on the graph. *GROWTH* is positioned near the constructs GROWTH and PHOTOSYNTHESIS, so too is *PHOTOSYNTHESIS*. Similarly, both the elements *ANIMALS* and *REPRODUCTION* are inextricably linked to the constructs ANIMALS and REPRODUCTION, displaying their strong linkage.

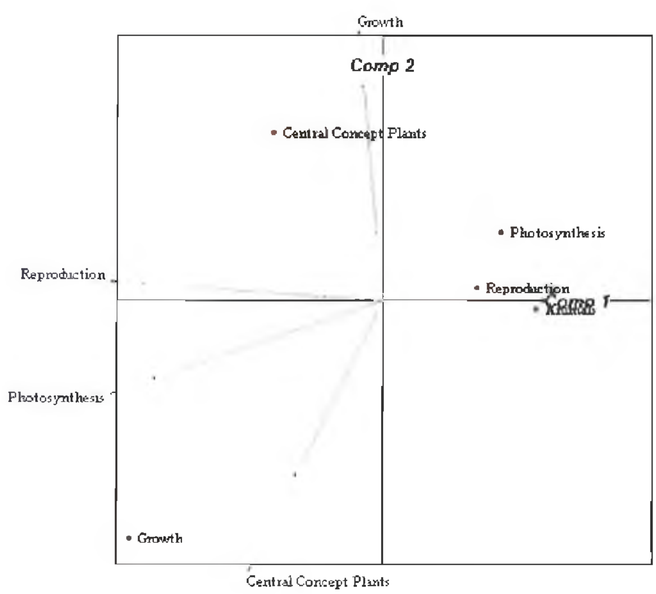


Figure 5.65 PCA varimax rotated graph of free concept map on PLANTS for ABP6201

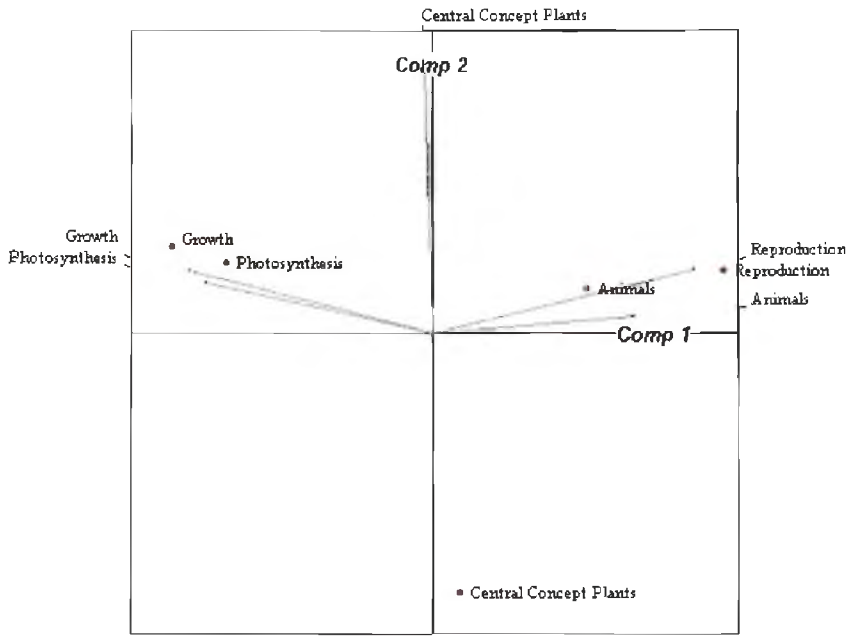
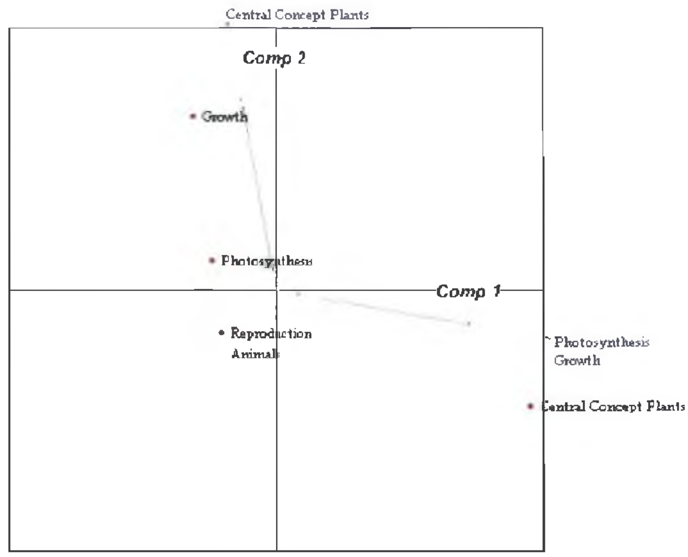


Figure 5.66 PCA varimax rotated graph of closed concept map on PLANTS for ABP6202

Both constructs REPRODUCTION and ANIMALS are excluded from LP6201 (Figure 5.67) graph, signifying they were not presented in the original free pre-test concept map. *GROWTH* and *PHOTOSYNTHESIS* are meticulously linked to the core concept PLANTS, however the graph suggests *GROWTH* holds a higher position than *PHOTOSYNTHESIS*.

LP6202 (Figure 5.68) differs from previous graphs presented by class 2, as *PHOTOSYNTHESIS* and *REPRODUCTION* are plotted nearby the core idea PLANTS and GROWTH. *PLANTS* and *ANIMALS* hold a link to ANIMALS, and although *GROWTH* is clearly linked to PHOTOSYNTHESIS on the graph, the link is not as equally presented vice versa.



Figure

5.67 PCA varimax rotated graph of free concept map on PLANTS for LP6201

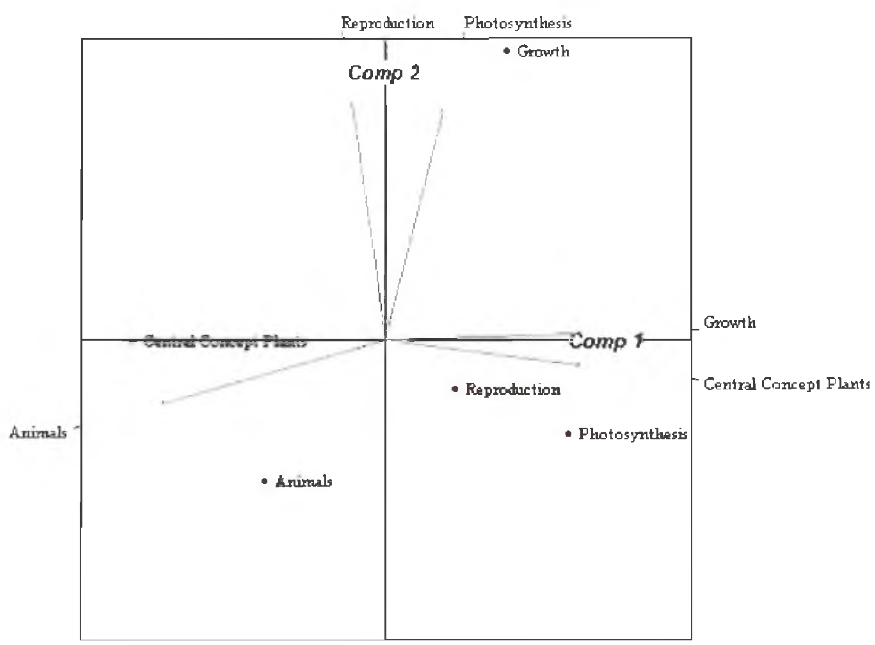


Figure 5.68 PCA varimax rotated graph of closed concept map on PLANTS for LP6202

In HP6201 (Figure 5.69) all 3 concepts *GROWTH, PHOTOSYNTHESIS* and *REPRODUCTION* are associated closely to the core idea PLANTS. *GROWTH* borders the main concept with *PHOTOSYNTHESIS* and *REPRODUCTION* following in line. ANIMALS is not represented on this graph in correlation to any other concepts.

In the graph produced by HP6202 (Figure 5.70), similar links are presented between elements and constructs as previously discovered in a selection of graphs, however the graph exhibits an interesting clear structure, along a number of various vertex. GROWTH and PHOTOSYNTHESIS are interconnected, so too are ANIMALS and REPRODUCTION. *REPRODUCTION* holds a central point between the constructs REPRODUCTION and ANIMALS.

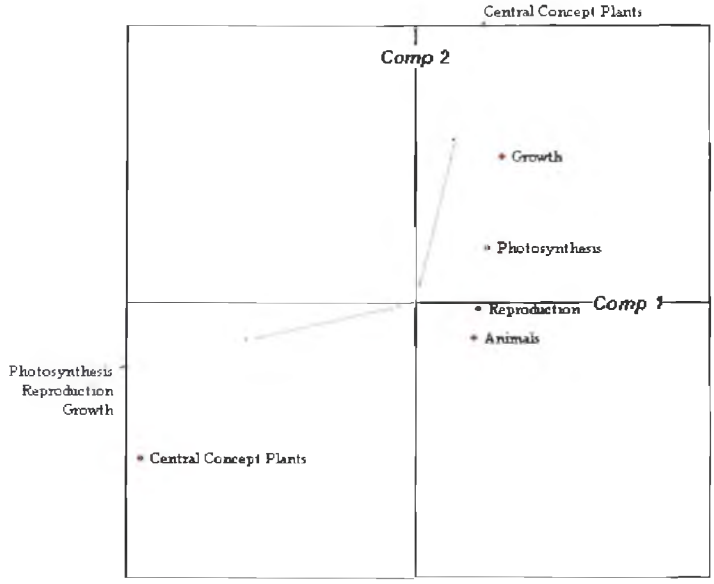


Figure 5.69 PCA varimax rotated graph of free concept map on PLANTS for HP6201

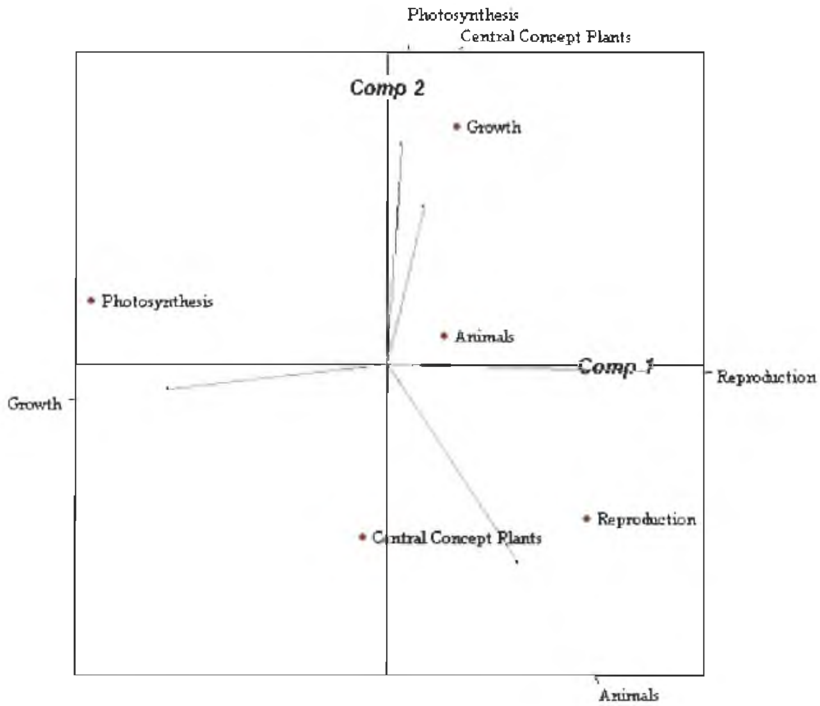


Figure 5.70 PCA varimax rotated graph of closed concept map on PLANTS for HP6202

Again, in the graph MZP6201 (Figure 5.71), there is no reference of the concepts ANIMALS and REPRODUCTION. *GROWTH* is once more the predominant link to the primary concept PLANTS. In MZP6202 (Figure 5.72) the central concept PLANTS holds a central position in the graphs produced. Both elements and constructs are reciprocally linked in pairs, ANIMALS and REPRODUCTION, and indeed GROWTH and PHOTOSYNTHESIS.

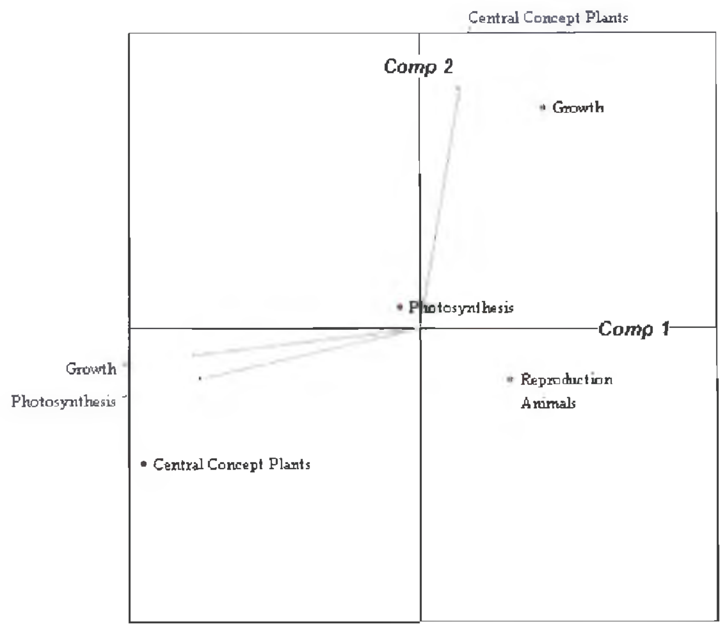


Figure 5.71 PCA varimax rotated graph of free concept map on PLANTS for MZP6201

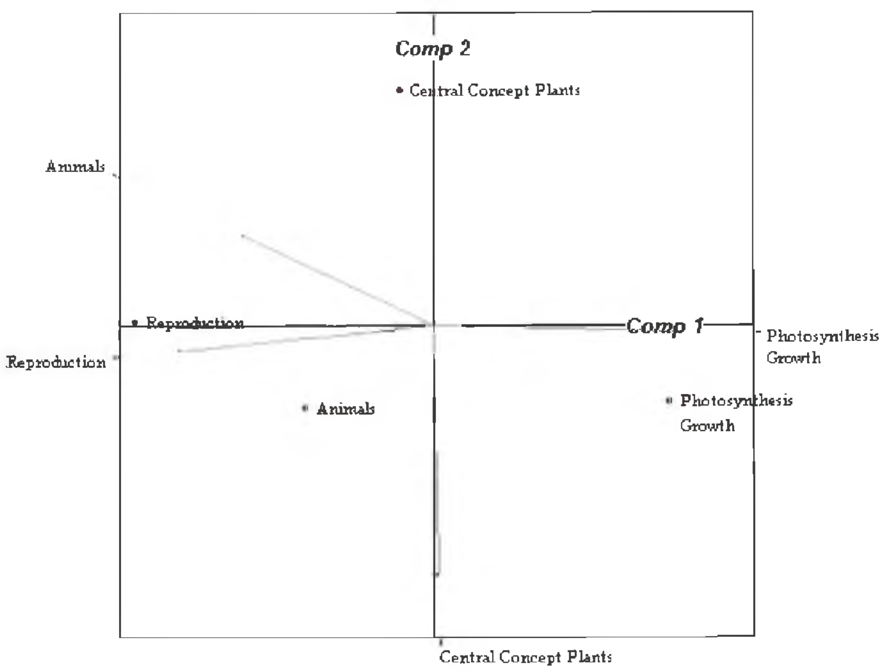


Figure 5.72 PCA varimax rotated graph of closed concept map on PLANTS for MZP6202

5.3 Results of questionnaire using RGA under PCA

Following the pre-test free concept map, students in both class 1 and class 2 were presented with a questionnaire. This questionnaire consisted of eight questions. The first four questions were worded with a Likert scale for answering. The remaining four questions consisted of a worded phrase and an image relating to the statement and the original Likert scale for answering. The author examined the results of the questionnaire for student's pre-conceptions and alternative conceptions based on photosynthesis in plants. The results were then recorded and graphed using RGA under PCA, similar to the graphs that have already been presented in this research findings chapter. Preceding graphs consisted of similar constructs and elements however, while the succeeding graphs will indicate varied constructs and elements.

5.3.1 Individual grid analysis of questionnaire results under PCA

An assortment of students' questionnaire results from both class 1 and class 2 were selected and analysed using principal component analysis (PCA). In the graph produced by TP601 (Figure 5.73), the student disagrees that plant is photosynthesizing when presented with an image, while also disagreeing that all plants photosynthesize. The participant does not recognise a beech tree as having chlorophyll and shows uncertainty in their understanding of chlorophyll. While no 'strongly' term has been used in the Likert scale, an alternative conception is presented in that a plant gets its food from soil in both the image and statement.

AP601 (Figure 5.74) disagreed that plant gets their food from soil in previous statement, however when shown an image of plant in pot of soil, then agreed that the plant gets food from soil. Uncertainly surrounding chlorophyll is present and neutral is selected on the Likert scale and therefore does not recognise a beech tree as having chlorophyll when presented with the image. The student recognises however that all plants photosynthesize and agrees that the image of a plant in the sunshine is a plant making its own food.

CP601 (Figure 5.75) is unsure of the conditions necessary for photosynthesis to take place, disagreeing that it takes place during the day. CP601 firstly showed uncertainty when asked if plants get their food from the soil, giving a neutral answer, however when shown an image, the student's alternative becomes greater and they are reassured that their conception is in fact correct.

In KDP601 (Figure 5.76), the contributor disagreed that plants get their food from the soil when the statement was firstly offered. However, once the image was presented, alternative conceptions and uncertainty formed and the student changed from 'disagree' to 'neutral' when shown image of plant in pot of soil.

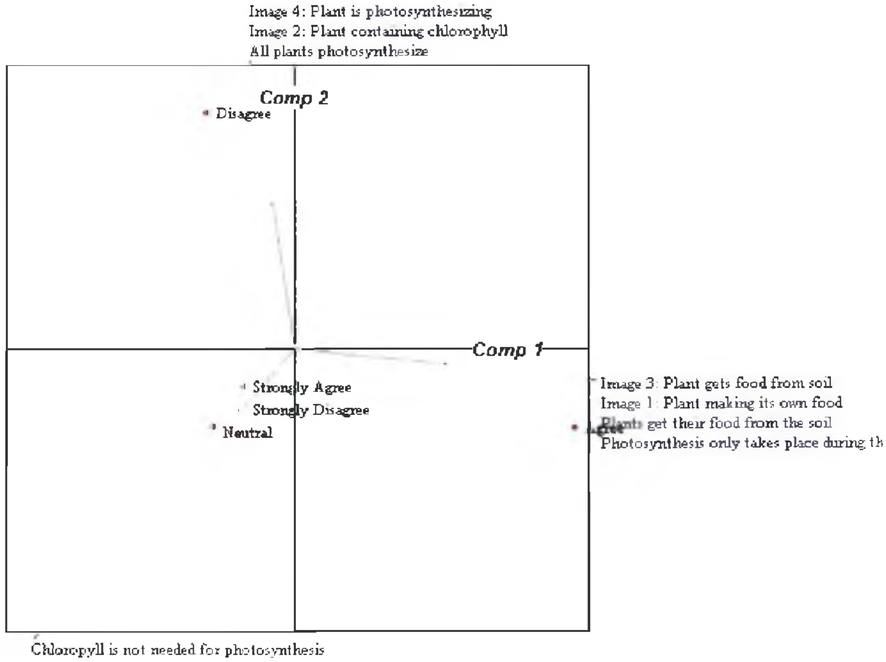


Figure 5.73 PCA varimax rotated graph questionnaire results on PLANTS for TP601

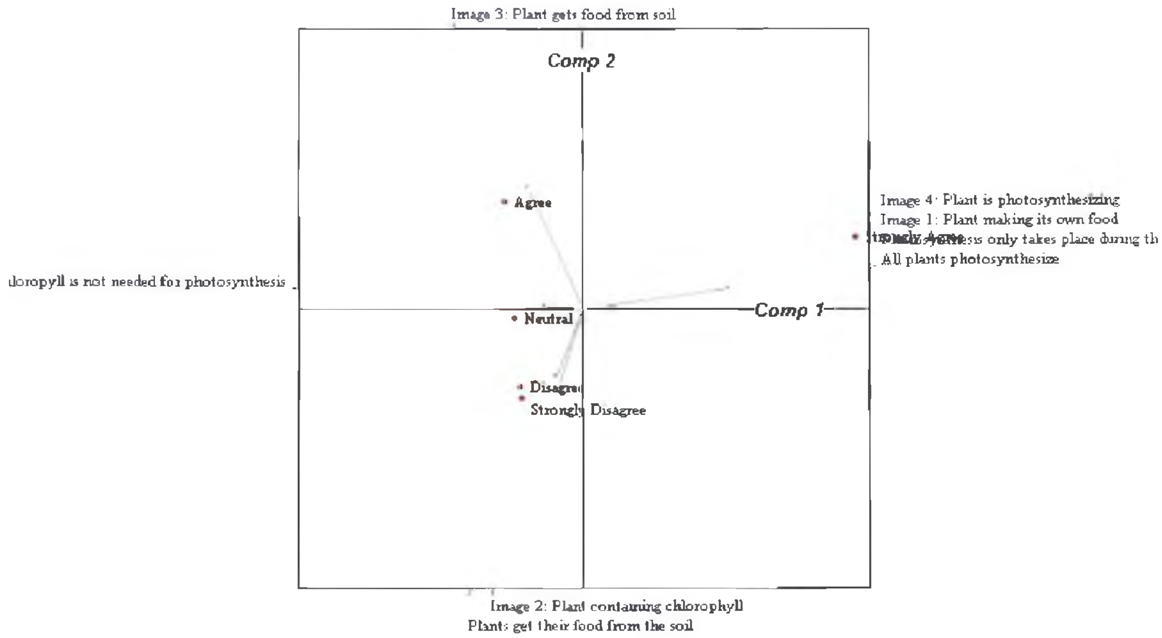


Figure 5.74 PCA varimax rotated graph questionnaire results on PLANTS for AP601

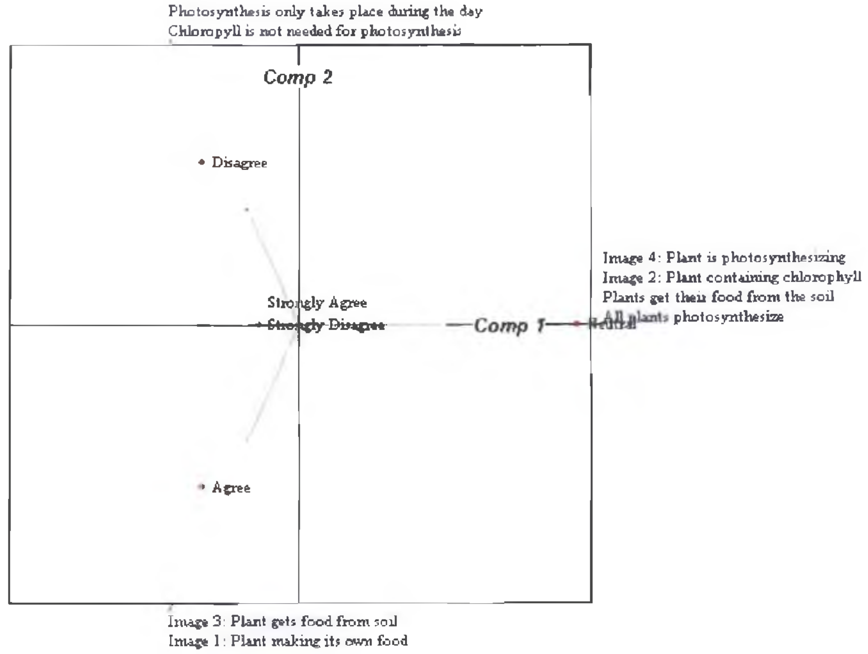


Figure 5.75 PCA varimax rotated graph questionnaire results on PLANTS for CP601

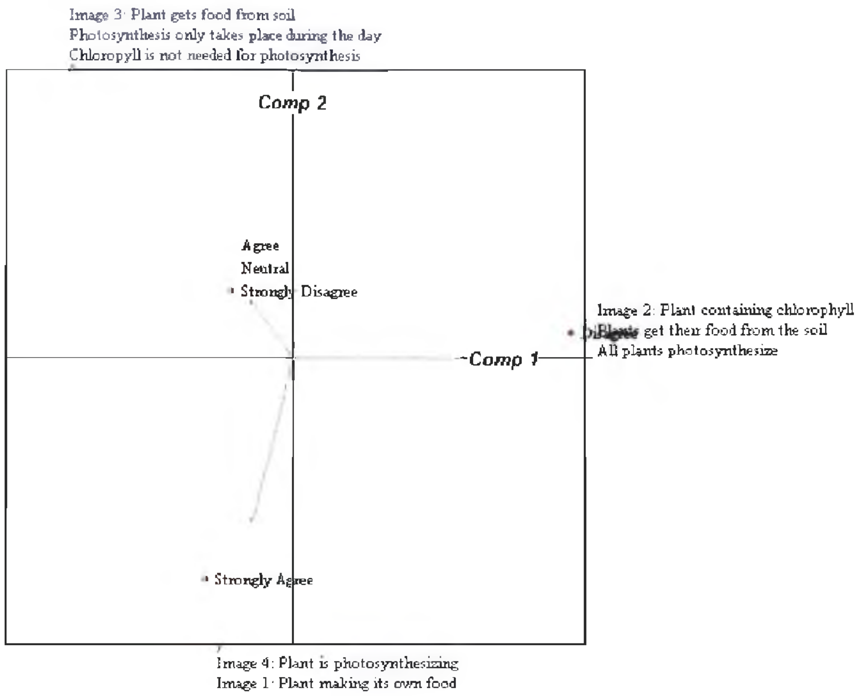


Figure 5.76 PCA varimax rotated graph questionnaire results on PLANTS for KDP601

NP601 (Figure 5.77) strongly agreed that all plants photosynthesize and need sunlight in order to make food. Despite this, NP601 firstly disagreed with statement that plants get food from soil however when presented with an image of plant in a pot of soil, the rating was changed from 'disagree' to 'agree'.

RP601 (Figure 5.78) did not utilise the scale to its full potential and used only 'agree' or 'disagree'. RP601 held a consistent view that plants do not get their food from soil, image included. This proved to be the only instance whereby a consistent correct idea of plants making their own food remained when presented with image of plant in pot of soil.

SDP601 (Figure 5.79) recognises that chlorophyll is needed for photosynthesis. The participant strongly disagrees however that a copper beech tree contains chlorophyll due to the fact that the green pigment is not visible in the image. SDP601 is an example whereby an image strengthens an alternative conception. The idea that a plant gets its food from soil strengthens from 'agree' to 'strongly agree' in this instance.

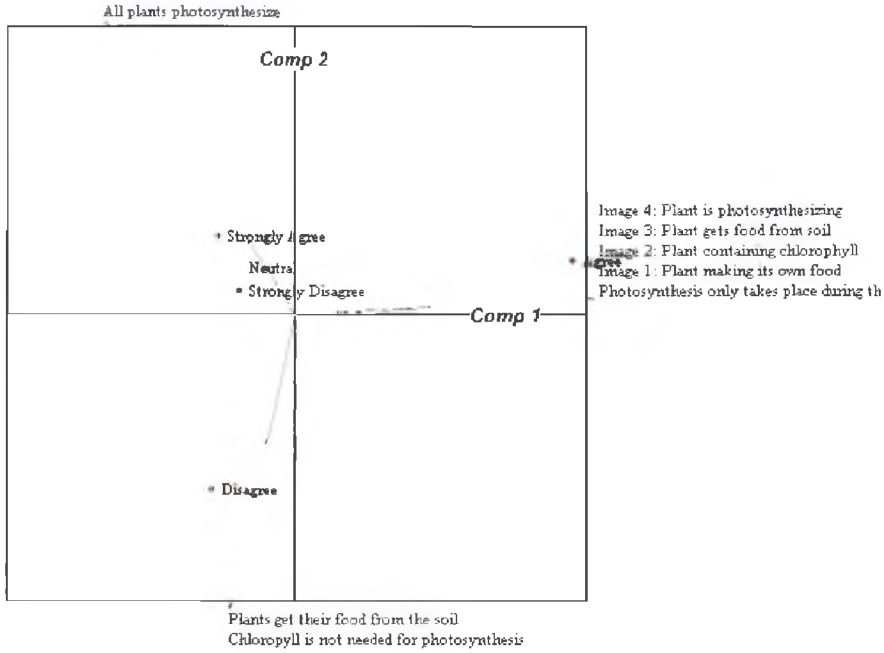


Figure 5.77 PCA varimax rotated graph questionnaire results on PLANTS for NP601

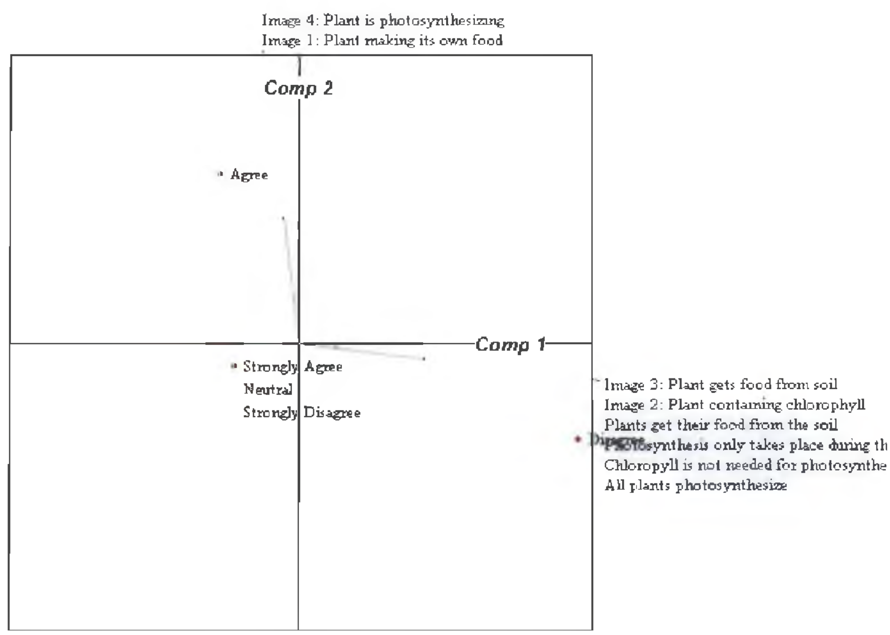


Figure 5.78 PCA varimax rotated graph questionnaire results on PLANTS for RP601

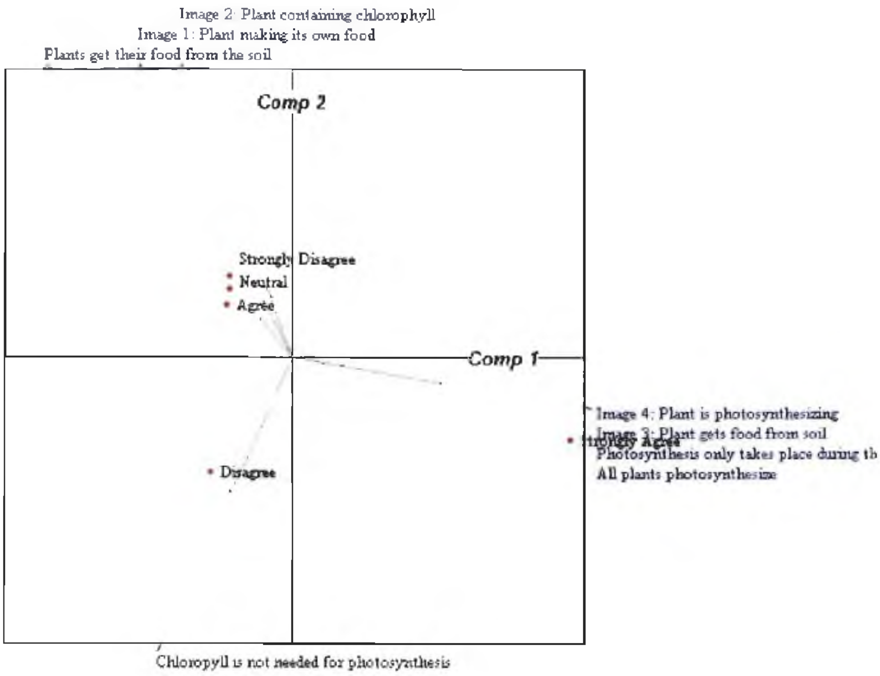


Figure 5.79 PCA varimax rotated graph questionnaire results on PLANTS for SDP601

ABP6201 (Figure 5.80) fails to recognise the conditions necessary for photosynthesis to take place and disagrees that a plant needs sunlight during the day in order for photosynthesis to take place when presented with the statement. However, when the image is conveyed, ABP6201 agrees that a plant is making its own food in the sunshine and all plants must photosynthesize.

In the graph produced by KP6201 (Figure 5.81), both 'neutral' and 'agree' are the two choices made in relation to all the statements made in the questionnaire. KP6201 shows uncertainty relating to chlorophyll and uses 'neutral' when mentioned. The participant agrees with the conception that a plat gets its good from the soil in both the statement and image, this alternative conception does not strengthen or lesson however.

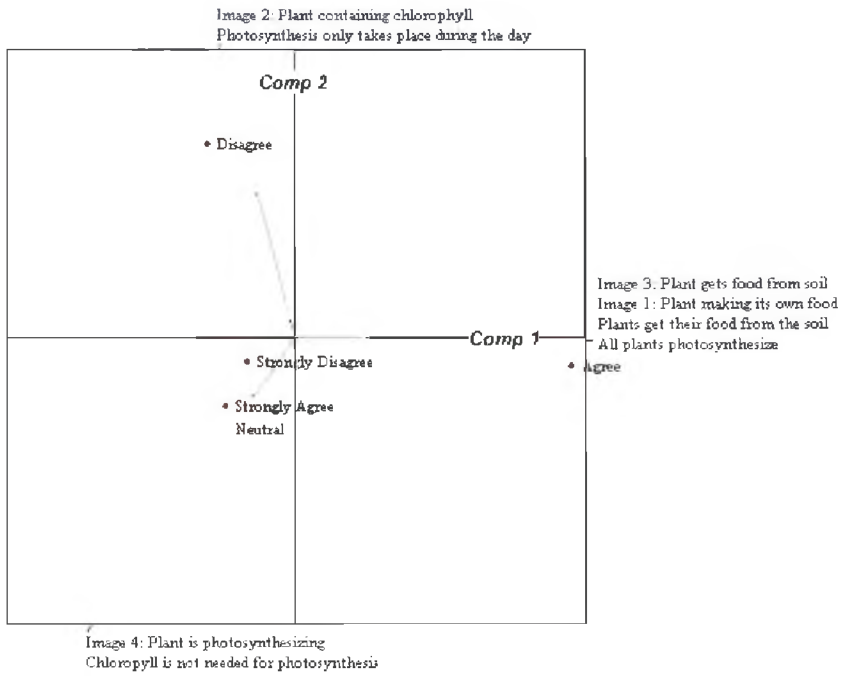


Figure 5.80 PCA varimax rotated graph questionnaire results on PLANTS for ABP6201

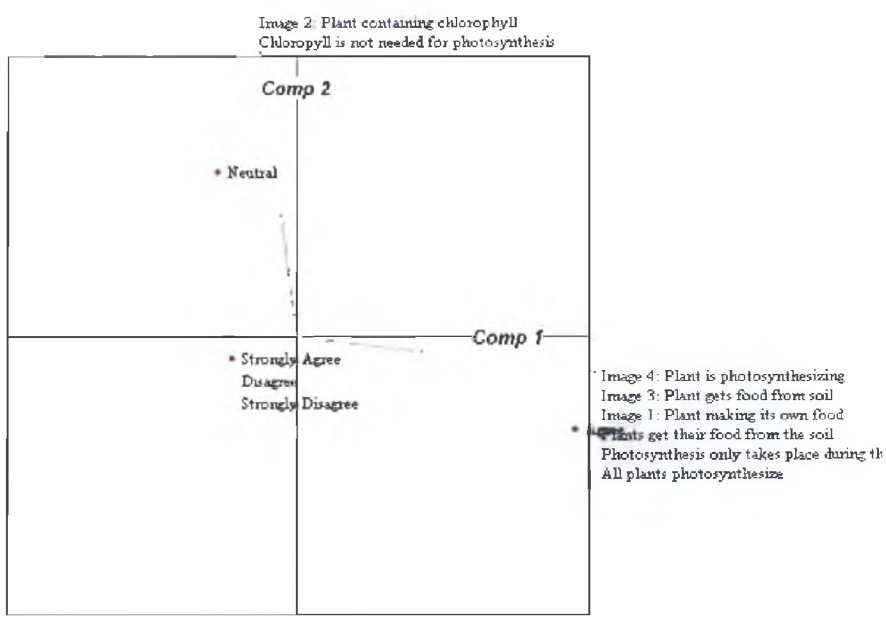


Figure 5.81 PCA varimax rotated graph questionnaire results on PLANTS for KP6201

MZP601 (Figure 5.82) strongly agrees with the alternative conception that plants get their food from the soil however the image corrects the conception in this case. Uncertainty remains when presented with questions surrounding the green pigment in plants, chlorophyll.

Figure 5.83, PYP6201, expresses the notion that plants get their food from the soil. Although it is strongly agreed that all plants photosynthesize and the plant in the sunshine represents a plant photosynthesizing, ambiguity exists around the processes of photosynthesis itself as the student believes a plant to be making its own food in a pot of soil.

LP6201 (Figure 5.84) exhibits many alternative conceptions involving the way in which a plant gets its food and agrees that a plant gets its food from the soil in both the statement and when presented with an image. Sunshine is not recognised as a necessary factor in photosynthesis and chlorophyll is given a 'neutral' response as a factor of photosynthesis also.

Finally, EP6201 (Figure 5.85) displays varying alternative conceptions similar to LP6201 (Figure 5.84). At first, it is agreed that a plant gets its food from the soil, although the image doesn't reinforce this conception, it does raise uncertainty and 'agree' changes to a 'neutral' response.

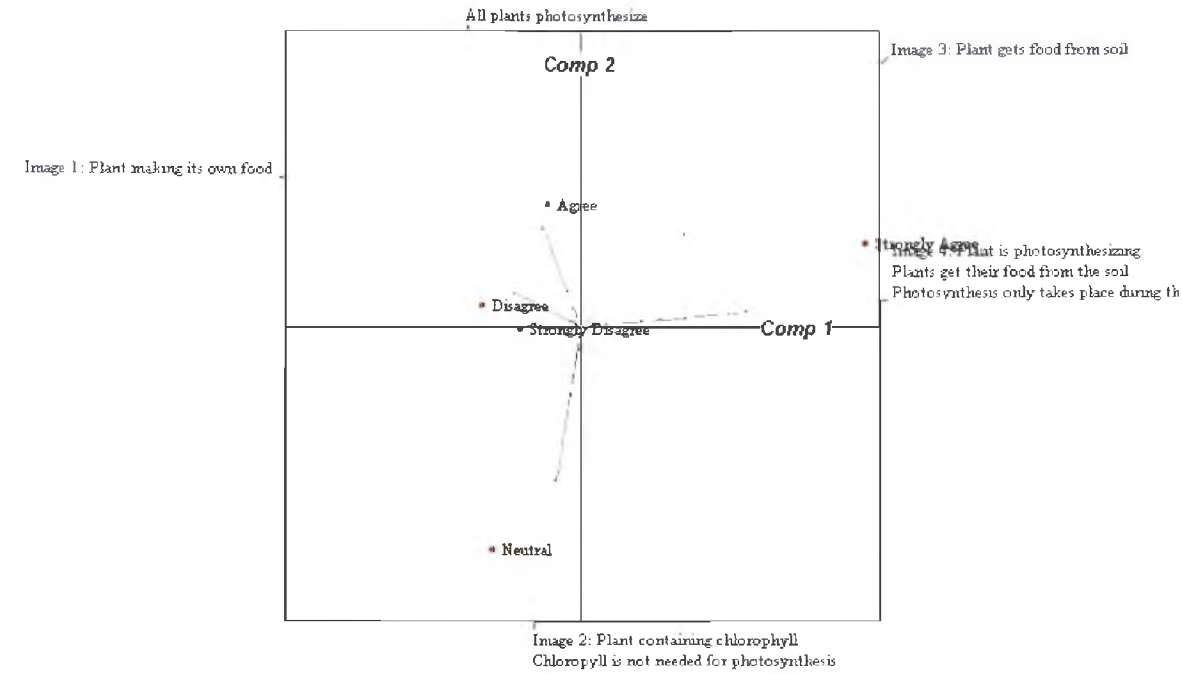


Figure 5.82 PCA varimax rotated graph questionnaire results on PLANTS for MZP6201

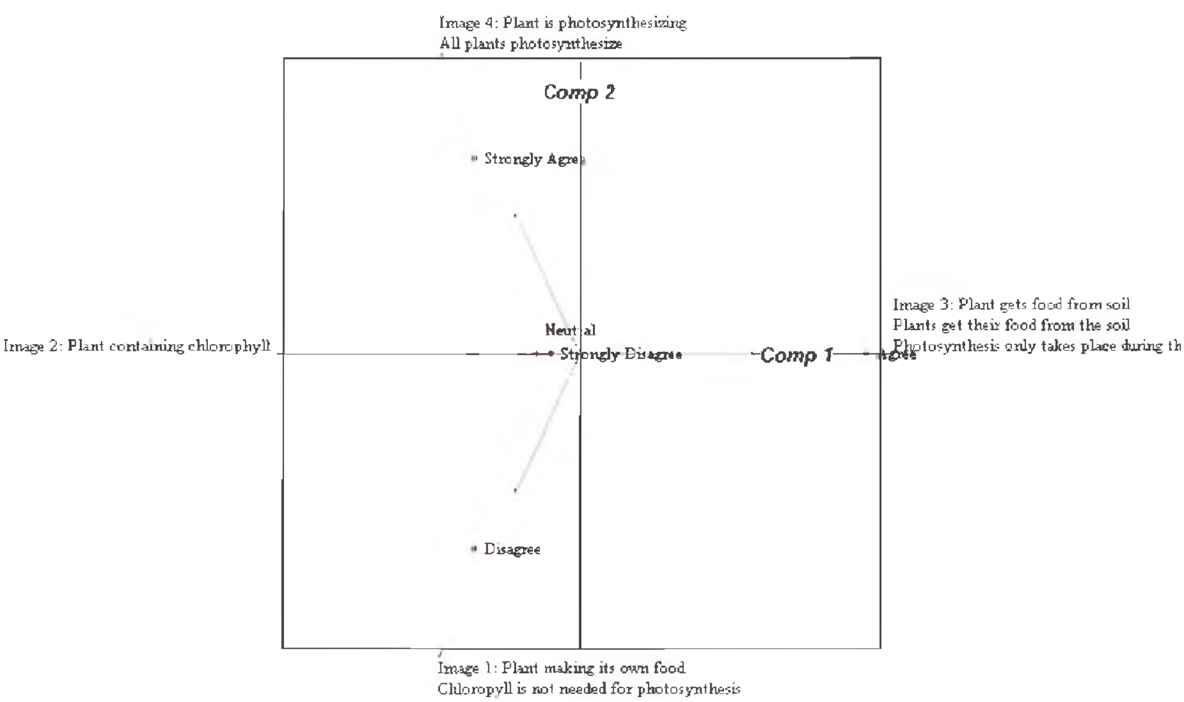


Figure 5.83 PCA varimax rotated graph questionnaire results on PLANTS for PYP6201

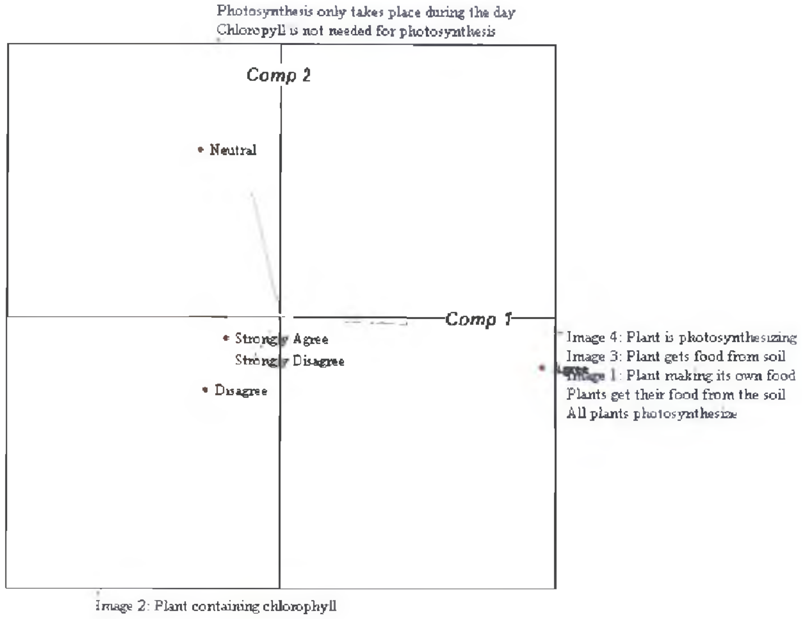


Figure 5.84 PCA varimax rotated graph questionnaire results on PLANTS for LP6201

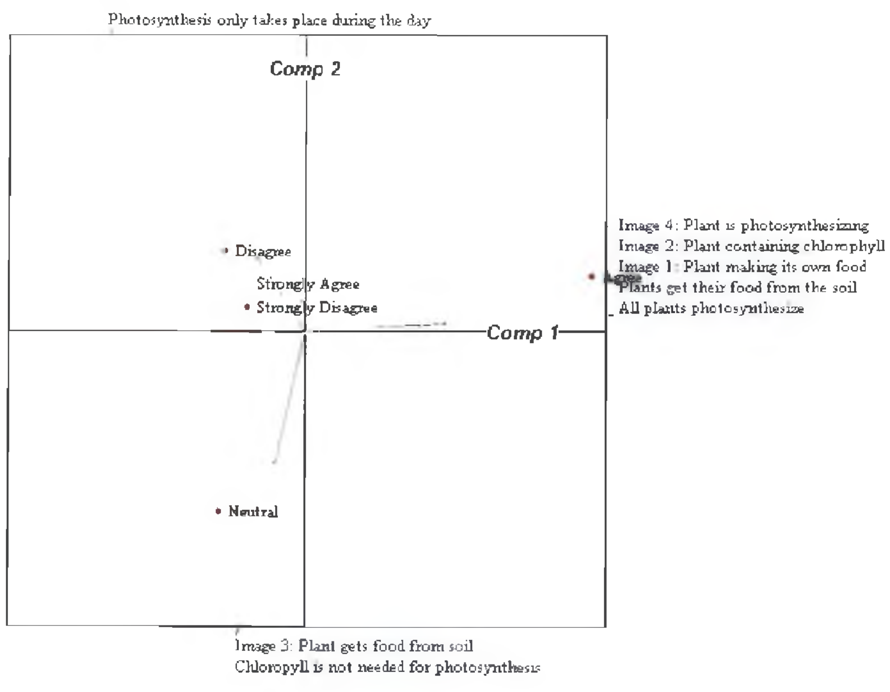


Figure 5.85 PCA varimax rotated graph questionnaire results on PLANTS for EP6201

5.3.2 Conclusion of RGA under PCA

Repertory grid analysis (RGA) under the protocol principal component analysis (PCA) proved to be an integral part of this study. This protocol outlined a detailed grid for analysis of free concept maps, closed concept maps, and questionnaire, which were rated using a Likert scale. Through the grids produced, the author recognised changes from the free concept map to the closed concept map following an intervention lesson.

RGA provided a clear analysis of both the pre-test and post-test concept maps while also highlighting the effect of images on prior knowledge and thinking from the questionnaire. RGA under PCA proved to display an accurate representation of conceptions and indeed alternative conceptions grounded in plant nutrition. Further discussion of the results will be delivered in chapter 6.

5.4 Introduction to Co-ordinate Grid Analysis

Co-ordinate grid analysis (CGA) aims to compare a construct against a construct. CGA is a repertory grid analysis procedure that enables a participant's work to analysed, ranking a set of constructs according to their similarity to each other. Each construct is ranked against all the constructs. The author sought to use CGA to highlight logical inconsistencies and integrative complexities in a student's thinking about the central concept PLANTS. CGA is carried out on each class group according to their pre-test and post-test concept maps produced. Both the magnitude and range of values in individual results through the use of CGA outline the variance in ideas and conceptual links in a single class group. The average values of logical inconsistency and integrative complexity are then outlined in table 5.6 to expose an overall understanding and association between the concepts listed, whereby increases and decreases are outlined across both class groups.

According to Grice (2004) logical inconsistencies are calculated by subtracting the explicit ranks from the implicit ranks, the author then took the total logical inconsistencies figure from a small selection of work. A student may assign a various rank to concepts when compared, giving a non-symmetrical view of two concepts. Comparisons are not always reciprocal.

The author also focused on the total integrative complexity figure created from a small assortment of work. A value other than zero, according to Chambers and Grice (1986), dealing with inter-personal relationships, indicate points of conflict in a person's construct system, and such point of conflicts require resolution. Complexity, too can also be indicative of 'richness' of thinking, since we are dealing with concretistic concepts, some judgement is required to determine if the complexity requires reducing or not. Inconsistencies suggest that a student's perception of PLANTS and the concepts relating to the core idea are not faultlessly consistent logically and single concepts and features may take priority over others.

5.4.1 Results of RGA for class 1 and 2 pre-test concept maps under CGA

Below, table 5.2 and 5.3 display the total logical inconsistencies and total integrative complexity figures in both class 1 and class 2 pre-test concept maps under CGA. In table 5.2, a large figure of the total logical inconsistencies per student is given, highlighting the overall degree of conflict amongst students in the co-ordinate grid.

The author identifies highs of logical inconsistencies that arose in class 1 in TP601 and CP601. Similarly, in class 2, ESP6201, HP6201, KP6201 and MZP6201 displayed levels of logical inconsistency totals above zero also. Grice (2004) however clearly states that no norms exist for what constitutes a particularly high or low level of logical inconsistency.

Table 5.2 and 5.3 also exhibit various levels of integrative complexity in AP601, KP601 and RAP601 in class 1, and MZP6201 in class 2. Values of zero in a selection from class 1 and class 2 specify a rich integration of each concept into the core idea PLANTS in the grid.

Table 5.2 *Class 1 students' pre-test concept maps under CGA*

Class 1 Students' Pre-test Concept maps	Logical Inconsistencies Total	Integrative Complexity Total
AP601	60.00	2.00
CP601	69.00	0.00
EP601	63.00	0.00
IP601	54.00	0.00
ISP601	54.00	0.00
KP601	65.00	8.00
LP601	59.00	0.00
NP601	65.00	0.00
RAP601	52.00	4.00
RP601	57.00	0.00
SAP601	42.00	0.00
SOHP601	57.00	0.00
SP601	49.00	0.00
TP601	75.00	0.00

Table 5.3 *Class 2 students' pre-test concept maps under CGA*

Class 2 Students'· Pre-test Concept maps	Logical Inconsistencies Total	Integrative Complexity Total
ABP6201	55.00	0.00
AP6201	55.00	0.00
AYP6201	59.00	0.00
EAP6201	66.00	0.00
EP6201	60.00	0.00
ESP6201	69.00	0.00
HP6201	67.00	0.00
KP6201	67.00	0.00
MZP6201	67.00	4.00
PP6201	62.00	0.00
PYP6201	63.00	0.00

5.4.2 Results of RGA for class 1 and 2 post-test concept maps under CGA

Below, table 5.4 and 5.5 display the total logical inconsistencies and total integrative complexity figures in both class 1 and class 2 post-test concept maps under CGA. A large degree of conflict continues to exist in the students in both class 1 and class 2 following a post-test structured concept and its analysis under CGA.

Large levels of logical inconsistency exist in KP602 and TP602 in class 1, and undoubtedly in ABP6202 in class 2 also once again highlighting the conflict present in the co-ordinate grid and amongst the selection of students in both classes.

Grice (2004) stated that total integrative complexities are more readily interpreted, values departing from zero can be clearly seen class 1 in IP602, ISP602, RP602 and SAP602. In class 2, only LP6202 indicates a level above zero in integrative complexity indicating less integration of the concepts ANIMALS, REPRODUCTION, GROWTH and PHOTOSYNTHESIS to the core concept PLANTS.

Table 5.4 *Class 1 students' post-test concept maps under CGA*

Class 1 Students' Post-test Concept maps	Logical Inconsistencies Total	Integrative Complexity Total
AP602	58.00	0.00
CP602	66.00	0.00
EP602	50.00	0.00
IP602	56.00	4.00
ISP602	67.00	4.00
KP602	79.00	0.00
LP602	51.00	0.00
NP602	74.00	0.00
RAP602	71.00	0.00
RP602	58.00	4.00
SAP602	67.00	4.00
SOHP602	43.00	0.00
TP602	79.00	4.00

Table 5.5 *Class 2 students' post-test concept maps under CGA*

Class 2 Students' Post-test Concept maps	Logical Inconsistencies Total	Integrative Complexity Total
ABP6202	75.00	0.00
AP6202	67.00	0.00
AYP6202	60.00	0.00
EAP6202	60.00	0.00
EP6202	61.00	0.00
ESP6202	66.00	0.00
HP6202	60.00	0.00
KP6202	60.00	0.00
LP6202	64.00	4.00
MZP6202	62.00	0.00
PP6202	56.00	0.00

5.4.3 Average grids under CGA

Total logical inconsistencies and integrative complexities were used to identify an average of the original grids from the selection in class 1, the experimental group, and class 2, the control group. Below, table 5.6 outlines the average grids for logical inconsistency and integrative complexity in both the pre-test and post-test grids under CGA.

Table 5.6 *Average grids for class 1 and class 2*

Average Grids	Logical Inconsistency (Pre-test)	Integrative Complexity (Pre-test)	Logical Inconsistency (Post-test)	Integrative Complexity (Post-test)
Class 1	59.00	2.00	63.00	1.50
Class 2	63.00	0.00	58.00	0.00

From table 5.6, an increase in logical inconsistency occurred in class 1 between the pre-test and post-test is visible, while a decrease is shown in class 2. The nature of the concept map changed between the prep-test and post-test concept map and this could result in a change in levels of logical inconsistency and integrative complexity in both classes. The pre-test consisted of a free concept map and the post-test consisted of a structured concept map with four branches of concepts, ANIMALS, REPRODUCTION, GROWTH and PHOTOSYNTHESIS which were presented stemming from the core concept PLANTS.

Integrative complexity on average became richer in class 1, while it was 2.00 in the pre-test grid; it then became 1.50 in the post-test, exhibiting a richer integration of the concepts and understanding of their interdependence. Class 2 remained a value of 0.00 regarding their overall integrative complexity.

5.4.4 Conclusion of RGA under CGA

Co-ordinate Grid Analysis was utilised to identify and recognise logical inconsistency and integrative complexity in pre-test and post-test concept maps based on the core idea PLANTS. Students' ideas based on the primary concept were highlighted and analysed using CGA. Individual results from a selection of students' are represented in the tables above, and an average of the grids was also created to give an overall view of the outcome.

From the results, it is clear that large levels of logical inconsistency exist amongst students in both classes 1 and class 2. This highlights the conflict in ideas surrounding the core concept PLANT amongst students in both classes. Levels rose by a small value in class 1 from the pre-test to post-test grids indicating a higher conflict amongst the students. Contrary to class 1, levels dropped by a small value in class 2 throughout the post-test grids.

Integrative complexity outlines the integration of students' ideas with varying concepts based on PLANTS. A value of 0.00 represents an opulent combination of concepts and integration of ideas. This value remained zero overall in class 2 across both the pre-test and post-test. The figure fell in value in class 1 in the post-test from 2.00 to 1.50, representing an overall richer integration of concepts in the four branched concept map as opposed to the free concept map in the pre-test.

5.5 Conclusion of research findings

In this chapter, a selection of free concept maps and closed concept maps has been presented from class 1, the experimental group, and class 2, the control group. A scoring technique was utilised to insert notions and relationships between concepts into Idiogrid (Grice, 2004) and create an opportunity to combine Novak's method of concept mapping with Kelly's repertory grid analysis technique. A variety of grids were produced, using data gathered from a questionnaire also, and the research findings were presented in this chapter.

In the next and final chapter, the author will offer discussion, recommendations and conclusions for the overall study. A number of examples will be employed from chapter 5 in order to carry out a detailed discussion and depict a rich insight into the research findings presented in this study.

Chapter 6: Discussion, Recommendations & Conclusion

It is in fact a part of the function of education to help us escape, not from our own time – for we are bound by that – but from the intellectual and emotional limitations of our time.

T.S Eliot (1916)[11]

In this final chapter, important structural findings will be used as examples from chapter 5, research findings and analysis, and discussed in detail. The results in chapter 5 will be reviewed, significant structural changes will be presented and evaluated, and the researcher will suggest recommendations based on these results. This chapter will also conclude the overall study.

6.1 Comparing pre-test and post-test concept maps

In chapter 5, the researcher outlined a number of examples of pre-test and post-test concept maps by class 1, the experimental group, and class 2, the non-experimental group in order to relate the structure of prior-knowledge and new knowledge. Pre-test concept maps strongly represented concepts relating to growth and plants, however notions surrounding reproduction in plants, the interdependent nature of plants and animals, and photosynthesis in order for plant growth to occur were often absent from the concept map, e.g., KP601 (Figure 5.3). Students began to think about the bigger picture, the environment, oxygen emission and carbon dioxide inhalation as in LP601 (Figure 5.11). The process through which our thoughts are linked is often visible in relation to plants, linking plants to the world around us, and indeed many of the issues we have on Earth, through deforestation and pollution evident in

[11] Influenced by his dissertation "Experience and Objects of Knowledge in the Philosophy of F.H Bradley" and Bradley's monist view of personality, Eliot made this remark on the function of education.

GP601 (Figure 5.5). In EP601 (Figure 5.21), a natural thought process is evident, creating links between plants, the weather, climate change, natural disasters and their effects on animals.

Students used various methods to produce their free-concept maps; some were linear in fashion branching only from the central concept, while others displayed various hierarchical levels of links and associations between concepts. EP6201 (Figure 5.33) exhibit all four concepts visually, similarly KP6201 which displays three concepts in a visual nature also, excluding animals. These particular concept maps demonstrate a visual method of learning and representing knowledge structurally. The free nature of the pre-test concept map resulted in a vast range of complexity across both classes 1 and 2.

Post-test concept maps, or closed concept maps, presented the students with the four concepts, growth, reproduction, photosynthesis and animals, relating to plants which resulted in students from both class 1 and class 2 to think about their inter-relationships with plants. The link between animals and reproduction became evident to students, displaying an understanding of their inter-dependent relationship throughout their closed concept maps, which was also apparent in the grids created as animals and reproduction often were plotted on opposite sides of the grid to growth and photosynthesis. A clear understanding of the concepts and their relationship with plants was often portrayed in the closed concept maps e.g., GP602 (Figure 5.6). In post-test concepts maps, e.g., ABP6202 (Figure 5.38) and HP6202 (Figure 5.42), the link between growth and photosynthesis grew stronger, so too the association between reproduction and animals, however cross-links between the four concepts relating to the core concept became less prominent.

6.2 Significant structural and conceptual changes in pre-test and post-test concept maps

Significant structural changes occurred in a selection of pre-test and post-test concept maps. Pre-test concept maps, or free concept maps completed by students varied greatly in structure and indeed complexity. Cluster maps or 'webs' displaying hierarchical links between conceptions were prevalent while 'radical' or 'spoke' concept maps were also presented by the participants in the study. Cross-links were similarly a feature across conceptual areas relating to plants and features of chain or linear concept mapping also existed in pre-test, free concept maps.

While free concept maps presented a student with the opportunity to construct-a-map, post-test or closed concept maps provided a 'skeleton' map with four concepts relating to plants, growth, reproduction, animals and photosynthesis, as branches from the core idea. The author offered a scaffold upon which students build. In this instance, concept maps were more 'radical' or 'spoke' shaped in nature, with notions stemming from each individual branch. 'Chains' or linear shaped concept maps were also evident, however once again chains only existed from single branches. Cluster maps or 'webs' were absent in the production of closed concept maps both in class 1 and class 2.

In RP601 (Figure 5.7), links were made between growth, reproduction and animals while photosynthesis was seen as an important individual process relating to plants. In RP602 (Figure 5.8), all four concepts were now present including photosynthesis, which had been previously omitted. The student recognised that photosynthesis is the process by which a plant makes its own food. While growth and reproduction are undoubtedly linked to the core idea plants, a string of consciousness begins, similar to KDP602 (Figure 5.16), when the student is presented with the branch labelled animals and the bond between plants and animals is not solely recognised.

EP601 (Figure 5.21) displays a string of consciousness far greater than the central concept plants, presenting natural disasters and climate change in a pre-test, free concept map, excluding the idea of plant reproduction. EP602 (Figure 5.22) continues to display concern for ideas far greater than the core concept, plants, itself. A thread of consciousness is presented ranging further once more to the laws of gravity and the links between science, smartphones and the Internet. A greater understanding of the four concepts is presented in the post-test concept map, recognising photosynthesis as essential for both human and animal survival through oxygen production. An understanding of plant reproduction is displayed and the features necessary for growth to take place are also existent.

RAP601 (Figure 5.19) presented an alternative conception in the growth of plants, with no reference to photosynthesis made in the pre-test concept map. A detailed map of cross-links is apparent however. RAP602 (Figure 5.20) recognises photosynthesis in the post-test concept map as almost central to plants and links associated with growth, animals and photosynthesis itself stem from the branch labelled photosynthesis. Although the post-test concept map presents specific links, overall cross-links between concepts have been reduced due to the branching system of the closed concept map.

EP6201 (Figure 5.33) represents a pre-test concept map visually using images including all four concepts on the map. Plant reproduction and animals are represented visually however they are not directly linked to the main concept. In the post-test concept map created by EP6202 (Figure 5.34), the process by which photosynthesis takes place is recognised however alternative conceptions exist in plant reproduction. Visually, the pre-test concept map consisted of correct information while alternative conceptions become prevalent in the post-test, closed concept map.

HP6201 (Figure 5.41) displays connections between the concepts growth and photosynthesis only, like EAP6201, the conditions necessary for growth to occur are present. Links stem from the core concept only. In HP6202 (Figure 5.42), growth, reproduction and photosynthesis are inextricably linked while growth and photosynthesis continue to form a strong relationship in the post-test concept map. In comparison, the post-test concept map offers a more detailed outline of the four concepts presented.

6.3 Evaluation of the changes in pre-test and post-test concept maps

The structure of the concept map held varying results for students depending on their learning style, which was in turn evident through the conceptual structure created by the participant (e.g., visual maps created, cluster maps) and informed by literature. The pre-test concept map provided students with a blank canvas, an opportunity to exhibit prior conceptions and further explore the main concept plants. The post-test concept map, although not fully closed, provided a scaffold for which the student could build. Cluster maps, 'radical' or 'spoke' concept maps and linear concept maps were structurally evident in pre-test concept maps however cluster maps or 'webs' were no longer a structure employed by the student in post-test concept maps. The progression from the free concept map to the closed concept map is displayed through a heightened sense of each concept individually, displaying overall a greater understanding and insight into each concept. Although fewer cross-links appeared visible in the post-test concept maps, a fuller integration of concepts was presented by class 1, following CGA.

The closed concept map consisted of more 'closed' ideas. Only when uncertainties relating to certain concepts exist, were natural thoughts exhibited. For those who learn visually, the closed concept map hindered their prior conceptions, lessening the information provided by the student and creating alternative conceptions relating to plants. Those who displayed a greater concern for issues outside the domain of plants, continued to express their string of consciousness, however these thoughts were only expressed when uncertainty existed in the area of plants relating to animals.

Pre-test concept maps for both class 1 and 2 analysed under PCA displayed little reference in many cases, or no reference in some cases, to the concepts denoting animals and reproduction in the grids produced. Post-test concept maps under PCA exhibited the undeniable association between growth and photosynthesis; however other concepts were often represented on the grid as stand-alone processes, linked only with plants.

CGA was used to indicate stability in the sample. A modest increase in logical inconsistency and conflict was observed from pre-test to post-test concept maps in class 1, while a small decrease was presented in class 2, the non-experimental group. The experimental group, class 1, now presented a higher level of conflict in their ideas, however class 2, the non-experimental group having participated in rote-learning style lesson presented a lesser degree of conflict. As mentioned above, a richer integration of concepts became evident in class 1, whereas class 2 remained complex in their integrity. Due to the qualitative nature of this study, as outlined in the methodology, no test significance was pursued in such a small group.

Following a varying intervention lesson, an improvement in 'correct' conceptions in both class 1 and class 2 is evidently displayed in both the pre-test and post-test concept maps and grids produced using repertory grid analysis. However, the post-test concept map left little room for 'thinking outside the box' and displayed only a list of learned ideas relating to plants. This is especially apparent in class 2, the non-experimental group, having experienced a 'rote-learning' style lesson.

6.4 Questionnaire and repertory grids

In this chapter, the researcher wishes to discuss also the questionnaire completed by both class 1 and class 2 following a free concept map based on the core concept PLANTS. The questionnaire, consisting of both questions and images was ranked according to a Likert scale (1932).

Upon analysing the questionnaire, it was found that images tended to over-ride thinking. Images have a strong impact on choice of answer and change answers in many cases to strengthen an alternative conception even further – especially when presented with image of a plant in a pot of soil "making its own food". In some instances, the image of a plant in a pot of soil changes the previous thoughts and answers completely. In each case, students felt certain of their previous perception and continued to agree with the statement "plants get their food from the soil". In many cases, students felt more certain of their alternative conception when an image was presented and in a number of cases gave a stronger view, highlight their conception even further through moving up the scale, ranging from 'neutral' to 'agree' and from 'agree' to 'strongly agree'.

On a particular occasion, a student showed uncertainty whether a plant gets its food from the soil or not, giving a 'neutral' answer. However, when presented with the image, the student felt more certain to disagree with the statement. Alternative conceptions still prevailed however as although the student now felt more certain that a plant did not get its food from the soil, they also disagreed that a plant makes its own food, leaving behind uncertainty. Images proved to reinforce both preconceptions and alternative conceptions right throughout the questionnaire section of the study.

6.5 Effects of teaching and learning on pre-test and post-test concept maps

As an educator, one must be acutely aware of students' different learning styles and individual understanding. Osborne and Hennessy (2003) state "teaching about science" rather than simply teaching the content from the curriculum is the future of teaching and learning. Class 1 responded positively towards a "hands on" and "minds on" (Pines, 1985) lesson, integrating active teaching methods with ICT and as a result a lower level of conflict is shown through post-test concept maps under CGA. Students who portrayed natural thought processes in pre-test concept maps, continued to do so in their post-test concept maps however only when uncertainty around a concept existed. Although class 2 remained at the same level in their integrative complexity, a higher level of inconsistency was prevalent. Students who presented visual methods of learning presented a structurally less efficient concept map, displaying alternative conceptions regarding plant nutrition. A significant change was made by many students, visible in the pre-test and post-test concepts, however while a selection of students benefitted from the scaffold existing in the post-test concept maps, others were hindered and the knowledge and structural conceptions presented were lessened in comparison to a previous free concept map.

Through close study of the pre-test and post-test concept maps, a range in complexity of the concept maps in both class 1 and class 2 is both visually and analytically unmistakeable, emphasising a mixed ability classroom. Bingimlas (2009) discussed the importance of ICT in education and the barriers that exist in relation to integration of ICT in teaching however he also suggests that "no one component in itself is sufficient to provide good teaching". Although there were evidently students in class 1 who benefitted from a "hands on" interactive approach to learning, the same can be said of those students in class 2 who benefitted from a textbook approach. Fensham, Gunstone and White (1994) discuss the way in which teaching and learning are driven by "social forces" and continue to change, and although a decade has passed since the writing of those words, they have never been truer.

6.6 Addressing the aims of the research

The research question is indisputably the purpose of this thesis, whereby the structures of students' conceptual prior-knowledge and new knowledge would be examined through the use and innovative combination of Novak's method of concept mapping and Kelly's technique of repertory grid analysis. The aims of the thesis were to investigate children's preconceptions and alternative conceptions of scientific concepts, photosynthesis in plant nutrition, and examine whether a method of teaching had an effect on the gaining of new knowledge in a positive or negative manner. Another aim of the research was to examine the way in which children learn in science and improve the teaching and learning of science in the primary classroom.

A novel adaption of RGA in combination with concept mapping in science education was also presented by the author and a scoring method enabling concept maps to be analysed using Kelly's repertory grid technique was created. The grouping of such methods proved to display similar connections between concepts using different structural means. The author wished to present a detailed study of the structure of a child's conceptions in science education in the area of plant nutrition through visual and analytical means.

This study has highlighted subsidiary concerns for the effect of images on learning in science education, and it was found that images hold an influential position in our learning and over-ride thinking in many instances, i.e., they are subject to cultural constraining. Images possess the ability to shape and change our thinking.

6.7 Recommendations and further study

Although Kelly's personal construct theory and repertory grid analysis technique have been widely used by researchers for a broad range of studies, there has been little or no study involving the combination of Novak's method of concept mapping with Kelly's repertory grid analysis technique in photosynthesis primary science education. It is hoped that the researcher's study of structural conceptions in primary science through the application of repertory grid analysis in combination with concept mapping, more research will be carried out using this distinctive combination of method and technique and a more accurate and holistic structure of a student's learning will be more readily available.

This thesis was concerned with a child's structural learning in science education, primarily in the area of plant nutrition. It is envisioned that this method of research could be applied to many areas of study, particularly in the way in which children learn. From this study, no one method of teaching and learning suited each individual student, which strengthens the notion that as educators, a variety of methods must continue to be employed each day in order to enable each child to reach their full potential.

In a number of cases throughout the questionnaire on plant nutrition and photosynthesis, students tended to use agree or disagree and veered away from using the 'strongly' term in many instances. Many students did not use a variance of scale; this may be due to an uncertainty of how the scale works. As a result, a new scaling system should be presented in the future studies.

In terms of using concept mapping into the future, the author would also recommend the employment of freely available concept mapping software, e.g., CmapTools (Cañas *et al.*, 2004b) in teaching and learning in the primary classroom to construct concept maps based on specific areas of study. Teachers also need to be given further training in concept mapping techniques; especially the ways in which this method can be incorporated into normal everyday class teaching across a range of curriculum areas.

6.8 Conclusions: The future of learning and science education

Osborne and Wittrock (1983) discussed the growing awareness among science educators for the way in which children learn, build conceptions and ideas of the scientific world around them, and this is essentially, an overview of constructivism. This study aimed to build a methodology of using visual representations of children's conceptions in plant nutrition through the combination of repertory grid analysis and concept mapping to triangulate the structures of concepts.

Science education is a fundamental part of the Primary School Curriculum (1999), as educators, it is our responsibility to set about improving the quality of our teaching and learning. Similar to Kelly (1979) and his strive for "personal meaning" in education, Dignath and Büttner (2008) argued that students should be responsible for their own learning and engage in "self-regulated learning". The traditional paradigm is merely to ask: "Do kids know facts? Or do they not know facts?" Looking at the structures of concepts enables one to see if they've got it and how the concept was formed. The free concept map enabled students to be responsible for their own learning, portraying a natural thought process of notions far greater than a single strand in a curriculum, yet stemming from a solitary strand - plants. Personal meaning was displayed through various methods of presenting a free concept map, whereas a scaffold provided students with limitations to where their thoughts could go.

This thesis outlined that although alternative conceptions were present in a selection of student's pre-test concept maps, new knowledge and structural conceptions became evident in post-test concept maps and the structures of the learners' conceptions. Kuhn (1993) urges educators to keep "natural" curiosity alive in the primary classroom; it is this curiosity that forms the basis for future theorists and scientists alike. It seems fitting to complete this thesis in the words of Kelly, whose ideas and theories have so heavily inspired this thesis. It serves us well to remember that "...no one needs to be the victim of his biography" (Kelly, 1955 p. 15). We can build upon what we know each day, we are not restricted, for we are all still learning.

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