A Study of Learners Conceptual Development in Mathematics in a Grade Eight Class Using Concept Mapping

by

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Submitted in partial fulfilment of the academic
requirements for the degree of
Master of Education in the
School of Science, Mathematics, and Technology Education
Faculty of Education
University of KwaZulu-Natal

February 2009

ABSTRACT

This study encompasses the use of concept maps to investigate learners' conceptual understanding of mathematics of a grade eight class in the predominantly Indian suburb of Shallcross. The grade eight learners that were the participants of this study were in the secondary school for the first time. They were in the middle of the Senior Phase within the General Education and Training Phase of their schooling career.

This study is embedded in an action research methodology and is conducted from an interpretivist paradigm. Operating on a mixed methods theory, concept maps constructed by learners were analysed through the duration of the study. Towards the end of the study learners completed a questionnaire. Based on certain responses in the questionnaire and the analysis of the concept maps, six learners were then selected and interviewed to probe learners' conceptual understanding of concept maps.

The results of the study reveal that most learners find concept maps enjoyable, fun and a creative way to learn mathematics. Further analysis of the questionnaire indicates that learners enjoy the social dynamics that group work provides and they found that working together also enhances their understanding. Further analysis of individual and group concept maps reveals that group work is effective in the use of concept mapping.

The results of the study suggest that concept maps might be successfully used in assessing learners' declarative knowledge. An important implication of this study is that concept maps can be practically and effectively applied to a variety of outcomes within the constraints of the classroom.

PREFACE

The work described in this thesis was carried out in the School of Science, Mathematics and Technology Education, University of KwaZulu-Natal, from July 2008 to February 2009 under the supervision of Dr V Mudaly (Supervisor).

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

Urmilla Moodley

February 2009

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ACKNOWLEDGEMENT

My heartfelt thanks are extended to

My supervisor, Dr V. Mudaly for your time, patience and guidance.

To my principal, Mr G. M. Govender

Thank you for your encouragement and support.

To grade 8B of 2008

I cannot thank you enough for being such enthusiastic participants.

To my dear friends at my school in Shallcross,

Sherri, Simmy, Rani, Veni, Jayshree, Vaneshree and Karunai

My sincerest gratitude for giving me your valuable time so generously

To my darling husband,

Who supported me unquestioningly throughout the writing of this thesis.

You were unwaveringly helpful despite the barrage of questions

I plagued you with.

I thank you for not abandoning me despite being busy

with your own thesis.

To my loving sons, Jashlin and Drishend.

Thank you for helping me with the household chores

That afforded me the time to complete this thesis.

My unbounded gratitude also for your invaluable technical

assistance with the computer.

To my wonderful mum,

Thank you for making me believe that I can achieve anything my heart desires.

You are a true inspiration.

DEDICATION

This thesis is dedicated to three truly special gentlemen in my life, my husband and two adorable sons. Your respect and appreciation for knowledge motivates me to no end.

CHAPTER 1

INTRODUCTION TO STUDY

The focus of this study is to assess the benefits of using the concept map method for teaching and assessing learners' conceptual knowledge in mathematics of grade eight learners at a previously disadvantaged school in Shallcross. Present practices in mathematics classrooms concentrate on symbols, notations, rules and mechanical procedures. This method does not promote effective acquisition, retention and transferability of mathematical concepts. Often this results in great anxiety and apathy in the learning of mathematics. I believe that novel and appealing methods that promote conceptual development should be utilized. This is not just a personal belief as the Revised National Curriculum Statement (RNCS) encompasses such thinking (2003). Past studies reveal that concept mapping is a visually appealing method to both teach and develop learners' conceptual knowledge.

I love teaching mathematics and I want my learners to love learning mathematics. I therefore decided to conduct a study to determine whether an alternate method of teaching and learning would help learners understand mathematics better. Hence my research is to explore learners' conceptual development using concept maps in a grade eight class. My interest in this field was sparked by a lecture on visual literacy delivered by Dr Mudaly (2007). He exposed us to the various ways of using visual representations to engage the interest of learners in mathematics classes. Concept mapping provides a non-competitive way to illustrate conceptual understanding and meaningful learning as opposed to the rote learning of procedural knowledge.

1.1 IMPLICATIONS OF REVISED NATIONAL CURRICULUM STATEMENT

After the first democratic elections in 1994 reform initiatives were launched at schools. One of these reform initiatives was the Outcomes Based Education (OBE). OBE now forms the foundation of the curriculum in South Africa. According to the Revised National Curriculum Statement (2003), OBE strives to make all learners reach their full potential by adopting a learner-centred, activity-based approach to teaching. This translates to a constructivist approach to teaching and learning where understanding is the foundation for all learning.

The changing milieu of South African Education demands an in-depth look at instructional practices in the classroom. Although it has been almost fourteen years since the introduction of OBE and the first cohort of matriculants have completed their exams in 2008, many educators are yet to embrace the principles underpinning OBE, where group work activities are encouraged, research tasks implemented and fun-filled activities that engage learners in meaningful learning are expected. The previous curriculum promoted rote learning as opposed to meaningful learning. According to Ausubel, Novak and Hanesian (1968) to learn meaningfully, learners must relate new knowledge to relevant concepts and propositions they already know, whereas in rote learning new knowledge may be acquired simply by verbatim memorisation and incorporated into a learners' knowledge structure without interacting with the previous knowledge that already exists (Novak & Canas, 2006). Novak (2002) argues that rote learning has two negative consequences. First, knowledge learnt by rote is easily forgotten, unless rehearsed frequently. Second, the knowledge or cognitive structure of the learner is not enhanced or modified to clear up ideas that are misunderstood. Novak (2002) explains further that rote learning allows misconceptions to persist and as a result knowledge learnt has little or no potential for use in further learning.

Novak and Canas (2006) believe that the concept map is a powerful tool that can be used to facilitate meaningful learning. They assert that concept maps serve as a kind of template or scaffold to help organise conceptual knowledge in small units of concepts that are build on by using linking words to join other concepts. Many teachers and learners see the benefit of this simple tool to facilitate meaningful learning that not only allows the creation of powerful knowledge frameworks that represents both pre-existing knowledge and new knowledge but also aids in the retention of knowledge (Novak, 2002).

1.2 AIMS AND OBJECTIVES OF THIS STUDY

The purpose of this study was to investigate learners' conceptual development in mathematics in a grade eight class. To achieve this, this study focussed on the question: Can concept maps be used to explore learners' conceptual development in mathematics? To fulfil this intention, formulated the following objectives to guide this study:

1. What are the advantages and disadvantages of using concept maps to teach mathematics? – A literature perspective.
2. Can concept maps facilitate group-work?
3. Are concept maps an effective learning tool for mathematics for grade eight learners?
4. Can concept maps provide valid information for the teacher about learners' knowledge of mathematical concepts?
5. How can concept maps assessments be practically applied to classroom

situations?

6. Do concept maps develop grade eight learners' conceptual understanding through the comparison of successive concept maps?

Since the purpose of this study is to find solutions to a social challenge, in particular a teaching method that will help learners' understanding of mathematical concepts, the study is embedded in an action research methodology. Grade eight learners were chosen to be part of the study as they are young learners and I believe that of them most probably had not become comfortable with any particular learning strategy as yet.

My study embraced the interpretivist paradigm since it was characterized by my concern to understand from within, learners' conceptual change of mathematical knowledge. A mixed method approach was utilized since it contains elements of both qualitative and quantitative methods to explore learners understanding using concept maps. In this study learners were involved in designing concept maps, which were then scored against a set of criteria. The content of concept maps were also qualitatively analysed. This was followed by a short survey in the form of a questionnaire administered to the whole class. The questionnaire (quantitative part) was designed to get a general idea of how learners felt about concept maps and whether they were comfortable using it in mathematics. A sample of six participants was thereafter chosen according to a set criterion, for the semi-structured interview (qualitative part). The purpose of the interview was to explore an in depth description of learners' perceptions regarding the use of concept maps.

Furthermore a comparison of concept maps done at the beginning and end of the study was examined in terms of the structural complexity to ascertain learners' conceptual development. A comparison of individual and group designed concept maps was also examined to determine the cognitive and social benefits of group work.

1.3 THE STRUCTURE OF THE STUDY

The introduction served to acquaint the reader with the motivation, background and data collection techniques of this study. The literature review in chapter two examines past and current trends in the use of concept maps both locally and abroad. It also highlights gaps and contradictions in past research that my study will endeavour to clarify. The theoretical and conceptual framework from which concept mapping is derived is discussed in chapter three. Chapter four discusses the underlying philosophical assumptions, the selection of participants, the data producing techniques and the type of data analysis. The qualitative and quantitative analysis of concept maps, analysis of the questionnaire and interview form the basis of chapter five. The final chapter provides a further discussion of the analysis; recommendations for the classroom practitioner and the limitations of this study conclude this thesis.

CHAPTER 2

LITERATURE REVIEW

The intention of this study is determine learners' conceptual development through the use of concept maps; this chapter begins with a brief history and development of concept maps as a tool for examining conceptual development. This is followed by a report of the extensive research done in the use of concept maps firstly, as a graphic organiser, secondly as a tool for teaching and learning, and finally as an evaluative tool in mathematics. I will also discuss the use of individually and co-operatively designed concept maps. I will end this chapter with the benefits and limitations of concept maps drawing from the vast literature available on concept maps.

2.1 A BRIEF HISTORY OF CONCEPT MAPS

Concept mapping as a research and an evaluation tool in science education is almost 35 years old. This technique had its origin at Cornell University. Under the leadership of Novak and his graduate students concept maps was used as a vehicle to explore meaningful learning acquired through-tutorial instruction in elementary school science (Novak, 1977). Since then concept maps has become a widely used strategy for assessing the structural complexity and propositional validity of knowledge in science-related fields (Novak & Gowin, 1984). A concept map is a visual technique that employs a two dimensional, hierarchical, node-link representation that depicts the major concepts found in a particular domain of knowledge. In a concept map, concepts are enclosed in an oval or any other shape that is appropriate to that learning domain. Lines are drawn between concepts and the linking phrase along the line indicates how the concepts are related to each other. This is known as a proposition. Novak and Gowin (1984) believe that concept maps is an overt representation of a learners internal knowledge structure and at the same time acknowledge the difficulty of judging the degree of correspondence between the map and actual internal representation. Recent studies indicate otherwise, see 'Theoretical and Conceptual Framework' under sub-section 3.3.

Using Ausubel's theory (Ausubel, Novak & Hanesian, 1968) that understanding occurs through the linking of new knowledge to existing knowledge, Novak (1977) proposes a hierarchical representation of concept maps, where the most general idea of the topic is at the top of the concept map and progresses to more specific concepts and ends with examples which are not enclosed in some shape as they are not concepts (Novak & Gowin, 1984). The map also includes cross-links such that relations between sub-branches can be identified. Concept maps are underpinned by major psychological theories of prior learning, assumption, progressive differentiation, cognitive bridging and integrative reconciliation which is designed to help learners reflect upon their own experiences and to construct new and more powerful meanings to knowledge (Ausubel & Robinson, 1969). It is important that learners construct the concept maps as the complexity of the knowledge network directly relates to the degree of learners understanding and linking words reveal whether or not students correctly associate the concepts.

Although Novak and Gowin (1984) adhere strictly to hierarchical concept maps, there are other researchers that hold alternate views. The associationist theory provided a basis for cognitive structure where concepts are represented as nodes, however the linking lines were unlabelled (Deese, 1965). This led to semantic networks where the concepts were linked by labelled lines (Ruiz-Primo & Shavelson, 1996). The associationist network theory like concept maps has it theoretical underpinnings in Ausubel's theory. The important difference is that semantic networks do not emphasise the hierarchical structure of networks. White and Gunstone (1993) argue that whether or not a concept map is hierarchical depends on the structure of the subject material. Buzan and Buzan (2003) propose another approach to learning known as mind mapping. The mind map has a central image from which main themes of the subject radiate as branches. Branches comprise of key words or images on an associated line. Topics of lesser importance are attached to higher-level branches. Based on this theoretical approach the concept maps used in this study are networks with concept nodes linked by lines that are labelled indicating the relationship between the concepts and are not necessarily hierarchical.

A review of the literature reveals that concept maps has been extensively used to describe a variety of outcomes. A primer study by Novak employed concept maps as a meta-learning tool. This means, "to help learners how to learn" (Novak, 1984, p8). This study showed that concept maps serves as an effective means of empowering students through knowledge of their own learning. A significant number of studies have examined the use of concept maps in science learning Novak (1990), Rice, Ryan and Samson (1998), Ruiz-Primo (1996), Wandersee (1990), Markow (1998). Many studies have also been conducted in the biology field too, Wallace and Mintzes (1990) and Markham, Mintzes and Jones (1994). These two fields have based their studies on using concept maps as a heuristic in promoting meaningful learning in a variety of instructional settings. In mathematics, concept maps has been used abroad as a research tool to understand learners conceptual change in functions (Williams, 2002). Karoline Afamasaga-Fuata'i (2004) tracked the conceptual development of six learners whilst learning and solving problems for selected new topics, Ozdemir (2005) analyzed concept maps as an assessment tool for mathematics. Leou and Liu (2004) used concept maps to develop an educator's mathematical professional knowledge through a period of eight years.

2.2 LOCAL STUDIES USING CONCEPT MAPS

Locally Mwakependa and Adler (2003) used concept maps as a tool to explore first-year university students' understanding of key concepts in the South African secondary school mathematics curriculum. After concise instruction in concept map construction students were expected to construct a map of 16 concepts. These concepts were selected because they cut across the algebraic, numerical, graphical and geometric settings of the mathematics school curriculum. The aim of the study was to determine whether students could link concepts across topics that are typically fragmented in the curriculum. Thereafter interviews were conducted. First, to establish a link between concepts, which students did not include in their maps, and second, to probe students thinking, to clarify meanings of links displayed in students' concept maps. Mwakapenda (2003) asserts that since students showed uncertainty about the links they used, may be an indication that learners understood the concepts whilst they were engaging with these topics at school but could not recall them after school. He justifies these findings by stating that many classroom practitioners teach mathematics as an unrelated body of facts and algorithms. My study delves into a conceptual development of learners in mathematics using concept maps. However, my study is classroom based.

Qhobela, Rollnick and Stanton (2004) conducted a four-stage intervention in the Science field at Lerotholi Polytech in Lesotho. The students that participated in this study were enrolled in a bridging programme aimed to fill in gaps between secondary level and tertiary level science. Here I reviewed the first stage of this intervention, which the researchers called the Conceptual Foundation Phase. The purpose of this programme was to get learners to talk or write and reach a consensus about a particular concept. Learners were given a concept map and they had to discuss the relationships between concepts, whether they were valid or not and finally make improvements on the maps. The findings from this study concur with that of Mwakependa and Adler's (2003) observation that concept maps were largely linear and have virtually no cross-links. However this study benefited the students in other ways. One, students were able to discuss and reach agreement about concepts and their relationship with other concepts. Two, rehearsing knowledge from secondary school allows learners to share meanings of scientific concepts. The literature does not specify the time spent on the technicalities of constructing a concept map. All the literature on concept maps point out that concept maps are different from other activities and learners have to be taught how to draw them. If they were not given this instruction on concept map construction then these researchers should not expect elaborately networked concept maps that include cross-links.

2.3 CONCEPT MAPS AS GRAPHIC ORGANIZERS

According to studies conducted by Willerman and Harg (1991) concept maps can also provide the classroom teacher with a meaningful and practical structure for using graphic organizers in their class. Graphic organizers may be defined as an instructional unit that is used before direct instruction, or before a new topic is introduced to assist the educator when introducing the more challenging topics (Hendron, 2007; Willerman & Harg, 1991). The effectiveness of using concept maps as graphic organizers is that the concept map developed by the teacher gives the learners greater direction for learning concepts and facts as compared to teacher talk objectives in the unit (Willerman & Harg, 1991). Moreover concept maps constructed by the educator will serve to familiarise learners with the techniques of constructing concept maps hence building learners' confidence in the use of concept maps.

2.4 CONCEPT MAPS AS A METALEARNING TOOL

Another aim of my study is to determine whether concept maps are effective learning tools for mathematics in a grade eight class. I will now review the literature of concept maps used in this area. Novak and Gowin's (1984) primer study was aimed at helping students 'learn how to learn'. They claim that as educators it is our responsibility to organize instructional material in a manner that is easy to learn. Novak (1990) found that concept mapping together with other metacognitive tools played a key role in helping students take charge of their own meaning making. Novak and Gowin (1984) claim that for too long educational theory has been influenced by behaviourism - a theory that emphasizes rote learning and verbatim instruction.

These authors suggest an alternate view to learning, one that is synonymous with meaningful learning where learners make sense of educative materials and discover knowledge for themselves. The authors discuss two principal educational tools to bring about meaningful learning– concept maps and Vee diagrams. They argue that concept maps and Vee diagrams help students to construct new and powerful meanings through classroom strategies that invoke meaningful learning.

2.5 STUDENT SUCCESS WITH CONCEPT MAPS

Of interest to me is the anxiety associated with the learning of mathematics and the associated apathetic attitude of learners towards mathematics. According to White and Gunstone (1993) learners rarely view concept map activities as competitive threats, although the intellectual demand cannot be denied. They add that no map is so poorly done that it can be preordained as completely incorrect. Furthermore no two maps are the same or perceptibly better than another. Hence the anxiety associated with traditional tests is rare during concept map activities. White and Gunstone (1993) therefore claim that the friendly nature of the concept map to probe understanding is a preferable tool to use in the teaching of mathematics. A study to support the non-threatening nature of concept maps was conducted in Nigeria by Jegede, Alaiyemola and Okebukola (1990). Their study had two groups; one group received conventional lecture-type instruction whilst the other group used concept map tasks. An important aspect of their research focussed on students' anxiety toward science. They used the Zuckerman's Affect Adjective Checklist to determine students' levels of anxiety and found that students using concept mapping displayed a highly significant reduction in anxiety levels.

2.6 CONCEPT MAPS REVEAL ALTERNATE CONCEPTIONS

Trowbridge and Wandersee (1998) report that concept maps are useful in identifying misconceptions. They explain that the presence of incorrect linkages that result in invalid propositions is evidence of misconceptions. Moreover inclusion of irrelevant concepts or concepts that are not related to the super ordinate concept is another indication of misconceptions. Missing concepts further signify gaps in learners' knowledge structure. Hence White and Gunstone (1993) assert that since concept maps elicit the relations learners see between concepts, they therefore reveal the degree of understanding of individual concepts as well as the whole topic. Concept maps for that reason serve as a powerful diagnostic tool that assists the teacher in making judgements about their method of instruction. Instructional techniques can be revisited to fill in the gaps where concepts have not been fully developed and to rectify misconceptions.

2.7 CONCEPT MAPS AS A TOOL TO DETERMINE LEARNERS' CONCEPTUAL DEVELOPMENT

Not only does concept mapping foster active engagement of learners, but is also an invaluable tool to measure changes in knowledge structure (Novak, 2002). Carey (1986) recommends the comparing of successive concept maps in determining knowledge acquisition. Wallace and Mintzes (1990) used concept maps to explore conceptual change in biology. There findings reveal that concept mapping offers a valid and useful mechanism for looking at changes in learners' cognitive structure. Novak (1990) conducted a 12-year long longitudinal study, which demonstrates that concept maps can be used effectively in analysing conceptual change over long periods of time. Williams (1998) investigated the conceptual knowledge held by college students in the domain of functions. Comparison of expert and novice concept maps lends credence to the conclusion that concept maps do represent to a degree, one's conceptual knowledge.

2.8 ASSESSING UNDERSTANDING WITH CONCEPT MAPPING

As an assessment tool, concept maps can be thought of as a procedure to measure the structure of a students' declarative knowledge (Ruiz-Primo & Shavelson, 1996; Royer, Cisero, & Carlo, 1993). The literature indicates that any particular age group of learners can use concept maps. Research reports indicate that learners from primary school are capable of constructing and explaining concept maps (Novak & Gowin, 1984; Novak, 1990; White & Gunstone, 1993). Researchers have also completed successful studies using concept maps with middle school (similar to our GET band) learners (Novak & Gowin, 1984; White & Gunstone, 1993; Willerman & Harg, 1991). There is also evidence that learners of various ability levels can become good concept map drawers. Previous research illustrates that concept mapping can be easily learnt and applied to large groups without any difficulty hence making it ideal for classroom settings (Ruiz-Primo & Shavelson, 1996). White and Gunstone (1993) suggest that concept maps not be scored whilst Novak and Gowin (1984) provide an elaborate scoring guide. White and Gunstone (1993) advise that the choice to score or not to score depends on the "purpose for which the scores are needed" (p39).

2.8.1 Assessment using Concept-maps in the mathematics field

Relatively few studies have investigated the use of concept maps as an alternate method of teaching and assessing of mathematics at secondary school level and even fewer have been conducted in the South African setting. Willerman and Harg (1991) claim that the few studies that have been conducted in secondary schools report contradictory findings. Baralos (c2005) conducted a study of grade 11 mathematics learners and found that there was no strong correlation between written tests and concept maps. He concluded that concept mapping is an essential supplement of conventional tests, which reveals a different view of students' cognitive structures. It is surprising that so few studies have been conducted in mathematics since Wallace and Mintzes (1990) suggest that concept maps may be used to determine learner's knowledge acquisition by comparing successive concept maps. As the learner becomes more adept at constructing concept maps the researcher will be able to see how learners knowledge becomes restructured. I plan to compare learners concept maps done at the beginning of the study to ones done towards the latter part of the study to see whether learners have developed as concept mappers and more importantly to see whether their cognitive structures have developed or not.

Baroody and Bartels (2001) declare that concept mapping is an invaluable tool for assessing meaningful learning as it provides a concrete record of how concepts are organized and inter-related within a learners' cognitive structure. They believe that the number of linking lines in a learners concept map can help one estimate a learners' depth of understanding. Furthermore concepts and examples reveal a complete and flexible knowledge structure. A simple example is illustrated, when learners were asked to draw linking lines specifying the relations among the following concepts: (a). decimals, (b). fractions, and (c). parts of a whole. One learner made several linking lines between decimals and fractions, which indicates a deeper understanding than another learner that drew just one linking line between the same two concepts. However a third learner reveals minimum understanding as no linking lines were drawn.

Baroody and Bartels (2001) also assert that accurate understanding is demonstrated by logical placement of linking lines between concepts whilst specific and descriptive linking phrases are strong indications of accurate and profound understanding of concepts. They add that the 'specificity' of the linking phrase is a sound indication of how well a learner understands a concept.

Pedro, Eduardo and Ramon (2003) investigated the possibilities of using concept maps to assess learners' conceptual knowledge. These authors concluded from their study that concept maps helps identify misconceptions, misunderstandings and variable meanings, which allows the teacher to promote learning of students. They also found that concept maps are a good indication of the level of competence of a learner since deep meta-cognition level is represented by meaningful structures and sub-structures of the concept map. Lastly, they found that learners do more maths whilst pondering to find ways of how concepts are related to one another than they do in other mathematics activities.

2.8.2 In the Science Field

In the science field I review four articles in chronological order. Markham, Mintzes and Jones (1994) did a study that sought evidence of the concurrent validity of concept mapping as a research and evaluative tool in the science field. Thereafter Ruiz-Primo and Shavelson (1996) examined the problems and issues in the use of concept maps in science assessment. This was followed by a study by Rice, Ryan and Samson (1998) that focussed on using concept maps to assess student learning in the classroom where the emphasis was whether it was necessary for different methods to compete. Lastly I review a study by McClure, Sonak and Suen (1999) who looked at the reliability, validity and logistical practicality of using concept maps as an assessment of classroom learning.

Markham et al. (1994) conducted a study of advanced college biology majors and beginning non-majors students. These students had to construct a concept map in the domain of mammals. Maps were scored using a modified version of Novak's (1984) scoring guide. Points were given for number of concepts, relationships, branchings, hierarchies, cross-links and examples found in each map. The propositions generated by students were then analysed. As expected the experienced students demonstrated a sound knowledge of mammals; as they offered twice as many scientifically acceptable propositions than the novices. The concept maps of the majors differed substantially from the non-majors in the structural complexity and organisational patterns of their cognitive knowledge of mammals. The results revealed that the majors scored significantly higher in all six categories. Markham et al. (1994) claim that these findings suggest that the concept map provides a theoretically powerful and psychometrically sound tool for assessing conceptual change in experimental and classroom settings.

Ruiz-Primo and Shavelson (1996) reviewed various studies pertaining to: (a). the task of concept mapping, (b). the type of response formats and, (c). the development of scoring guides. They described the task of concept mapping. The literature on concept maps reveals that there is a vast array of concept map techniques, which in turn produce different representations and scores. The type of technique employed should determine the type of concept map used. However Ruiz-Primo and Shavelson (1996) propose for further study that a theory be developed to guide the structural representation and the number of possible techniques to a manageable set.

Rice et al. (1998) explored the use of concept maps to assess learning in science classrooms. They compared concept map scores to multiple-choice test scores. Concept maps were scored on the correctness of propositions. High correlations between the concept map scores and multiple-choice scores present strong evidence of the content validity of the map scores. Furthermore correlations between map scores and state criterion-referenced and national norm-referenced standardized rests were indicators of high concurrent validity.

McClure et al. (1999) conducted a study to determine the reliability, validity and logistic practicality of using concept maps as an assessment technique in the classroom environment. Their study entailed scoring the same concept maps by three different methods. One used the holistic scoring method where based on the overall judgement of the map learners were allocated a score of one to ten. The second method employed a relational scoring method. This technique meant identifying separate propositions and a score of one to three was awarded depending on the correctness of the scoring guide. The final score for the map was found by adding up the individual scores. The last method was termed the structural scoring guide and points were awarded for correct propositions, hierarchical levels, cross-links and examples. This study found that the reliability scores for the relational scoring guide together with a criterion-referenced map were the highest. The researchers believed that since the raters were not familiar with concept maps, they found this method the easiest use to assess the map. The proposition is the least complex structure on a concept map and analysis using this technique is probably least taxing on a rater of the map. However the authors hypothesise that as the educator becomes more familiar with concept scoring, the other methods may become easier to implement.

2.9 ADVANTAGES AND DISADVANTAGES OF CONCEPT MAPS

According to Rice et al. (1998) concept maps produced by learners reveal a wealth of information about their understanding of concepts. These insights go beyond the right and wrong information produced by scoring multi-choice questions.

Gaps in knowledge structure and misconceptions can be easily recognised, however this is not readily seen in conventional tests since they are aimed at computational procedures. Even whilst awarding scores to concept maps, researchers easily developed a qualitative sense of where instruction has been successful and where it has been unsuccessful. They qualify that although confusion between concepts can be recognised in multiple-choice questions upon careful analysis, educators do not have the time nor the inclination to carry out such analysis. However with concept map assessments, failure in instruction is easily recognised and can be subsequently remedied.

Baroody and Bartels (2001) report similar benefits of concept maps for diagnosis and instructional feedback are reported by. They assert that by examining learners' concept maps, the educators can determine the extent of learners' conceptual understanding. This information may be used to make the necessary adjustments to instruction and to judge learners' progress.

Goldsmith and Johnson (1990) claim that commonly used evaluation techniques are one-dimensional and knowledge acquisition is expressed by the "percent correct" in tests based on recall of terms. The problem with these assessment tasks is that they do not show the understanding of relationships among the different concepts. What's more is the consensus between cognitive scientists and psychologists that structural representations (such as concept maps) capture the configural property of knowledge better than any other presently available technique (Markham et al., 1994). Goldsmith and Johnson (1990) add that compared to essay tests, concept map assessments are less time consuming and demanding of expertise.

Whether an educator will implement a new technique depends on its educational value. According to McClure et al. (1999) the value of a technique is expressed as the relationship between potential costs and the educational benefits associated with the technique. With regards to concept maps the cost factor is the time required to train learners in the mapping technique, the time required to complete a concept map task and the time required to rate a concept map. Additionally learners' skills in developing concept maps will affect the quality of their concept map artefacts and will affect the reliability and validity of the scores of the assessment. It is also assumed that learners and educators are both comfortable and familiar with common assessment tasks. However this may not be the case with concept map tasks.

McClure et al. (1999) conducted a study that addressed these issues. Their findings suggest that it is possible to train learners using a direct instruction method in a 90-minute session. In these sessions most of the time is devoted to guided practice. They also found that the time required to produce a relatively complex map took approximately twenty-nine minutes. This fits easily into a normal class period. McClure et al. (1999) results reveal that the cost in terms of time is comparable to a traditional pencil and paper examination. The final time consideration is the evaluation of concept maps by educators. These researchers found that scoring of concept maps can take from one to five minutes, depending on the scoring guide selected. They concluded that these times are comparable with objective assessments such as short answer tests but concept maps are similar in degree to open-ended responses such as essay exams. The assertion is that the comparison between times to score essay type assessment and concept map assessments favour concept mapping. Many researchers indicate the time factor as a disadvantage for the use of concept maps within the classroom. However this study is a clear indication that the educational value of concept maps far outweighs the time factor and that the time for scoring is comparable to essay type questions.

Baroody and Bartels (2001) pointed out that concept map assessment plays an integral part of instruction. They believe that even when concept maps are used for instructional purposes, observing learners build concept maps provides invaluable diagnostic information and instructional feedback for the educator. Observing learners allows the educator to see the gaps in learners' knowledge structure and helps the educator gain information about the success of instruction. This allows the educator to make the required modifications to instruction to fill in the gaps of learners' knowledge. They report that concept map assessments can also be used to expand learners' knowledge. Similar findings are reported by (White & Gunstone, 1993). They found that the value of concept maps as a probe lies not only in the end product, but also in the process that can be observed while they are being constructed. Reflection of what the maps reveal about teaching can cause reconsideration of the teaching style so that learners' knowledge converges to that of the educators.

White and Gunstone (1993) found that the construction of concept maps during group work encourages lively discussion and hence promotes meaningful learning. They found that learners that are generally shy also participate freely in the co-operative and unthreatening activity of building concept maps. They believe that this is probably because learners do not see concept maps as a competitive threat since with concept maps there are no right or wrong answers. Boxtel, Linden, Roelofs and Erkens (2002) also suggest that concept map activities provide opportunities for learner interaction, thus the more learners talk about science concepts and the more elaborate the talk, the higher the learning outcomes.

Edmondson (1995) claim that concept mapping is a valuable tool for developing integrated curriculum courses. This study used concept maps to draw the inter-relationship between the veterinary curriculum, specific courses and case-based studies. Zeilik, Schau, Hall, Teague and Bisard (1997) makes similar assertions about the advantages of concept maps. They believe that concept maps shift the emphasis from inert, static knowledge to contextually embedded knowledge, from isolated facts to theoretical frameworks of related concepts.

Willerman and Harg (1991) found that concept maps used as graphic organisers can significantly improve science achievement. A concept map designed by the educator and used as a graphic designer presents new content information in a visually appealing, logical and organised manner. Since a concept map constructed by an educator is complete and accurate it is effective in anchoring the new information in the learners' cognitive structure. They add that concept maps developed by the educator provides learners with greater direction for learning of concepts and facts. Zeilik et al. (1997) also believes that concept maps used as graphic organisers allow learners to focus on the "big picture" enabling them to devote more of their time to conceptual understanding rather than rote learning.

Zeilik et al. (1997) offers the following disadvantages of concept maps. He reports that comparison of concept maps to a criterion-referenced map is difficult because concept maps reveal the idiosyncratic way that learners view content knowledge. As a result evaluation can become time consuming for the instructor, especially in large classes. However he explains that this can be circumvented if a particular variation, such as select and fill in the blanks is adopted. Another disadvantage offered by Zeilik et al. (1997) is that learners that have developed a strong competence for rote learning sometimes find concept mapping intimidating. Moreover concept maps is a demanding cognitive task that requires training before it is implemented in the classroom (Zeilik et al., 1997). White and Gunstone (1993) also caution against the overuse of concept maps. They explain that concept maps involves intellectual effort, and if they are used too often learners will produce superficial maps that will be of no value to them or the educator.

For learners to fully appreciate the educational value of concept maps the timing of when it is introduced to them is vital. Studies conducted by Santhanam, Leach and Dawson (1998) found that first year students at university showed no evidence of the long-term benefits of concept maps. It appears that most students at this stage of their academic careers have already nurtured reliable approaches for learning. Due to the outcome of this study, these researchers suggest that concept maps be introduced in high school or even earlier. Hence, I decided to use grade eight learners for my study as they were the youngest learners at my school and had probably not found a particular learning strategy that they preferred as yet.

A further advantage of concept maps is its use in planning for lessons. According to White and Gunstone (1993) it is helpful to the teacher to do a concept map in order to determine the progression of presentation of ideas and to identify relations that are to be highlighted. When the educator draws a concept map only then does it become apparent how concepts should be taught. Another study by Leou and Liu (2004) indicates that an educator's entire belief system about teaching and learning changed due to the use of concept maps in her planning and instruction of mathematics lessons. Before the study she believed that learners should do as many exercises as possible and she inundated them with copious notes. However since her study her learners have become active participants who discuss their concept maps with their peers. The educator has moved from the deliverer of knowledge to facilitator of knowledge. The educator herself claims that she is more effective and confident in the classroom.

2.10 SUMMARY

This chapter discussed, from a literature perspective the various constructs for which concept maps can be used. Concept maps have been successfully used as graphic organizers, as a tool to stimulate lively group discussions and to assess learners' conceptual development through the comparison of successive concept maps. Concept maps were also used by educators to design lessons and was effectively used to design the curriculum in the medical field. This chapter finally ended with the advantages and disadvantages of using concept maps.

CHAPTER 3

THEORETICAL AND CONCEPTUAL FRAMEWORKS

Teachers are entrusted with the job of educating the nation. It is commonly accepted that educators are expected to be relative experts in the understanding of the human learning process. The more we learn about ways to improve learning the more efficient and effective our teaching becomes. This chapter discusses the epistemological approach of concept maps, as well as the conceptual theories that frames this study. Here I show how concept maps can be used effectively within the constructs of constructivism. This chapter also discusses the concepts that frame this study, namely 'visual literacy' and 'visual learning'. The literature reflects that concept maps are visual tools that appeal to learners who appreciate visual representation when learning.

3.1 HOW LEARNERS' LEARN

According to Howe (1991) there are two factors that directly influence a child's learning. He believes that the first category consists of activities that the child actually engages in, whilst the second category that influences learning depend on what the learner already knows. Existing knowledge acquired through past experiences makes it possible for the learner to understand new information and events.

Indirect influences on learning include the effects of attention, boredom, interest and motivation. Perceptual disorders such, as deafness, family background and social class are also factors that indirectly affect learning. Another influence of learning is teaching. However, the acquisition of knowledge depends on the learner, hence the ultimate aim of education should be for learners to learn how to learn. According to Howe (1991) no educational objective is more important than teaching learners how to learn and how to function as autonomous and independent learners. These qualities that should be imbued in learners are echoed in the Revised National Curriculum Statement (2003). It states that learners who emerge from the Further Education and Training (FET) band should be able to think logically, analytically and holistically. The RNCS (2003) document further emphasizes that the curriculum should aim to train learners to transfer skills from familiar to unfamiliar situations; hence developing the intellectual, social, emotional, spiritual and physical needs of learners.

The earliest teaching of mathematics emphasized the skill of calculation. For almost a century the behaviourists believed that learning was synonymous with a change in behaviour (Novak & Gowin, 1984). Thorndike (1920) was of the view that drill and practice were essential for the mastery of mathematical techniques (cited in Howe, 1991). Educators such as Brownwell (1992) cautioned against rote learning. Traften (1975) also made attempts to bring relevance to computation by relating it to everyday life occurrences such as grocery bills and buying of yards of material (cited in Howe, 1991).

In the early 1960's schools in the United States of America were under pressure to produce learners whose mathematical sophistication matched that of the space age. These reform initiatives meant the integrating of mathematical knowledge with other disciplines and learning of mathematics that was relevant and meaningful and not just a body of unrelated facts and procedures. The advocates of this type of mathematical learning emphasized a conceptual rather than a computational approach to instruction (Resnick & Ford, 1981).

This was the onset of research into how learners make meaning of mathematics.

The field of cognitive psychology was born – the study into humans' cognitive processes and suggestions of how mathematical instruction might be made meaningful by responding to specific intellectual capabilities of learners (Resnick & Ford, 1981). Piaget (1941; 1952) an American psychologist was of the view that learning was based on the psychological development of children. Within his theory, learning is based on discovery methods (Resnick & Ford, 1981). They believed that knowledge is actively created or invented by the individual, and not passively received from the environment (Clements & Battista, 1990).

Bruner did extensive work in the 1960s on the cognitive process. One part of that work was concept development (Howe, 1991). He asserted that for students to make meaning of instruction, teaching should fill in the gaps of knowledge that learners have and it should be based on experiences and contexts that are familiar to the child's learning (Huitt, 2003). This meant that classroom instruction should move from concrete and physical to the realm of mental imagery. He believed that any idea or concept could be presented in a simple enough manner so that any child could understand it. Concept mapping is a visually appealing tool that is simple to employ and lends creativity to mathematics and other disciplines (Edmondson, 1995). It helps educators to see the gaps in learners' knowledge and adjust teaching to fill in these gaps and other misconceptions that the concept maps may reveal (Zeilik et al., 1997).

Lev Vygotsky (1896-1934) a Russian psychologist criticized Piaget's emphasis on individual idiosyncratic construction of meaning. He argued for the social aspects of learning, which included linguistic factors, cultural factors, interpersonal interactions such as peer relations, and the role of the educator (Ernest, 1994). Vygotsky used this background to develop a model called The Social Cognition Learning Model, which asserts that culture is a key determinant of individual development (Doolittle, 1997). Culture has a two-fold effect on a child's intellectual development. First, through culture a child acquires much of his/her content knowledge. Second, culture provides the means of thinking which Vygotsky calls the tools of intellectual development (Vygotsky, 1978). Hence it can be seen that the curriculum should be designed to emphasize interaction between learners and learning tasks (Doolittle, 1997). Vygotsky believes that with appropriate adult help, children can perform tasks they are incapable of completing on their own. This can be achieved through scaffolding (part of Social Cognition Model). The term Zone of Proximal Development may be seen as comfort zones of learning for a child. What a child can do by himself/herself is their level of actual development and what they can do with help is their level of potential development. Vygotsky believes that through the assistance of an adult a child can develop within this zone (Vygotsky, 1978).

Piaget contrarily argued that cognitive growth occurs through stages that correspond to a particular age (Charles Stuart University, 2000). His theory posits that each individual constructs their own understanding of the world and is primarily responsible for the development of their own intelligence as a result of experience (Matthews, 2003). The contrasting views between Piaget and Vygotsky lies within teacher involvement. On one hand the Piagetian view suggests that teacher involvement may inhibit learning whilst on the other hand the Vygotskian approach of scaffolding and guided discovery suggest that a guiding hand by the educator is essential for effective learning (McMahon, c1999).

3.2 CONSTRUCTIVISM IN THE USE OF CONCEPT MAPS

Using this brief history of how learning occurs as a backdrop, the theoretical framework, from which concept mapping is derived, is based on a constructivist epistemology. An alternative to behaviourist learning theory that focuses on the presentation of information and its transfer from the teacher to the learner, the constructivist approach encompasses practices are strategies that enhance education by helping learners to learn about learning and about the nature and construction of knowledge which will serve to liberate and empower learners in the classroom. Novak and Gowin (1984) propose strategies that help the teacher and learner apply heuristic tools that promote meaningful learning and empower the learner to be responsible for their own learning. In their endeavour to reach this goal Novak and Gowin (1984) propose two strategies viz. concept maps and vee diagrams. Concept mapping is one instructional technique, which allows the theoretical ideas of Piaget, Ausubel and von Glasersfeld to be implemented by educators. Since the rationale of this study is to explore the use of concept maps, I will concentrate on concept maps for the rest of this thesis. According to Novak (1984) concept mapping is a tool that allows both learners and educators to learn key points that they must focus on for any specific learning task. He explains further that concept maps present meaningful relationships between concepts and prepositions and provide a schematic summary of what has been learnt. During concept mapping learners are actively involved because they construct the concept maps. Ausubel believed that the most important thing to do before teaching was to ascertain what the learners already know and teach from that point on. White and Gunstone (1993) claim that pre-tests used to determine learners' prior knowledge are not popular with learners. However concept maps can be used to determine what learners already understand about a topic since they are less threatening because concept mapping is open and less concerned with right answers than a test. White and Gunstone (1993) explain that if learners agree to concept mapping before a section, this map can be compared to one at the end of the section. Comparison of the two maps provides the educator with invaluable information about learners' understanding of the topic and their conceptual development.

Ausubel also promoted the use of advance organizers or graphic organizers to introduce topics of higher order abstractness (Klausmeier et al., 1974). He again claimed that advance organisers helped to bridge the gap between what a learner already knows and what they need to know in the new section. According to Hendron (2007) there are other valuable benefits of using advanced organizers. Firstly, they are fluid and dynamic since diagrams can be updated and manipulated easily. Secondly, saved organizers can be used for direct instruction and for review in follow-up lessons. Finally the graphic organizer can be easily adapted in note taking and summarisation. Hendron (2007) also suggests various ways of using a graphic organizer, such as a pictograph for social studies, drawing for science, or concept maps, which lend themselves to any discipline. Willerman and Harg (1991) showed in their study of using concept maps as advance organisers that concept maps provide classroom practitioners with a meaningful and practical structured approach for using advance organisers in their classrooms. Their study also found that advance organisers using concept maps also served to improve levels of understanding and recall.

Vygotsky's notion of 'zone of proximal development' suggests that the educator provides a guiding hand during discovery learning and that this technique is critical for effective learning (Huitt, 2003). In this study the educator's role was vital in introducing learners to the technique of constructing concept maps. The pace and manner in which it was introduced was chosen to build learners confidence and not overwhelm them as this was a new technique they were being exposed to. It was not practical to expect these learners to read up on concept maps and construct it on their own without the facilitation and encouragement of their educator. According to Chall (2000) constructivism supports a learner-directed approach to learning where the educator makes skills relevant to the learners' background and experience by anchoring learning tasks in meaningful, authentic and visual situations (cited in Matthews, 2003). Concepts maps can be helpful to meet these conditions, by identifying the concepts held by the learner through prior learning and assisting the educator in introducing more explicit knowledge that can be anchored into a learners developing conceptual frameworks (Novak & Canas, 2006).

Consistent with the constructivist theory, is 'understanding' which is characterised by knowledge being constructed by the active process of integrating new experiences and information with existing concepts (Olivier, 1992). Hence the focus is not just the understanding of facts but how the facts are organised and how they relate to one another (Charles Stuart University, 2000). The goals of instruction are therefore deep understanding and conceptual development and not behaviours or skills like in the Behaviourist Theory of Learning (Baralos, c2002). The constructivist model underscores the need for learners to be actively engaged in their learning. Learners are expected to ask questions and must be encouraged to test their own ideas. Educators must seek out learners' ideas, promote cooperative group learning and encourage learners to challenge each other's ideas. In addition advocates of the constructivist approach suggest that educators use: collaborative styles where learners learn from their peers (Artz & Newman, 1990), reflective processes where learners talk about what was previously learned, discussion through which they construct knowledge, and engage in inquiry-based activities (Educational Broadcasting Corporation, 2004).

White and Gunstone (1993) found that group work endeavours of concept mapping promote serious debate, even amongst learners who are generally less likely to participate in class discussions. These authors presume that the task of concept mapping is purposeful, involves creativity and more importantly to the learner there is no one correct answer. Consequently learners do not notice a competitive threat in concept mapping, although the intellectual demand cannot be denied.

Evaluation compares learners to themselves rather than to peers, there is de-emphasis on formal assessment (Matthews, 2003) and an emphasis on alternate assessment methods such as open-ended questions, doing research and developing products, assessing student portfolios, and so on (Charles Stuart University, 2000). Other authors suggest that concept maps are ideal for this purpose: White and Gunstone (1993) suggest that the comparison of concept maps done before and at the end of a section shows the development of knowledge and helps the learner to see their own progression which in itself is a powerful learning experience. Zeilik et al. (1997) add that initial concept maps can be given back to the learner to modify by adding new concepts and making necessary corrections that they then feel they understand better.

3.3 CONCEPTUAL DEVELOPMENT

According to Baddely (1994) we can acquire two types of knowledge, namely *procedural* and *declarative* knowledge. Procedural knowledge refers to the acquisition of skills, applying of rules and formula, and so on. Declarative knowledge is the acquisition of new knowledge or experience and the acquiring of factual knowledge (Royer, Cisero & Carlo, 1993).

In this study I focus primarily on declarative or conceptual knowledge as opposed to procedural knowledge. Mathematicians are of the view that meaningful learning will occur if teaching emphasized the structures that underpin mathematical procedures and how old concepts linked to new knowledge will serve to enrich the intellectual capacities of the child (Resnick & Ford, 1981). This accentuates the relevance of conceptual knowledge to make sense of computational skills. The importance of conceptual development in mathematics was discussed at Woods Hole Conference in 1963. The outcome of this conference suggested that mathematics will only be fully understood, easily remembered and applied to other novel situations if the "reasons that underlie mathematical operations are made clear by the concepts that link one operation to another" (Resnick & Ford, 1981, p104). As far back as the 1960's, educationists were emphasizing the importance of both the conceptual knowledge as well as the procedural knowledge. It is important to note that these are not competing factors. They in fact complement each other and enhance understanding and learning.

Procedural knowledge can be assessed by criterion-referenced assessment techniques such as short answer, true and false, matching and multiple-choice tests (Royer et al., 1993). Concept maps are functional tools that have been specifically designed to detect a learners' conceptual structure on a certain topic and to externalise, for both the learner and educator, what the learner already knows (Novak & Gowin, 1984). The construction of a concept map requires the mapper to relate salient concepts to a general upper-ordinate concept. Unlike a lecture or linear text that reflects the logical structure of knowledge, concept maps reflect the psychological structure of knowledge (Wandersee, 1990). Hiebert and Carpenter, (1992) suggest that understanding can be viewed as a connection between two pieces of information and the number, accuracy and strength of those connections determine the degree of a learners' understanding. This claim is supported by neurobiologists' researches that study the functioning of the brain (Posner & Raichle, 1994). They also emphasize the importance of links and the connection with concepts, images and meaning.

Recent research into the brain indicates that the brain is a multidimensional, organism that does not think in a linear monotonous way but in multiple directions from a central trigger point, which Buzan (2006a) calls Radiant Thinking. Buzan (2006b) states that since we speak and write in sentences we are of the view that information is stored in our brain in the same way. This linear emphasis continues in schools, tertiary education and the workplace. Buzan (2006b) argues that this is not the best way to record information that has to be memorised since the brain prefers key words that represents the big picture. I believe that concept maps is an extension and an elaborate form of mind maps and hence portrays the same benefits for memorising.

3.4 CONCEPTUAL FRAMEWORK – VISUAL LITERACY

The concepts that frame this study are visual literacy and visual learning. The term visual literacy is credited to the writer John Debes in 1968 (Wikipedia, 2008). He provided that visual literacy is a group of competencies that a human being can develop by seeing and simultaneously having and integrating other sensory experiences. Bamford (2003) states that visual literacy is the development of skills and understanding through the use of visual images. A similar definition is offered by

Haas (2003), he believes that visual literacy is the ability to read, interpret and understand information presented in pictorial or graphic images.

Although the term visual literacy dates back to the 1960's the concept of reading signs and symbols is prehistoric (Bamford, 2003). Symbolic representation dates back to the Paleolithic Age almost 30 000 years ago. The early drawings in ancient caves, like the one in Lascaux, France, are early forms of visual literacy whilst evidence of the written word appeared in Iraq just 5 500 years ago (Flattley, 1998). Human beings rely on images to make meaningful interpretation and understanding of X-rays, maps, and complex ideas such as mathematical and chemical formulas through the mixing of linguistic and pictorial elements (Bamford, 2003).

Linda Kreger Silverman (2002) author of Upside Down Brilliance claims, after extensive research on gifted children in the 1980's that some learners are inclined towards the visual spatial learning style whilst others prefer an auditory-sequential learning style and very importantly for educators, the two styles are not mutually exclusive. She explains in more detail that the brain is made of two hemispheres, the left and the right. According to her research, on the one hand the left-brained learner responds best to auditory stimuli, such as sequential, analytical and time-orientated activities and on the other hand, the right-brained learner perceives the whole, synthesizes and learns the best by seeing relationships.

Silverman (c2007a) claims that even the most dedicated teacher cannot accommodate the different learning styles and intelligence of learners. She suggests that to have happier learners and to teach effectively we need to reach both the left-brained learner and the right-brained learner. The right-brained learner or visual-spatial learner thinks in pictures rather than words, learn better visually and are whole-part learners who need to see the big picture first before they learn the details (Silverman, 2007b).

In the past teachers taught sequentially. The three R's - reading, writing and arithmetic were undisputed parts of the curriculum. This type of learning served the sequential left-brained learner who is dependent on auditory stimuli. This type of learning is insufficient as research is continuously showing that learning relies heavily on technology – with learners being bombarded by the internet, play station games, I-pods, cell phones, cyberspace entertainment and data-projection presentations. Silverman (2002) maintains that in the new age of information the right hemisphere of the brain is favoured and needs to be utilised in the classroom if our learners are to be successful at the work place.

Silverman (2002) outlines the comprehensive learning styles of visual-spatial learners. She explains that these learners learn all at once and once they understand, learning is permanent. They do not learn from repetition and drill. They learn best when they know the goals of instruction, so that they have an idea of the whole picture. They prefer visual presentations and visual techniques such as mind-mapping (similar to concept mapping) and pictorial notes. Haas (2003) suggest that in the secondary school math classes' learners be engaged in demonstrations and participatory activities as opposed to memorising facts and formulas to assist the visual-spatial learner. West (1997) claims that learning of mathematics is more effective when learners 'do' mathematics instead of 'watching' mathematics.

The literature however, reveals that visual treatments in the classroom enhance learning in varying degrees. Chanlin (1997) reports that when prior learning is low, graphics are better for learning descriptive facts than text alone (cited in Stokes, 2001). Further studies conducted by Kleinman and Stokes (2001) indicates, that the use of colour graphics as opposed to black and white graphics in instructional modules promotes achievement, particularly when learning concepts. A study conducted by Willerman and Harg (1991) further illustrates the benefits of visual learning. Their study reveals that concept maps as graphic organisers presented to learners at the beginning of a section, help learners see the relationship between concepts. This again favours visual-spatial learners, since these learners prefer to see the relationships between concepts when learning. Haas (2003) believes that visual-spatial learners are holistic learners; they grasp whole concepts rather than individual facts. They synthesize and construct conceptual frameworks to show connections between a particular topic and the rest of the subject. Haas (2003) believes that concept maps is an effective tool to represent such learning.

Stokes (2001) cautions, that although studies repeatedly show that visuals aid in learning, it must be carefully integrated with instruction. Visuals should not be excessively entertaining that the underlying objective of the lesson is lost. Furthermore with regards to the visual aid, concept maps, White and Gunstone (1993) suggests that although learners enjoy doing them, concept maps require intellectual effort and if they are done too frequently learners will lose interest and produce superficial maps that are of no educational value. In this study concept maps were sometimes used to introduce a section. Classroom activities were follow up exercises from the textbook or worksheet, research tasks using the internet or a concept map generally at the end of a section to recap all that was learnt in a particular topic. I believe that learners were not overwhelmed by the construction of concept maps as they were interspersed with other fun activities in the mathematics class, such as designing questionnaires, doing surveys, research in the library and building prisms and pyramids from jelly tots and tooth-picks.

3.5 SUMMARY

This chapter focussed on a visually appealing way to motivate learners to make sense of learning material within a constructivist epistemology. Within this paradigm of teaching and learning learners become active participants to learning and not passive recipients. In this thesis concept mapping is used as a teaching and learning tool to engage learners in meaningful learning. Past studies have shown that if introduced early in a learners' schooling career, concept maps can be effectively used as a learning tool.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

This chapter will provide a description and an in depth explanation of the suitability of the methods employed in my study to determine the benefits of using the concept map approach for teaching and assessing learners' conceptual knowledge in mathematics in a grade eight class. This study is guided by the following objectives:

1. What are the advantages and disadvantages of using concept maps to teach mathematics? – A literature perspective.
2. Can concept maps facilitate group-work?
3. Are concept maps an effective learning tool for mathematics for grade eight learners?
4. Can concept maps provide valid information for the teacher about learners' knowledge of mathematical concepts?
5. How can concept maps assessments be practically applied to classroom situations?
6. Do concept maps develop grade eight learners' conceptual understanding through the comparison of successive concept maps?

4.1 RESEARCH DESIGN AND METHODOLOGY

According to Nieuwenhuis (2007) a research design is defined as a plan, which moves from the underlying philosophical assumptions to specifying the selection of participants, the data producing techniques, and the type of data analysis.

Since the aim of this study is to find solutions to a social challenge, in particular a teaching method that will help learners' understanding of mathematical concepts, the study is embedded in an action research methodology (McNiff & Whitehead, 2005). Educational action research in a sense is an educational technology in which teachers take action to improve learners' learning and at the same time improves their own practices (Swain, 2001). Action research frequently emerges in situations where people want to make changes thoughtfully – when social beings become dissatisfied with the way things are and want to change it for the better (Kemmis & McTaggart, 2000).

According to Mouton (2001) the advantages of using action research is that it involves participation and close involvement of all the part of subjects, which enhances chances of high construct validity, low refusal rates and 'ownership' of findings, whilst limitations of action research are that the small number of cases and low degree of control affect overall generalisability and possibility of strong causal and structural explanations. Kemmis and McTaggart (2000) level other criticisms against action research – they believe that the prominence given to teachers' knowledge with the hope that significant changes can be accomplished in the classroom without the support from the community and the education department is overemphasized.

In this study, thirty-four learners of a grade eight class participated in this action research that extended over ten months. Learners were taught how to construct concept maps over an extensive period that was not only determined by hours but by the activities that they engaged in. Thereafter concept map activities were used across a range of topics and at different stages of my lessons. Both the learners and I constructed concept maps. I constructed concept maps: (a). to introduce sections, (b).

to summarise previous work and (c). to revise before a test. Figure 5.1 represents a skeleton concept map (a drawn concept map with links and branches but the concepts are missing), which was used to check whether learners remembered their class-work activities from the previous day. Learners constructed concept maps as classroom activities, homework tasks and as assessment tasks. range of concept map activities used was: (a). as tasks that invite learners to provide evidence of their knowledge structure in a particular domain where they would construct a pencil and paper concept map from a list of given concepts, (b). as a format for learners' response where skeleton concept maps were given and learners had to fill in the correct concept (Figure 5.1), and (c). as a pencil and paper task to construct concept maps for a particular domain.

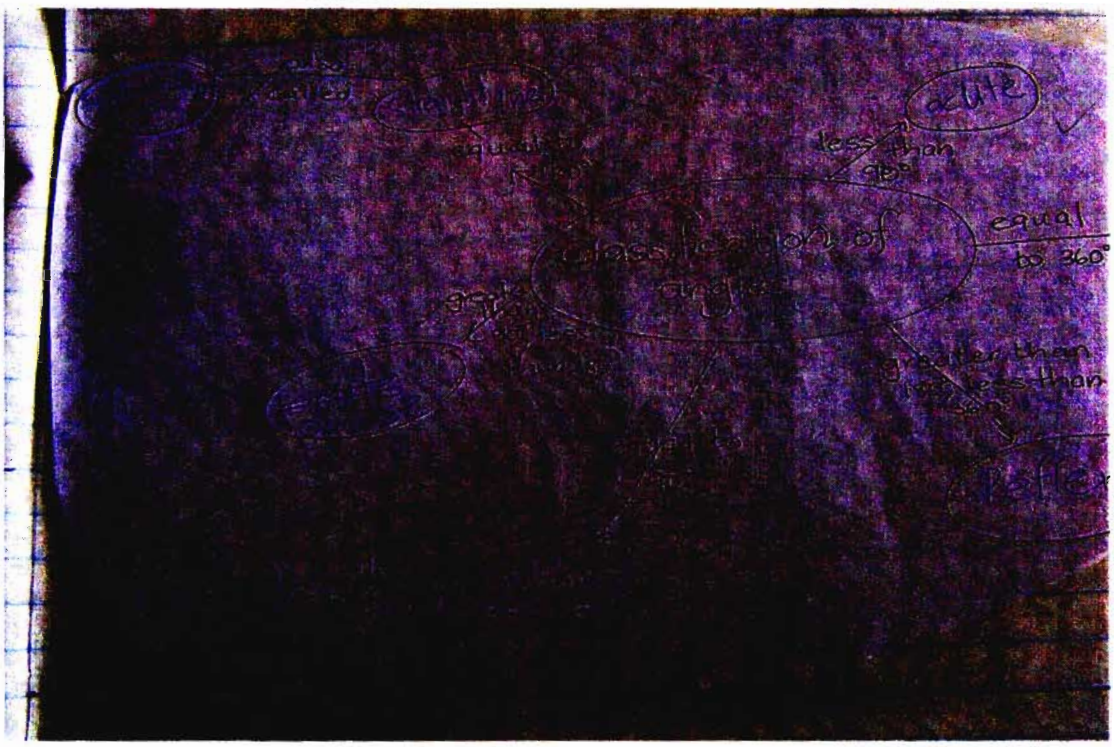


Figure 4.1 Skeleton concept maps drawn by educator and filled in by learners

This study will be conducted from an interpretivist paradigm. Within this paradigm concern for the individual is paramount. Hence the central endeavour of the interpretive paradigm is to seek to understand from within the subjective world of the human experience (Cohen, Manion & Morrison, (2007). These authors believe that this is in opposition to where humans are studied by observing and the observer reflects his or her viewpoints. Hennie, Rensburg and Smit (2004) assert that since measurement in this paradigm is fallible, the interpretive researcher is encouraged to use different methods of data collection and analysis to ensure validity of results. They propose unstructured observations; open interviewing and qualitative data analysis as ways to capture "insider" information. My study embraced the interpretivist paradigm since it is characterized by my concern to understand from within, the learners' conceptual change of mathematical knowledge.

Hence, this study will utilise a mixed method approach since it contains elements of both qualitative and quantitative methods to explore learners understanding using concept maps (Vos, 2006; Ivankova, Creswell, & Clark, 2007). Spicer (2004) declares that the benefit of using mixed methods allows the researcher to capture the best of both approaches. Greene (2008) further asserts that in the social field of education the practical demands of the educational context require both 'generality and particularity'. Vos (2006) claims that to investigate and understand the complexity of human beings it is necessary to adopt dispassionate neutrality as well as contextual stories about lived experience.

When the quantitative and qualitative methods are combined to acquire multiple measures of the same phenomena by the application of various research instruments the process is known as triangulation (Vos, 2006). Triangulation is critical in facilitating interpretative validity and establishing data trustworthiness (Terra Blanche, 2004). However critics argue that triangulation may not necessarily corroborate findings nor does it necessarily increase validity, reduce bias or bring objectivity to the research (Cohen et al., 2007).

For my study I will employ the Sequential Explanatory Strategy since I think it is the most appropriate of the six major mixed methods models (Ivankova et al., 2007). Ivankova et al. (2007) characterized this strategy as a collection of the quantitative data first, which is then followed by the qualitative data and then integrating the two methods during the interpretation phase of the study. This model enabled me to use the results from the questionnaire (quantitative analysis) to explain and interpret the results of the interview (qualitative component) of the research. Research that mixes methodologies can 'temper biases in each tradition' and a quantification of outcomes together with rich contextual lived experiences can only yield valuable and in depth findings (Sosulski & Lawrence, 2008).

4.2 DATA COLLECTION STRATEGIES

In this study learners were involved in designing concept maps, which were then scored against a set of criteria. This was followed by a short survey in the form of a questionnaire administered to the whole class. The questionnaire was designed to get a general idea of how learners felt about concept maps and whether they were comfortable using it in mathematics. All learners answered the questionnaire. A sample of six participants was chosen according to set criteria, see chapter five for details for the semi-structured interview. The aim of the interview was to explore an in depth description of learners' perceptions regarding the use of concept maps.

4.2.1 Content Analysis

During the first part of the study that spanned ten months, learners engaged in concept map activities that encompassed:

- Filling in of skeleton concept maps,
- Building concept maps from a list of given concepts and
- A pencil and paper concept map of a given section.

Thereafter concept maps were scored against a drawn up set of criteria by analysing the content of the concept maps. Krippendorff (2004) defines content analysis as a research technique that makes replicable and valid inferences from texts or other meaningful matter which provides insights and increases a researchers understanding of a particular phenomenon (in this case concept maps) to the contexts of their use. Holsti (1969) offers a broad definition of content analysis in that it is a "technique for making inferences by objectively and systematically identifying specified characteristics of messages" (p14). This definition does not constrain content analysis to textual analysis but to analysing any means of communication. Reliability, which demonstrates the trustworthiness of data, is defined as the extent to which a measuring procedure yields the same results on repeated trials (Neuendorf, 2002). Reliability is achieved through duplicating the analysis under various conditions such using several researchers of varying personalities or by relying on different but functionally equal measuring devices to obtain the same results (Krippendorff, 2004). To ensure the trustworthiness and reliability of the scores for the concept maps my supervisor and I scored the concept maps to ensure reliability of the scores.

In this study the content of concept maps were analysed. The focus was to concentrate on the complexity of the structural nature of the map. This entailed examining the number of correct concepts used and whether they were corrected linked to other concepts with a descriptive linking word. The levels of branching were also examined. This structure reveals valid information about a learners' conceptual development (Baroody & Bartels, 2001)

The strengths of using content analysis is that it is an unobtrusive method which means that errors associated with the interaction between researchers and participants are avoided whereas the weakness of this method lies in the authenticity and representativeness of the material analysed which makes the overall external validity of the findings limited (Mouton, 2001).

The evidence of concurrent validity of concept maps was established by a study conducted by Markham and Mintzes (1994). Concurrent validity is demonstrated by correlations that concur from past studies (Krippendorf, 2004). In this study Markham and Mintzes (1994) explored the concept maps constructed by new students that enrolled for an introductory course in biology and compared them to those constructed by graduate level students majoring in biology. Comparison of the concept map scores would indicate the differences in structural complexity of the student's knowledge bases. These researchers used the findings from previous studies that found that knowledge structure and application are tightly linked; hence concept maps will provide a fairly accurate account of the way learners' structure their knowledge. These results are often quoted for the concurrent validity of concept mapping as an evaluation tool.

Analysing series of concept maps will determine learners' conceptual change if any. This analysis will help me determine learners' conceptual understanding of a topic but it does not help me determine how learners' feel about concept maps, whether they will use it whilst studying, if it helps with retention of knowledge, or whether it is a method that they are comfortable using in their mathematics lessons.

Stemler (2001) states that content analysis allows inferences to be made, which can be corroborated using other data collection methods. Hence, I followed the analysis of the concept maps with a questionnaire

4.2.2 The Questionnaire

A questionnaire is a written list of questions where participants are expected to read and interpret what is expected of them and then responds in writing (Kumar, 2005). Oppenheim (2004) claims that a well-designed questionnaire should provide accurate answers to the questions of the investigation. Besides it should not leave loopholes in conclusions, it should allow valid generalizations to be made and lastly it should not produce irrelevant information. To make certain that the criteria for a good questionnaire was met I took the liberty of engaging the help of my supervisor and colleague who is familiar with my study instead of using a pilot. A pilot is the lengthy but valuable process of designing and trying out questions before the actual instrument is used (Oppenheim, 2004). Studying a questionnaire rarely reveals problems of interpretation or usage however it does become apparent and clear through testing (Willis, 2005). In addition before we ask questions we need to ascertain exactly what we need to know. Vague questioning is often clarified through testing. Oppenheim (2004) further illustrates the benefits of a pilot by stating that it assists us with the sequence of questions and reduction of non-response rates. I however could not heed the advice offered by Oppenheim (2004) when he suggested that researchers engage the help of their respondents since the pilot could only be carried out with learners that knew how to construct concept maps. This was not possible as I only taught concept maps to my research participants. I therefore engaged the help of my supervisor and a colleague that was familiar with my study and concept maps.

My questionnaire (see Appendix C) included both open-ended and close-ended questions. Closed questions are where respondents are offered a choice of alternatives and in my case tick the most appropriate response (Kumar, 2005). Closed questions are easier and quicker to answer and quantification is straightforward however the disadvantage is that we cannot record the spontaneity and expressiveness of participants (Oppenheim, 2004). He adds that closed questions also stand the risk of bias in that respondents are forced to choose from the given alternatives. Moreover they are forced to think of alternatives that may not have occurred to them. Kumar (2005) maintains that closed questions are open to greater investigator bias as the researcher may list only the responses that he/she is interested in.

Closed questions alternately allow the respondents to answer in writing in their own words (Willis, 2005). The advantage of open questions is the freedom it offers respondents which yield data they take time to think about whereas in an interview there is the risk that respondents don't necessarily give a full account of their feelings but offer what is uppermost in their minds (Oppenheim, 2004). Maree and Pieterson (2007) assert that one of the advantages of open questions is that it reveals participants' thinking processes and it could reveal other interesting information. Since respondents are free to express themselves it eliminates the possibility of investigator bias (Kumar, 2005). However the disadvantage of open questions is that responses may differ among participants, which could result in difficulty whilst coding the responses (Cohen et al., 2007). Bloch (2004) argues that to ensure the measurement validity of a questionnaire the novice should seek help from professionals to determine whether questions are framed so as to elicit the information that is needed. This was achieved by engaging my supervisor's assistance.

4.2.3 The Interview

Once the quantitative data was captured, eight learners were selected for a post-hoc semi-structured interview (see Appendix B). Greeff (2006) define semi-structured interviews as those that are designed around areas of particular interest in this instance determining learners' feelings about concept maps, whilst still allowing flexibility in scope and depth. Post-hoc interviews are used to rank learners according to their ability levels and then some learners are selected from each ability level, ranging from high achievers, average performers to low achievers (Wallace & Mintzes, 1990). Since I am a novice researcher it was essential that I build a pilot venture of the interview into my study schedule. Greeff (2006) acknowledges that pilot endeavours ensure that researchers come to grips with at least some of the practical aspects of access and conducting of the interview, as well as becoming alert to their own level of interviewing skills. I learnt from my pilot that I should not talk too much because then I become the focus instead of the participants whose opinions I sought.

The learners' names for each ability level were put into separate hats to ensure that all learners had an equal chance of being selected. Durrheim and Wassenaar (2002) point out that participants be assured of the extent of confidentiality of the information supplied by them. Hence before the interview process learners were informed that the interview will be recorded and that summarized information will be used or some excerpts may be published but it will be reported anonymously.

The reason for the interview was two-fold: firstly it clarified thoughts that I had about a particular learners concept maps and secondly it allowed me to explore any other information, relevant to my study that came up in the questionnaire. This is supported by Nieuwenhuis (2007) who claims that semi-structured interviews are defined as a 'line of inquiry' that allows the attentive researcher to prod and explore emerging lines of inquiry that are related to the topic under scrutiny. The advantage of using semi-structured interviews is that the interviewer can pick up on non-verbal cues and explore interviewees suggested feelings or thoughts (Fontana & Frey, 2000). One of my main reasons for using interviews is that it allowed me, the researcher to use visual aids during the interview. I needed to show interviewees a series of concept maps that they had designed (Kumar, 2005). This could not be done in the questionnaire. Cohen et al. (2007) offer other strengths of this method. They maintain that this method allows for any gaps that may be anticipated in the data to be filled. In this study it was necessary for me to probe to gain an in depth understanding of learners perceptions regarding their changing conceptual understanding. It was therefore essential to use an interview as a data collection method as it facilitates this requirement.

4.3 ETHICAL ISSUES

According to Fontana and Frey (2000) gaining access to participants that one wishes to study is difficult in certain instances. However being an educator and studying my own learners made it ideal for me for many reasons. I have easy access to my learners and they also trust me. Since I teach these learners I have established a good rapport with them. The importance of this is confirmed by Fontana and Frey (2000) who asserts that since the aim of unstructured interviews is 'understanding' it is of utmost importance that the researcher ascertains a rapport with the participants.

According to Ali and Kelly (2004) getting informed consent is a procedure that supports individual autonomy and helps safeguard the rights of participants by letting them decide for themselves what are in their best interest and what risks they are prepared to take. Since these learners are minors' consent was also sought from parents (see Appendix A). Learners will also be asked to sign a letter of consent (see Appendix A). The letters informed learners and parents about the nature of the study and that the children will be interviewed during the breaks and not during tuition time. It also explained that learners could leave the process at any time without any repercussions. This is supported by Durrheim and Wassenaar (2002) who assert that consent should be voluntary and informed, and should contain a clear non-technical explanation of the task so that participants can make informed decisions whether to participate in the study or not.

When interviewing I needed to be mindful of introducing bias to the interpretation of questions and also in the framing of questions (Kumar, 2005). In order to avoid bias in the interpretation of questions, probing questions will follow responses made by participants in order to clarify responses and not to gain the responses that I am looking for. To avoid bias in framing of questions, I engaged the assistance of a peer to check the interview schedule.

I also need to be aware of power relations that exist between the learners and me. Schostak (2003) affirms that within the limits of the classroom, teachers are powerful beings in the lives of children. This is more so with grade eight learners who have just come from the primary school. These learners hold their educators in high esteem and may feel intimidated or compelled to give answers that they think their educator wishes to hear. Nieuwenhuis (2007) suggests asking a variety of questions that range from 'experience and behaviour' questions (Tell me about this concept map) to 'opinion and value questions' (How did you feel about the group work activity?) to help circumvent this.

McNiff and Whitehead (2002) mention many practical issues that researchers are faced with in the research process itself. They emphasize maintaining good ethical practice – he warns that as educators we should be mindful of abusing our power. They add that as researchers that we be aware of propagating false results in our enthusiasm to find something concrete at the end of our investigation. He also asserts that researchers should be realistic about what they can achieve and set deadlines that are achievable and ensure that you honour it to safe guard your credibility. Durrheim and Wassenaar (2002) warn that novice researchers conduct research in fields that they are competent to conduct. For example medical doctors should conduct research on trauma patients and educators on educational issues. According to Cohen et al. (2007) and Kumar (2005) qualitative research is evaluated by its credibility. Credible research produces findings that are convincing and believable. Cohen et al. (2007) and Kumar (2005) believe that this can be achieved by triangulation, prolonged engagement in the field, reflexive journals and an audit trail. My study uses three forms of data collection, which includes qualitative and quantitative methods. I believe that would be sufficient triangulation of results. Furthermore I will keep a reflective journal where I will record my field notes of every incident in the class that centres on the study; this will ensure validity of the processes involved in the study.

Durrheim and Wassenaar (2002) confirm that with interpretive research transferability is achieved by producing detailed and rich descriptions of contexts. They explain that this gives the reader detailed accounts of observations and the context in which it occurred. Durrheim and Wassenaar (2002) declare that interpretive and constructionist researchers cannot expect to find the same results repeatedly however they propose that findings be dependable. This is achieved through opulent and detailed descriptions that show how certain actions and opinions are rooted in and developed out of contextual interaction.

4.4 SUMMARY

The content of learners' concept maps were analysed qualitatively and reported as a narrative in Chapter 5. The questionnaire was quantitatively analysed. A short report that accompanied each question was justified by extracts taken from learners' responses. The interview served to fill in gaps of information that I could not gather from the questionnaire or the concept maps.

CHAPTER 5

PRESENTATION AND ANALYSIS OF FINDINGS

In this chapter I discuss the findings of my research in detail. I had used a multimode methodology to collect data. Initially I will present a brief outline of my introduction of concept mapping to my learners. This is essential because it sets a platform for the work that follows. The purpose of this study was to determine whether concept maps were effective teaching and learning tools and whether they were appropriate for assessment purposes.

Learners had to have a fairly good knowledge of how to construct concept maps. At the outset it was essential to introduce it in a manner that encompasses the existing curriculum structures and a method, which portrayed my personal teaching style. My thinking was influenced by a study conducted by Santanam, Leach and Dawson (1998) who did a study on how concept maps should be introduced, and whether they presented evidence for long-term benefits. One of their findings was that when learners were given a choice, they totally avoided using concept maps as they felt it played no part in their coursework. These researchers concluded that the way in which it was introduced could have been the reason learners reacted in this way. What's more, is that the researchers concluded that these learners had not gained sufficient expertise and confidence in constructing concept maps and hence could not see the value in concept maps. I sought to eradicate this by ensuring that I spent sufficient time introducing concept maps.

5.1 TRAINING LEARNERS TO CONSTRUCT CONCEPT MAPS

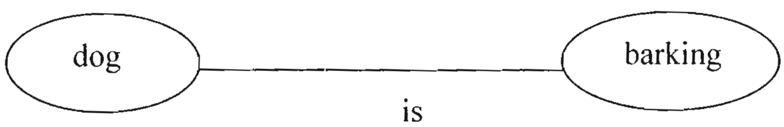
I introduced concept maps as described by Novak and Gowin (1984) in their book *Learning How to Learn.* I drew two columns on the board. The heading of one column was "objects" and the other was "events". I used *dog* as an example of an object and *barking* as an example of an event. The learners were then to give some examples, which they did. For objects we recorded words such as *kennel, bone, cat, book, table* and *car*. For events we recorded words such as *eating, playing, jumping* and *running*. It was interesting to note that the concept that learners listed were all associated with the dog. I would use this later to construct a simple concept map.

Then I asked them to close their eyes and asked them what they 'saw' when I said "*dog*" and I got a few responses like *"fierce", "cuddly", "dirty"*, etc. This was actually a good array of thoughts because everybody was thinking of different things. Then I went on to explain that the mental images that they conjectured were referred to as concepts. I had now introduced the word 'concept' to them, albeit a rather intuitive one. Then I drew their attention to the fact that the word '*dog*' made everybody think of something different. I then went on to explain that even though we use the same word we have differences in our mental images, which explains why we sometimes have problems understanding each other (Novak & Gowin, 1984). I added that words were labels for concepts; however we each make our own meaning of the word (Novak & Gowin, 1984).

I then enclosed the word dog and barking in an oval and asked them if it made any sense to them.

One learner shouted out: *"It could mean the dog is barking"*.

This provided the necessary response that was used as a springboard to introduce 'linking words'. I explained that linking words are used to join concepts together to create a short sentence, hence giving the concepts more meaning. I then provided an example to illustrate what I meant.



We did a few more examples of joining concepts with linking words such as *is, has, contains, includes*, etc.

Then I asked them to list some mathematical concepts that they knew. They listed *square, add, triangle, sum.* This was a useful list as it contained both concepts and associated events. I then asked learners if I could use Wingen Heights as a concept. Some said 'yes' and some said 'no'. I then explained that proper nouns were not concepts. I used a few more examples until I was confident that learners understood what concepts and events were. I then made some short sentences using mathematical concepts to illustrate how linking words and concepts are used together to convey meaning. The examples I used were: *a square has 4 sides* and *sum is the addition of numbers.*

Learners were then asked to construct a few of their own short sentences. A few learners put their sentences up on the board and together we identified the concepts and linking words. I ringed the concepts and used a line to join them. The linking word appeared along the line. As a follow up activity learners were then given a relatively simple skeleton map of geometric shapes with the concepts on a card (Figure 5.2).

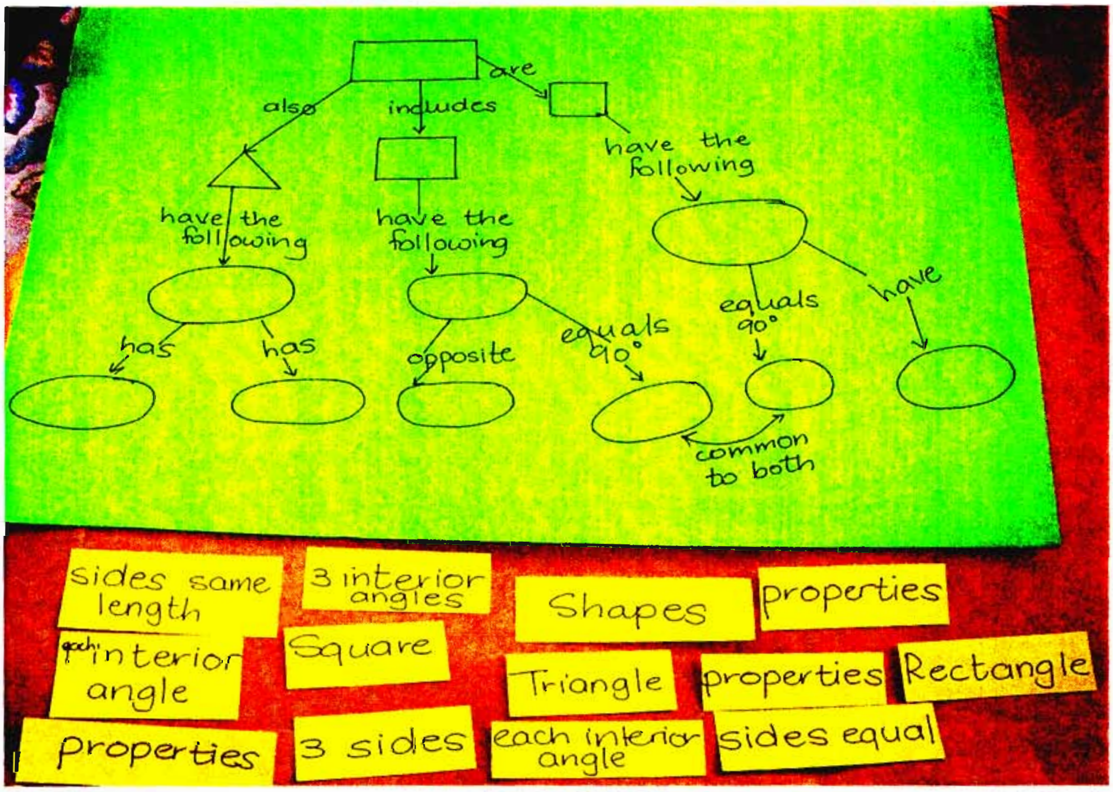


Figure 5.2 Skeleton concept map filled in by learners

They were expected to put the cards in the correct places. The purpose was for them to be exposed to expert concept maps so that they could get a feel of how to link the concepts. From my observation learners were animated during this first activity. The topic was familiar so they could see the connections quite easily and hence completed the activity successfully and in a short time. During this activity learners' talked positively about concept maps. This is indicated by comments such as, 'this is fun' and 'this is easy'.

As the homework task learners were given a short extract on 'the history of numbers' since the topic I was currently teaching was the number system. Learners had to compile a list of concepts from this extract. In the next lesson I recorded a list of concepts from learners responses on the board. Together with the class I constructed a concept map. The purpose of constructing this concept map with learners was to discuss the relevance of linking words and to talk about cross-links. We also discussed the relevance of propositions or linking word together with the concepts and highlighted that propositions tell the reader of the map how well you understand the relationships between concepts.

Within a few days the topic, real numbers was completed. I now felt that learners were ready for their first attempt at constructing a concept map. This time they had to produce a list of concepts using their notebooks and textbook and whatever other related concepts they could think of from primary school that they could link to the new concepts that they learnt in this section. I expected at least twenty-one concepts since this is what I compiled after examining their class work exercises and the textbook. These concepts were *real numbers, rational numbers, irrational numbers, integers, whole numbers, natural numbers, multiples, factors, prime numbers, composite numbers, squares, square roots, perfect squares, non-perfect squares, terminating decimal, recurring decimal, infinite decimal, fractions, mixed fractions and identity element.*

Learners were now challenged to construct a concept map of real numbers. They were then expected to present their work to their peers whilst working in groups of fours.

During this time the learners were expected to demonstrate and communicate their understanding of real numbers so that critics (peers and the educator) could make sense of this section. Thereafter the group had to jointly submit a concept map but this time they had to collectively decide on all the concepts they could think of and use in a single group concept map.

5.2 ANALYSIS OF CONCEPT MAPS

In order to enhance the analysis of concept maps, pictures of learners concept maps have been included, however pseudonyms have used to protect the identity of these learners. This was especially necessary as judgements were made about learners which could have a negative impact on the learner should he/she read the thesis.

During the analysis of the concept maps I focused on both the qualitative and quantitative aspects of learners' concept maps, with particular emphasis on the accuracy or validity of the knowledge represented by learners. A scoring guide represented by Table 5.1 was used to judged learners' concept maps. It was designed by modifying the Novakian scheme of scoring concept maps (Novak & Gowin, 1984) and that employed by Markham et al. (1994). Points were awarded for the nature of concepts used, the structural complexity of the network of concepts, valid links and relevant linking words. It needs to be emphasized that I did not see the need to teach my learners about the hierarchical arrangement of concepts; but marks were given for levels of branching. I felt this was relevant because I could then judge the extent of integration of learners' mathematical knowledge in that topic. Propositions that correctly describe the inter-relationship between concepts (Novak & Gowin, 2004), indicates the accuracy and strength of learners' connections (Baroody & Bartels, 2001). Points were also awarded for concepts used as this indicates the nature of students' perceptions of mathematical knowledge in a section (Karoline- Afamasaga-Fuantai, 2004) and their depth of understanding (Baroody & Bartels, 2001). I also awarded points for examples, as the number of concepts and examples linked together portray the learners' complete and flexible understanding of a topic whilst Markham et al. (1994) assert that examples represent specificity of knowledge. This simply means a way to ascertain whether a concept is really understood by a learner. Cross-links form an important part of concept maps as they reveal how previously learnt concepts could be integrated with new knowledge. Markham et al. (1994) refer to this as "conceptual integration or cohesion" (p 97). Karoline- Afamasaga- Fuantai (2004) affords another reason for including cross-links in assessing concept maps, in that redundant concepts indicate students' tendency to learn information in isolation from each other instead of identifying potential cross-links when the concept was first used. Generally concept maps are not scored out of a particular total since it is possible that a learners' map could have more links and concepts than the criterion-referenced map. In this study I use concept maps as a tool to explore concept map development. Quantitative scores will only assist in making qualitative judgments about learners' concept maps.

Table 5.1 Modification of Novak and Gowin's (1984) scoring guide

Category	Description	Score
Valid links	A meaningful relation between two concepts which is indicated by the connecting line and linking words	1 point for each meaningful, valid proposition
Branching	Is each subordinate concept more specific and less general than the concept drawn above it in terms of the topic being mapped.	1 point for each level of branching
Cross-links	Are there meaningful connections between concepts from one segment of branching to another concept in another segment	1 point for each valid cross-link
Examples	Specific events or objects that are valid instances of those designated by the concept level.	1 point for each example

5.2.1 Assessing individual versus group concept maps for real numbers

Here I assessed five individual concept maps and compared them to five concept maps that were done in a group. Learners first worked alone on a concept map on real numbers, thereafter they worked on a group effort on the same topic. The purpose of this exercise was to ascertain whether concept maps facilitated collaborative learning. I wanted to use group work early in the study as group work has a strong social function of providing support to learners. Since concept mapping was a new technique to these learners I felt that discussion amongst group members could enhance their understanding of concept maps. It was also possible that members of the group could grasp the technicalities of concept mapping and the value of using concept maps better from a peer than from an educator. Analysis of the interview revealed that learners felt that the group activity improved their understanding of concept maps. Typical responses offered by learners were: "Group work helps me to understand concepts because if I don't know I can ask someone who is in my group" (Nkanyiso).

To me it was essential that learners' got a firm grasp in constructing concept maps. Furthermore I also wanted them to feel comfortable drawing them. Several studies in the past indicate that the instruction time was too short or rushed and hence learners did not appreciate the value of concept maps. For example, an extensive study by Williams (1995) that included 2000 learners revealed that concept maps were extremely divergent. Students produced concept maps with over 300 different concepts over different terms. Some critics argue that the reason for this diversity resulted from students' not understanding the construction of concept maps. I therefore conducted various concept map activities during my study to ascertain were learners found it most helpful.

Table 5.2 reflects the mean scores of individual and group concept maps of the topic real numbers. Figure 5.3 represents the mean scores for individual concept maps as well as group concept maps graphically.

Table 5.2 Summary of Mean scores of individual concept maps and group concept maps

Categories	Individual mean scores	Group mean scores
Concepts	10	13.83
Valid links	8.83	13
Branching	1.83	2.33
Cross-links	1.50	0.50
Examples	4	8.33

The results reveal that in most cases the concept maps produced in a group scored higher points than in individual concept maps. According to Markham et al. (1994) the categories labelled "concepts' and "valid links" serves as a quantitative estimate of acceptable knowledge that is typically assessed in conventional evaluation measures. The group produced substantially higher scores for concepts and valid links. There is a 38% increase of concepts and 47% increase in valid links in the group artefacts. This implies that the social support characteristic of group concept map activities promotes building of knowledge structure. Further evidence in progressive change in knowledge structure is evident in the levels of branching. Group concept maps improved in the levels of branching by 27%. The number of cross-links is an indication of integration of knowledge. Here the concept maps displayed much divergence since in the group concept maps, some learners produced many cross-links whilst some concept maps displayed none. The group artefacts produced similar results. Nonetheless the cross-links decreased in group endeavours. Finally the number of examples representing specificity of knowledge increased in the group concept maps by over 108%.

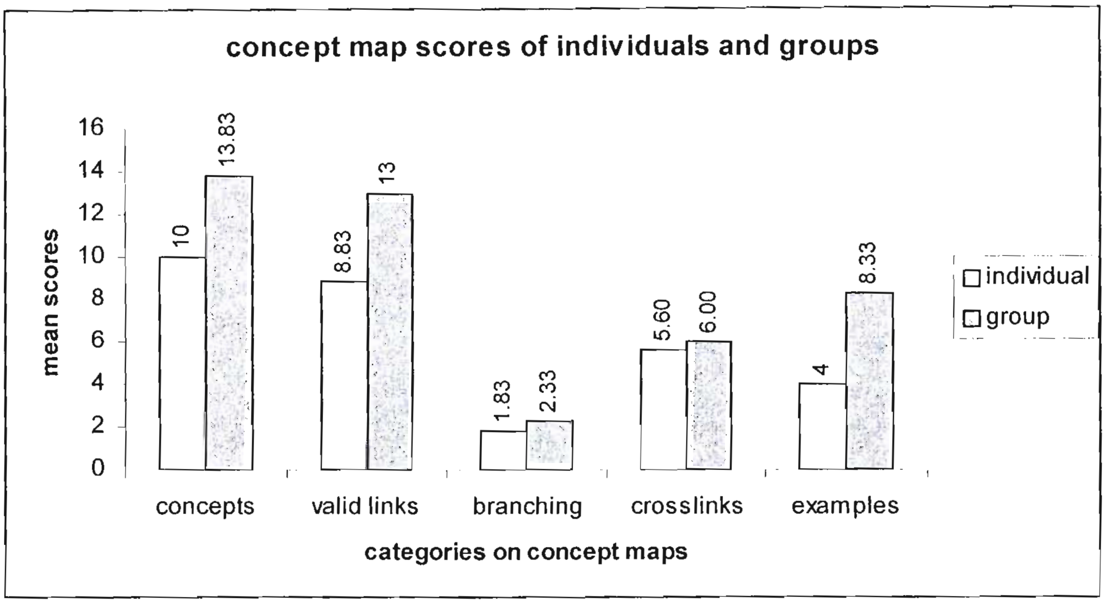


Figure 5.3 Dual bar graph representing individual and group mean scores

Further analysis of the interview revealed that all learners that were interviewed enjoyed the group work activity and found working with their peers supportive and helpful. This is exemplified by the comments: "When we do an activity in a group I understand because they (members of the group) explain to me when I don't understand (Sindiswa), "I found out what mistakes I made and my classmates helped me correct them" (Carl) and "It is easier to work in a group than alone because they help you to understand the work" (Portia).

Figure 5.4 is Atish's individual concept map on real numbers whilst figure 5.5 is a group concept map on real numbers of which Atish was a member. At a glance the concept maps are so similar one could conclude they were done by the same person. However a closer look at the two concept maps revealed some interesting features. Researchers such as Roth and Roychoudhury (1992) describe concept mapping as a valuable tool to help learners organise and reflect on their conceptual understanding.

Whilst Malone and Dekkers (1984) propose that concept maps are a visual representations of how our learners think. The purpose of this study is to explore learners' conceptual development during the course of this study whilst a sub-question is to determine whether group-work facilitates learning through the use of concept maps. For this purpose individual and group concept maps of the same section were compared. Both maps, Atish's individual concept map and the group artefact reveal relatively structured branching and cross-links. A key assumption of concept mapping is that concepts are linked with other concepts rather than being seen as entities on their own (Zeilik et al., 1997). Furthermore these links together with the linking word helps educators discern what statements learners are making about the relationship between concepts. Concept mapping has been frequently used as a pedagogical tool to help learners "learn more meaningfully" and form a "conceptual understanding of the subject" (Novak, 1990, p943). Upon close inspection the concept maps did reveal subtle but very important differences. For example, there were ten concepts that were common to both the individual and group concept map viz. *rational, irrational, whole numbers, natural numbers, prime numbers, composite numbers, factors, multiples* and *fractions.* The concepts *recurring decimal* and *terminating decimal*, occur in the individual concept map only whilst the concepts: *decimals, square roots, perfect squares, cube roots and identity element* appear in the group artefact only. It is difficult to actually hypothesize why significant concepts like: *terminating* and *recurring decimals* were left out in the group artefact, however it could be attributed to the nature of the group dynamics. The concept *terminating decimal* which was incorrectly linked in the individual map was left out completely in the group artefact. It might be that the group could not reach a consensus about its actual position on the concept map and hence left it out completely.

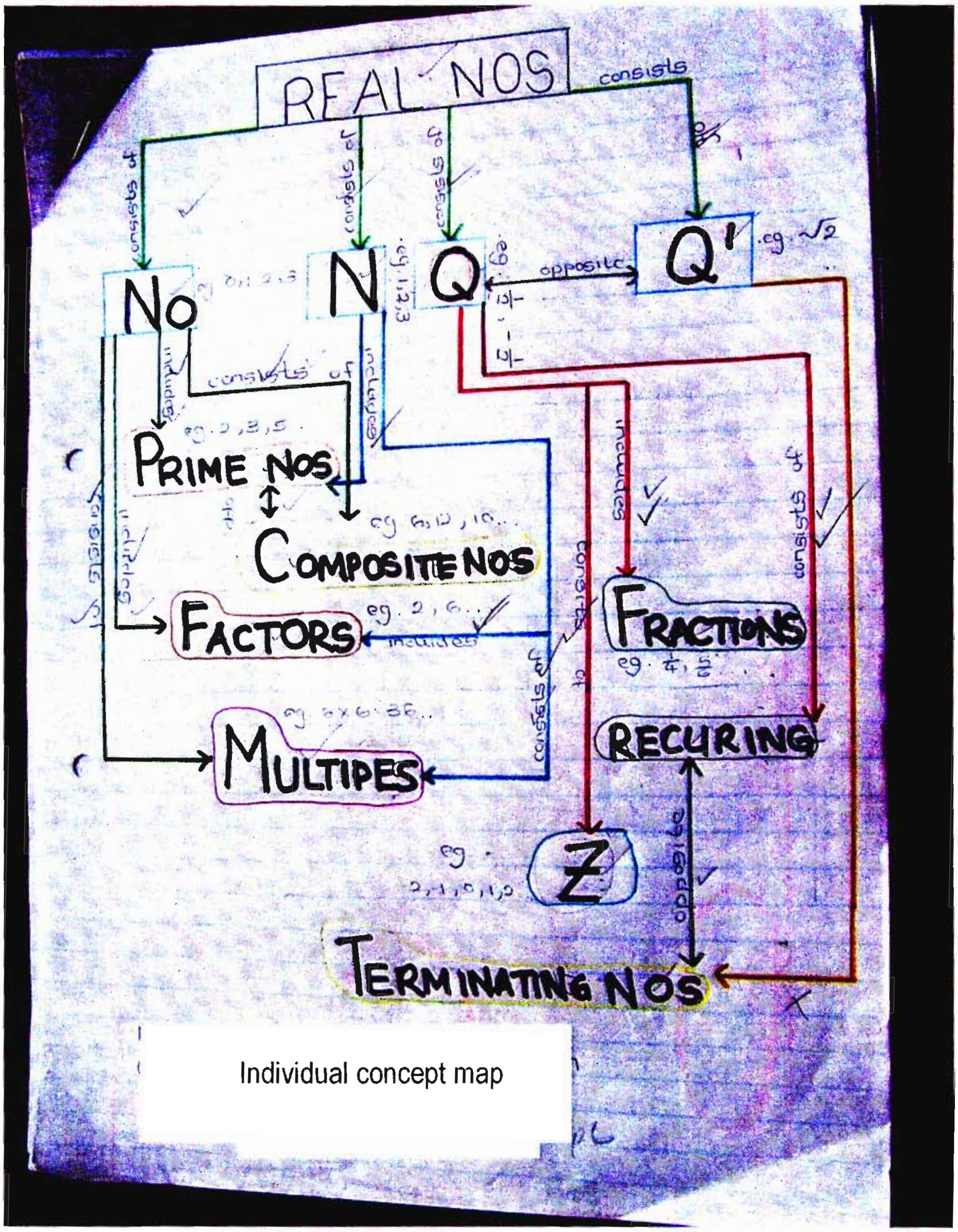


Figure 5.4 Atish's Individual concept map on real numbers

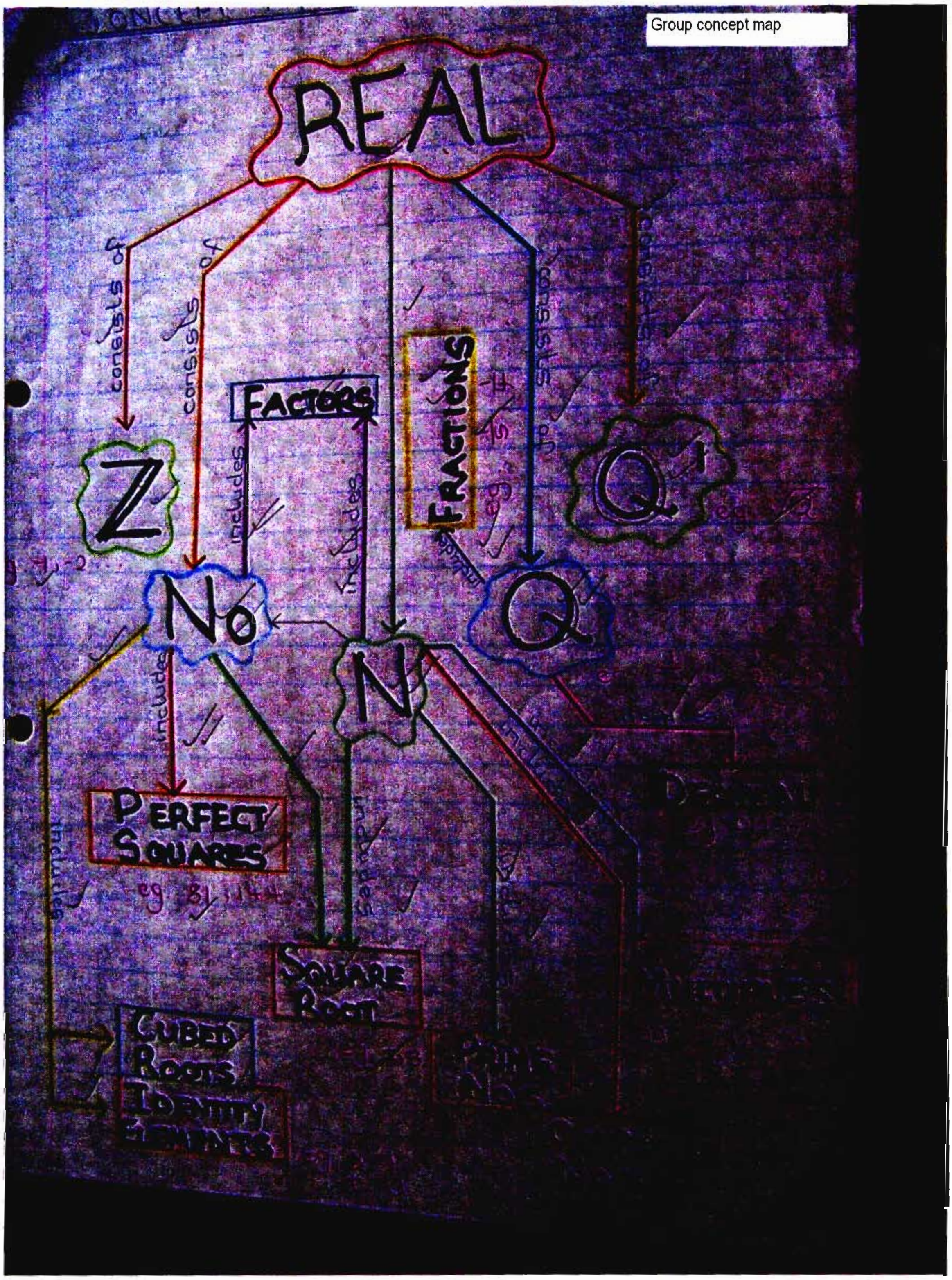


Figure 5.5 Atish's group concept map

The number of cross-links shown in a concept map is taken as a measure of integration of the knowledge base in a particular section. In Atish's individual concept map there were three valid cross-links, between the concepts: *rational* and *irrational numbers, recurring decimals* and *terminating decimals* and lastly between *prime* and *composite numbers* whereas in the group effort there were no cross-links at all. As I walked around during this activity I noticed there was heated debate amongst the members of this particular group. I gathered from listening in to their discussion that Atish wanted to include everything from his concept map, as it appeared to be better than the others in the group. This indicated to me that the group was probably frustrated by Atish's dominance and chose not to include the cross-links just to let him know that he could not have his way all the time. However this was at the expense of losing points for the cross-links.

The overall structure of Atish's group effort is far more complex than the individual effort. There are more concepts in the group endeavour indicating growth in this topic. Moreover the levels of branching increased substantially as well, revealing an integrated knowledge structure that the learners are developing when they work as a group. According to Wallace and Mintzes (1990) these findings imply a significant shift in the degree of concept differentiation and an increase in the total number of mathematically acceptable links encoded and stored in learners cognitive structure.

Figures 5.6 and 5.7 are individual and group concept maps, respectively for Shival on the topic real numbers. The largest difference in scores occurs between Shival's individual concept map and his group's concept map. Shival's effort did not include linking words just concepts linked to the central concept but the fascinating thing about this concept map was that the central concept was numbers whilst real numbers appeared in the first branch. If we assume that Shival meant number system when he wrote *numbers* then his understanding is quite profound since he sees real numbers as a part of the number system. However the learner fails to see that *rational numbers, integers and decimals* lie within the ambits of real numbers. Although the group endeavour included many more concepts indicating that together as a group they complemented each other's knowledge of the section it did not indicate much depth in the understanding of real numbers as most of the links stem from the main concept, *real numbers.* There is some branching from the concept *natural numbers* and even a cross-link between prime and composite numbers indicating learners' complexity in the understanding of *natural numbers.* Why was the group comfortable in drawing links from natural numbers only? It's possible that they are most familiar with this concept as it was introduced early in their primary school years and hence they understand this concept better than the others.

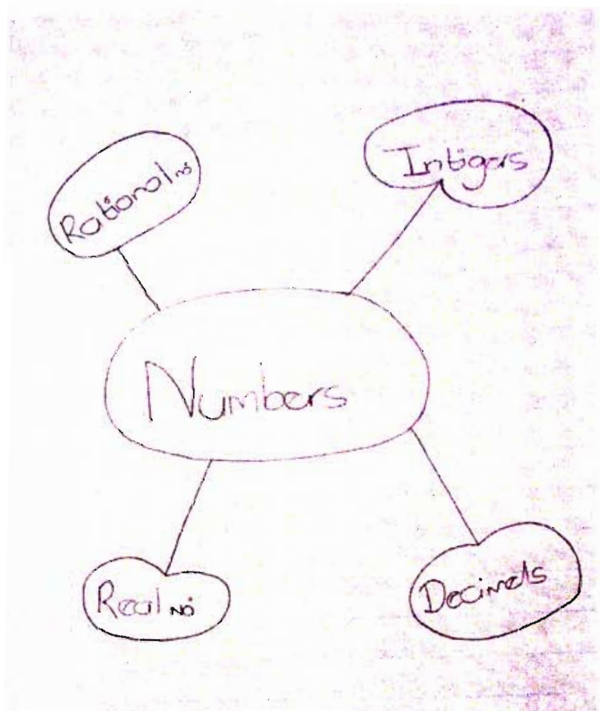


Figure 5.6 Shival's individual concept map on real numbers

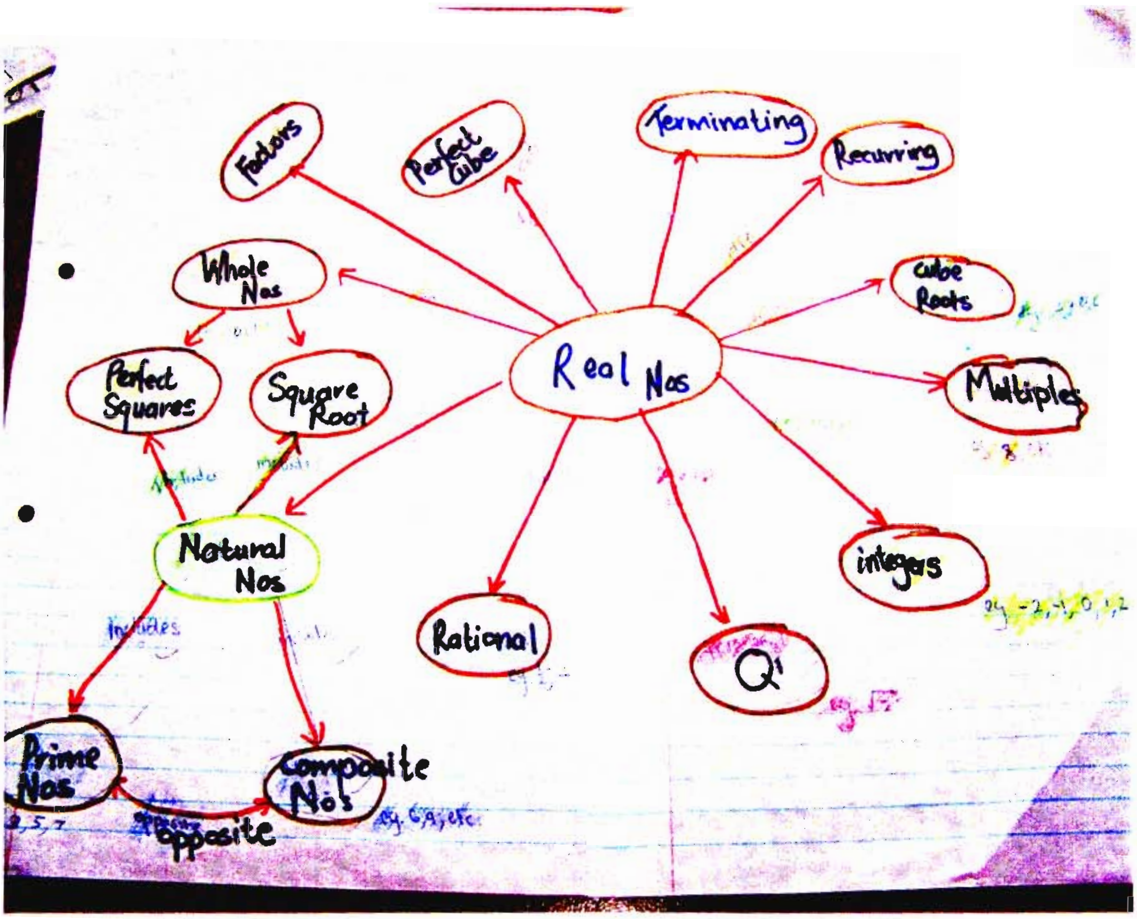


Figure 5.7 Shival's group concept map on real numbers

5.2.2 Assessing concept maps of real numbers and data handling

Concept maps of real numbers were done right at the beginning of the study whilst data handling was done eight months later, towards the end of the study. The rationale for comparing these two concept maps was to see how learners developed in the construction of concept maps, which will also reveal their conceptual development during the course of the study. Both individually constructed concept maps for real numbers and data handling were scored using Table 5.1. The concepts that I expected for this section were drawn up from learners' textbooks and their notebooks. They include: *data representation, data collection, data representation, data interpretation, surveys, questionnaire, tally tables, stem and leaf, bar graph, dual bar graphs, mean, median* and *mode.* For the construction of concept maps on data handling they were given the same instructions as for the construction of real numbers, that is to use as many concept as possible – these could be chosen from class discussions, textbooks, notebooks and any others that they knew from previous knowledge. For the analysis of the concept maps I chose six learners based on their scores in the June examination, ranging from the upper to the lower levels of the academic rung.

Table 5.3 Summary of mean scores for concept maps on Real numbers and data handling

Categories	Mean scores for real numbers	Mean scores for data handling
Concepts	11.83	23.33
Valid links	6.50	12.69
Branching	2.17	3
Cross-links	1	0.67
Examples	4.17	8.83

Figure 5.8 reveals that learners generally scored higher points in the latter concept map of data handling than in real numbers.

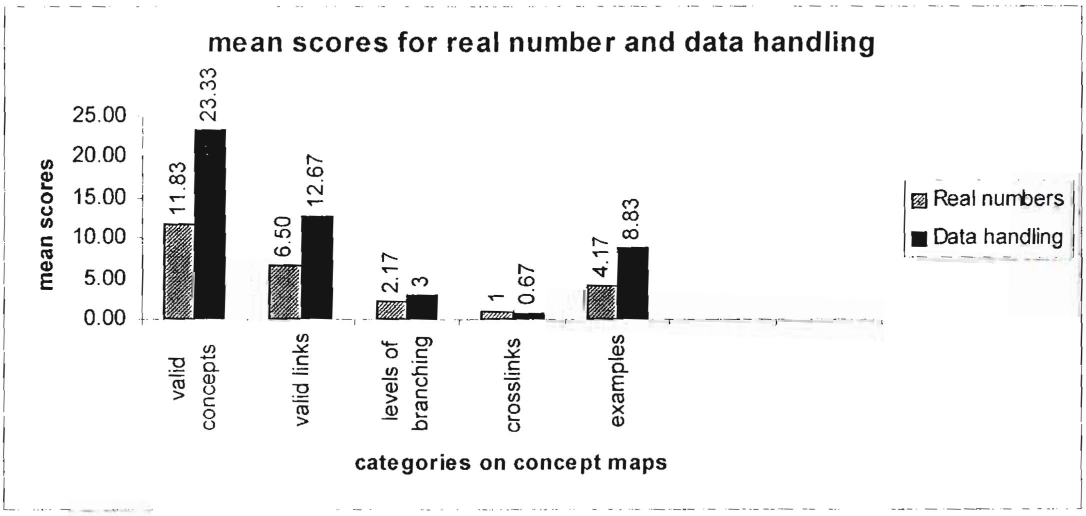


Figure 5.8 Dual bar graph representing mean scores for real numbers and data handling

The scores for 'concepts' and 'valid links' for the concept map on data handling is significantly higher than for the concept maps on real numbers. There is a 97% increase in concepts and an increase of 95% in valid links. This is an indication of the profound increase in the depth of knowledge as time progresses. The increase in valid links reveals that learners have improved in the accuracy of their understanding. The number of examples increased by an appreciable 111%. This is a clear indication of the substantial increase in learners' specificity of knowledge. The number of cross-links is an indication of the cohesion in knowledge. Here the cross-links decreased by 49%. In this category the analysis revealed similar results to the previous set of concept maps. Again the number of cross-links between learners' concept maps showed no coherence. There was a maximum of two cross-links in some concept maps whilst some had no cross-links at all.

I will now look at a few learners' concept maps. Figure 5.9 and 5.10 represents Mitchlin's initial and latter concept maps. Mitchlin is an above average learner, his scores reveal the highest difference between real numbers and data handling. The following discussion reports on Mitchlin's progress. Firstly, in the concept map for real numbers there are no examples cited to show how well he understands each concept. Whereas in the concept map for data handling he offers examples for all the ways to analyse data, for example he drew tally tables and stem and leaf plots. For data representation he mentioned the various graphs and even drew little bar graphs, pie charts, and so on. Under interpretation of data he offers a brief definition for the concepts: *mean, median* and *mode*. The concept map shows that the learner has a firm grasp of concepts and a sound knowledge of how the concepts in data handling are linked to each other. This signifies that he has a good understanding of the relationship that exists between the various concepts in this section.

For the concept map on real numbers Mitchlin used thirteen concepts whilst for data handling he used thirty-four concepts. In data handling most concepts that appear on his concept map were mentioned in class activities however a number of the concepts discussed in class were not, for example under data collection he mentions various other ways of collecting data other than those discussed in class. This leads me to conclude that the learner engaged in extra reading on the sub-topic of data collection and included it in his concept map. This is further evident as he offers advantages and disadvantages of the various data collection techniques. This is perhaps a reflection of how this learners' conceptual development has improved in this section. For real numbers many concepts that were mentioned in class activities are absent and two concepts are incorrectly linked, namely *terminating decimals* and *irrational numbers*. *Irrational numbers* should have been linked to *infinite decimals*. However it is interesting to see that this particular concept, "*infinite decimal*" is absent from all learners' concept maps on real numbers. This is where I find concept maps especially useful – it makes me, the educator aware of gaps in learners' knowledge structure and areas that I may have not have discussed very well. Although there are linking words, they are repeatedly used and nondescriptive. According to Baroody and Bartels (2001) this indicates an incomplete understanding of the relations between concepts or a lack of confidence in this section.

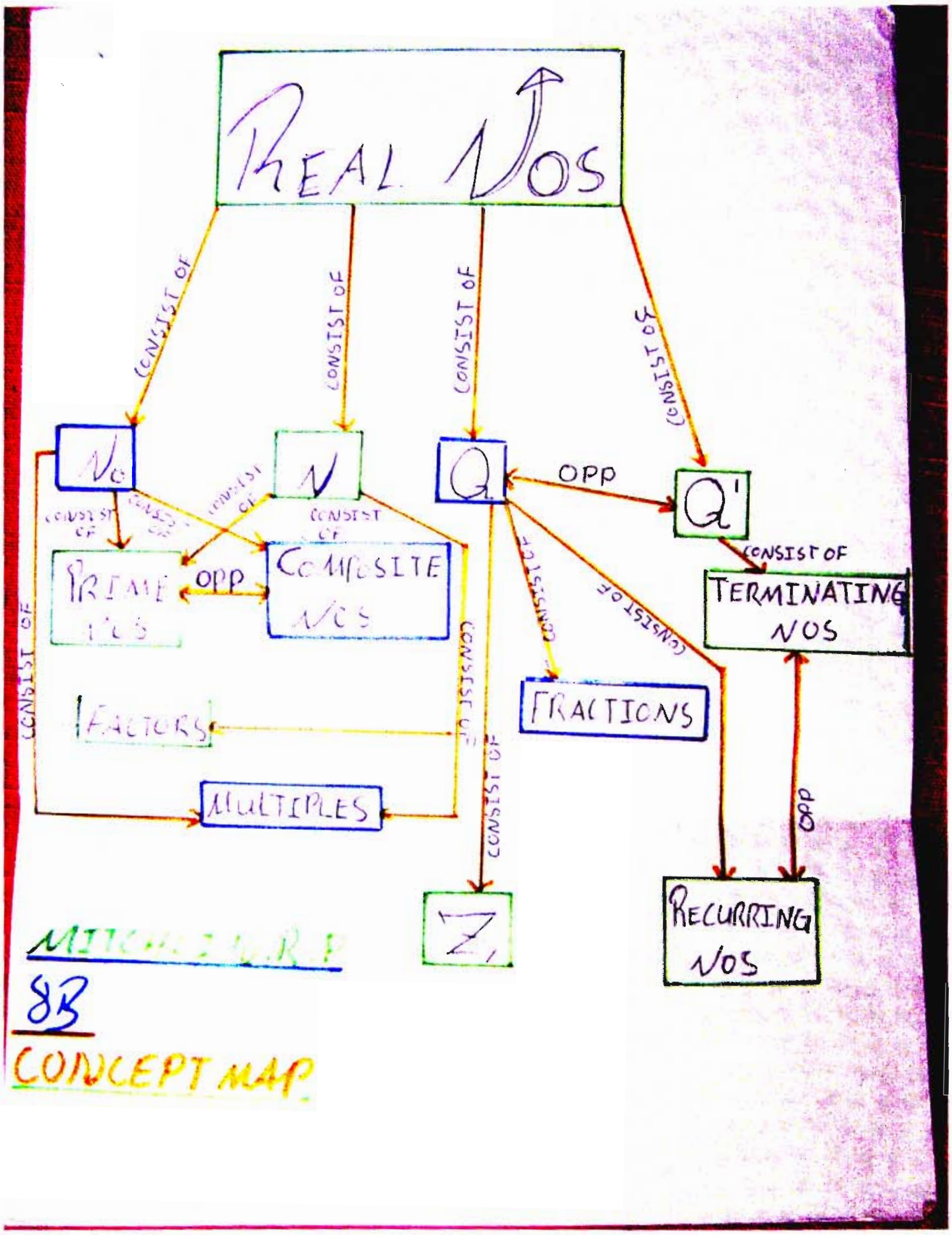


Figure 5.9 Mitchlin's concept map on real numbers

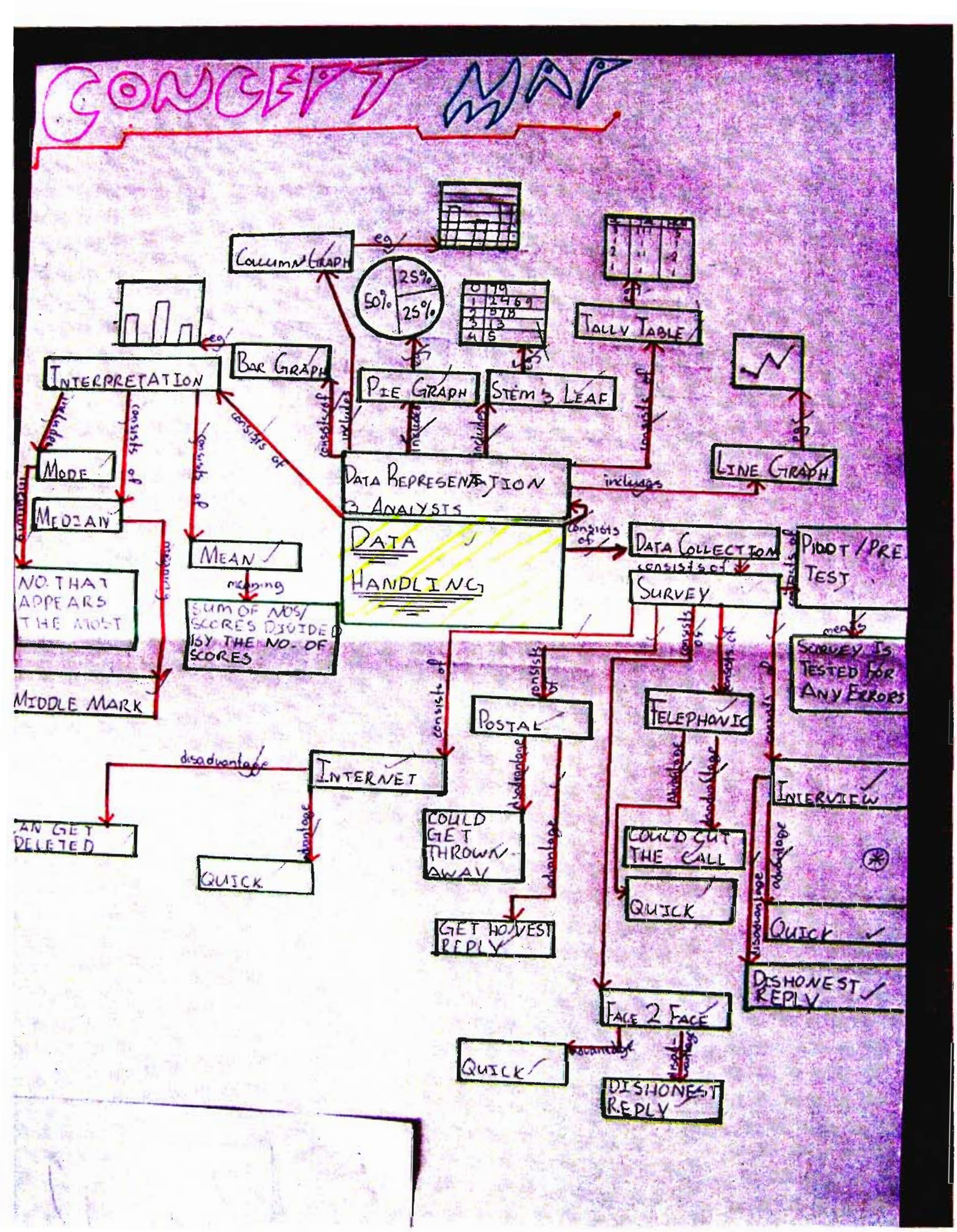


Figure 5.10 Mitchlin's concept map on data handling

The other concept map that I would like to comment on is Vukani's. His performance in mathematics has been below average but has shown great enthusiasm in class from the beginning of lessons using concept maps. He particularly enjoys the assessments we engaged in this year, like the research project, designing a questionnaire and collecting data and off-course the concept maps. There was a difference of eleven points between his concept map for real numbers and that for data handling.

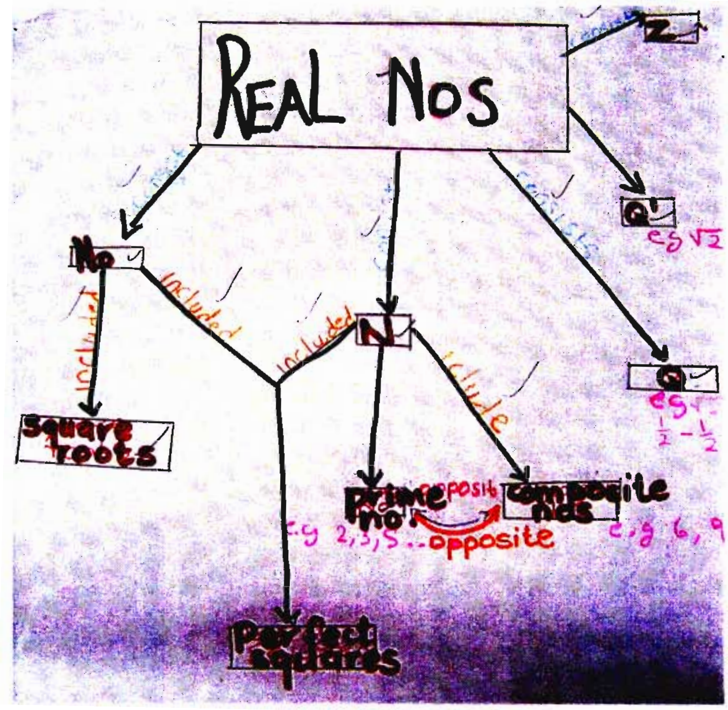


Figure 5.11 Vukani's concept map on real numbers

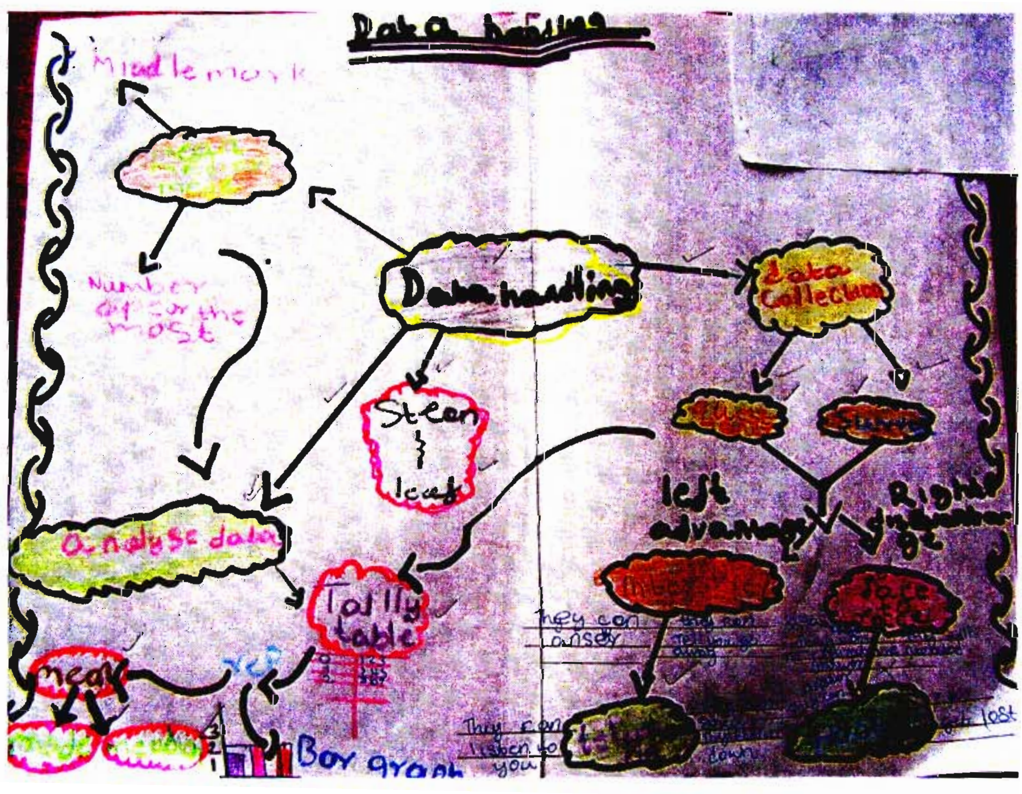


Figure 5.12 Vukani's concept map on data handling

All of the ten concepts used in the real numbers concept map is valid however there were many more concepts that were discussed in class that do not appear on his concept map. This is probably an indication of an incomplete understanding of this section. Yet concepts that are used are linked to other concepts using relevant linking words. Thus I hypothesise that although he does not have a good knowledge of all concepts, he does have a good grasp of the few concepts that he does list.

In data handling too, there are many concepts that were covered in class that are excluded from his concept map but it does have more concepts than the concept map for real numbers. For data handling there are thirteen valid links however there are no linking words to suggest the extent to which he understands the relationship between these concepts. In real numbers he uses one cross-link between *prime* and *composite numbers* with the linking word *opposite.* Although this may be a mediocre word to describe the relationship between the two concepts, it nevertheless expresses his understanding of the link. This suggests that he has an accurate understanding of the relationship between these two concepts and it indicates some complexity of understanding of concepts that are already on the concept map. In data handling there is one cross-link between questionnaire and tally tables but there is no linking word. This is a valid link since data from the questionnaire is organized on a tally table however I can only guess that he did not include a linking word because he was unsure of the relationship that exists between the two concepts. Although both concepts maps have peculiar strengths and weaknesses, judging from the scores for each concept map I can conclude that there is some improvement in Vukani's conceptual development across the study.

I am now going to examine Shahil's concept maps for real numbers and data handling more closely. Shahil is an above average learner and I wanted to compare the development of his conceptual knowledge from the start of this study to the end of this study by comparing his concept map on real numbers and data handling. For the concept map on real numbers he used fifteen concepts and three levels of branching with fourteen valid links. Whilst for data handling he used twenty-nine concepts, three levels of branching and forty-four links. This shows a solid grasp of concepts and a profound level of understanding, which is represented by the complex nature of his concept map, and the elaborate connections that he sees between concepts in data handling.

Shahil's knowledge and understanding of concepts in real numbers is satisfactory compared to other learners' in this study. For example when compared to Atish's individual concept map on real numbers, Shahil's concept map has fewer concepts and most are incorrectly linked.

Shahil's concept map on data handling shows a complex structure, indicating an immense conceptual development across the study. The large number of levels of branching and linking words in data handling is evidence of a more integrated structure of his knowledge base than for real numbers. In addition he uses a vast number of concepts for data handling than for real numbers that surpasses concepts covered in class. For his concept map on real numbers many concepts that were discussed in class are absent from the map, such as "recurring decimals and fractions". Moreover the branching attached to Q` should have been linked to Q. This indicates that the learner lacks the basic knowledge of real numbers. The use of linking words is non-descriptive indicating a poor understanding of concepts in real numbers. Even the examples quoted in some instances are incomplete for his concept map in real numbers; "2" the first prime number is absent from the list he made. For "terminating decimals" he incorrectly gives an example for "recurring decimals".

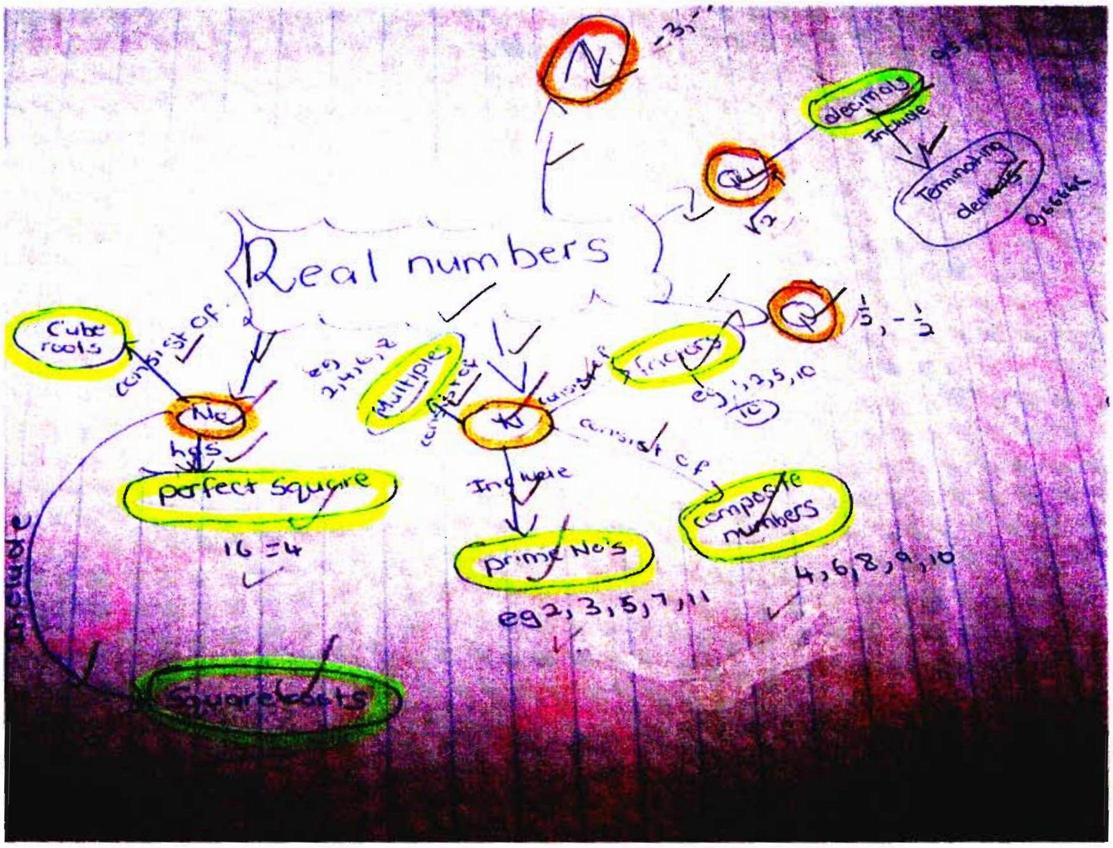


Figure 5.13 Shahil's concept map on real numbers

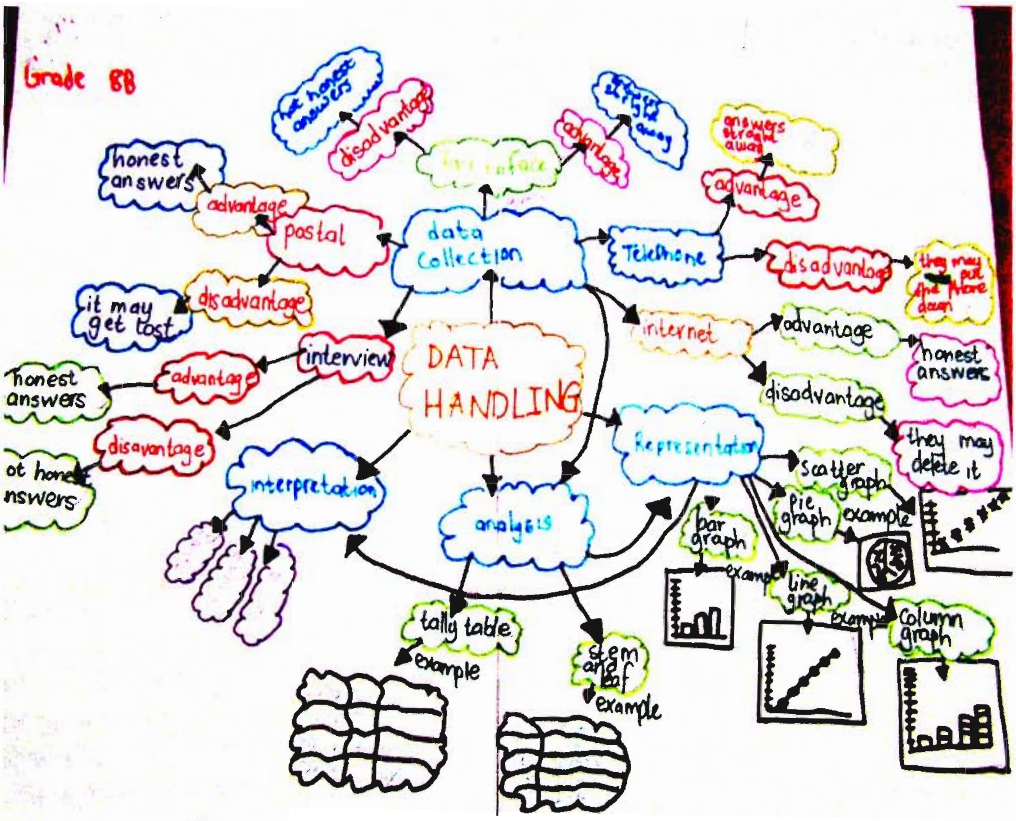


Figure 5.14 Shahil's concept map on data handling

The analysis of concept maps helped me, as the educator to identify gaps in learners' knowledge structure and to identify misconceptions in specific areas. This insight helps me to make the necessary adjustments to my instruction to fulfil learners' educational needs.

5.3 THE QUESTIONNAIRE

After ten months of concept map activities integrated with other mathematics activities the grade eight learners who took part in this study answered a questionnaire. All learners completed the questionnaire. The questionnaire that I used was not a traditional one but incorporated some concept maps as well. Learners did not experience any problems with understanding the concept maps in the questionnaire. There was only one query from a second language speaker – she did not understand what 'grasp' meant. After a brief explanation the learner continued answering the questionnaire.

5.3.1 Response to whether learners liked using concept maps during their maths lessons and their reasons thereof

Of the thirty-four learners that responded to the questionnaire 29% liked using concept maps in their mathematics lessons whilst 70% preferred using concept maps sometimes during their mathematics lessons. 1% did not like using concept maps at all. Some reasons offered by the 29% of learners that like using concept maps in their maths lessons were: "Concept maps are fun and creative way to learn and understand " (Denelle), "it is a helpful way to learn" (Vukani), "all the work is summarized so it is easier to learn" (Denise), " It helps me remember the different topics more easily"

(Presantha) and "It helps me understand the whole section in one simple map (Netrisha). The one learner that did not like using concept maps, found that " It is hard to do and I don't understand it" (Jessie). According to my reflective journal this learner was not in my class for almost two weeks as he was part of the school choir that was preparing for a competition. He missed the entire introductory lesson and follow up activities that were designed to build learners confidence in constructing concept maps. This could be a possible reason why he found it difficult.

Of the 70% that preferred to use concept maps 'sometimes', the general feeling was that they, at times, found concept maps confusing and at other times they did not. The reasons vary but three general categories seem to emerge.

The first one was that learners felt that it was easy to construct concept maps for certain sections only. This is supported by the comments: " I chose sometimes because when using it, it can be very helpful but for difficult sections it can be very confusing" (Leshav), "It helps with certain topics in maths not all" (Kershan) and "Sometimes it is confusing and sometimes its easy to understand, it all depends on what it is about" (Shival). From these reasons it is possible that learners find it difficult to construct concept maps for the more challenging sections. This was also evident from analysing learners' concept maps. Learners produced far more integrated concept maps for data handling than for real numbers. Real numbers is in fact a difficult topic within the grade eight syllabus.

The second general category that became apparent was learners' preference to use concept maps that were drawn by their teacher rather than concept maps drawn by them. This is exemplified by the following responses: " It is a nice way to learn, but sometimes gets confusing when constructing your own" (Akshay), "Sometimes when my teacher is drawing on the board, it just clicks in my head and I understand everything." (Wandile).

A third general theme that emerged was based on the time constraints of constructing concept maps. This is demonstrated by the comment: "It can be very helpful although it can be very time consuming…"(Leshav).

Learners' who preferred using concept maps, 'sometimes', had many positive comments to make about concept maps. Firstly, learners found it to be helpful in their understanding of maths concepts during the times that they did like using them. This is indicated by the statements: "… but when we do one it helps to understand how sections are linked but sometimes I just don't get it" (Kamilla), and "It does make your work easier when you do use it" (Serisha). Secondly, some learners found it useful whilst revising. This is illustrated by the following: " it is also good when we study because we can see how each concept is linked to the other" (Renita) and "Sometimes it is easy to do and understand and it can help with the exam" (Denise).

5.3.2 Responses to when learners found concepts maps useful

In Table 5.4 learners' reasons for using concept maps at the beginning of a section are recorded. In response to when learners found concept maps most useful,

Table 5.4 Aggregated responses for the usefulness of concept map

	Yes	No
End of section	79%	21%
During section	85%	15%
Beginning of section	48%	52%

79% found it most helpful at the end of the section, 85% during the section and 48% at the beginning of the section. The lowest percentage was recorded for the use of concept maps at the beginning of a section. This could probably be contributed to learners' not having developed concepts fully at the beginning of a section and it is therefore difficult to see the relationship the different concepts. It is clear that once concepts are developed and well-understood learners find it easier to draw a concept map. The 85% that prefer using concept maps during a lesson felt that concept maps helped them to grasp the concepts quicker and helped them to see how the new concepts are linked to old ones. It also helped learners to see how the new concepts are linked to each other.

5.3.3 Response to how concept maps affecting learners' learning when used at the beginning of the section

Table 5.5 represents the aggregated responses for use of concept maps at the beginning of a section. 94% of the students indicated that concept maps helped them to link previous knowledge to new concepts. Perhaps it is the act of drawing up the concept maps that made them reflect on what links the old knowledge to the new. This action could possibly be stimulated by some active thought.

Table 5.5 Aggregated responses for the use of Concept maps at the beginning of a Section

	Yes	No
Linking to existing concepts	94%	6%
Improving understanding	88%	12%
Recall of concepts	85%	15%

Furthermore 88% of learners felt that the construction of concept maps improved their understanding of what had to be learnt in the new section. This is a fairly high percentage and its significance lies in the fact that introducing lessons using a visual method such as concept maps may increase interest and motivate learners. 85% of learners agreed that concept maps helped them to remember the new concepts. This is likely since all the concepts of a section are seen together as well as how they are related to each other.

5.3.4 Responses to how the use of concept maps during classroom activities affected learners' learning

Below in Table 5.6 are the summarized percentages of how the use of concept amps during classroom activities assists with learning. 76% of learners felt that concept maps used during a section helped them to grasp the concepts quickly whilst 88% felt that it made it easier for them to see how old concepts were linked to new concepts and 88% found that it made it easier to see the relationship among the different concepts.

Table 5.6 Aggregated responses of concept maps during classroom activities

	Yes	No
Grasping concepts quickly	76%	24%
Linking concepts to new concepts	88%	12%
Relationships between the different concepts	88%	12%

5.3.5 Responses to how the use of concept maps used at the end of a section affected learners' learning

The responses for the use of concept maps at the end of a section are shown in Table 5.7. Analysis of the questionnaire reveals that 91% of learners found it helped them to see how old concepts are linked to new ones. Again it can be noted that at the end of the section the learner can appreciate seeing all the concepts and the relationships that exist among concepts in just one map. This observation is supported by 85% of learners who claim that concept maps helped them to see the relationship among the different concepts. In addition 79% of learners found concept maps

Table 5.7 Aggregated responses for the use of concept maps at the end of a section

	Yes	No
Linking old concepts to new concepts	91%	9%
Grasp the concepts quickly	79%	21%
Helped to see the relationship between concepts	85%	15%

discussed at the end of the section helped them to grasp the concepts quickly which assists in understanding how the whole section fits together. This is probably due to the concept map displaying all the concepts of a section in a single map. Denelle who felt that concept maps "summarizes all the work so it is easier to learn" supports this.

5.3.6 Responses to whether learners will use concept maps to revise

The reasons quoted by the 82% of learners that will use concept maps when revising, were varied but insightful. The general feeling was that it made understanding of mathematical concepts easier and that this method of learning was quick and easy. This is characterized by the following comments: "It is easier to learn from as less reading is required" (Akshay), "It helps me to fully understand when I'm revising" (Kraig) and "It will make it easier for me when I'm learning and I will understand it better" (Nirashika).

The other 18% of learners provided different reasons for how concept maps helped with their understanding during revising. The reasons could be grouped into three themes. In the first instance learners claim that it synthesizes and integrates information, ideas and concepts which assists in memorizing of subject matter. This is exemplified by the following responses: "I learn quicker because it is easy to remember" (Vukani) and " It helps me to remember what to learn and it is easy to learn in this way" (Dalene).

The next theme relates to the linking of concepts that helps to organize information into meaningful groups. These learners felt that seeing all the concepts at once, helps to improve their understanding of the topic. Denelle responded, "It shows me which sub-heading falls under which heading and shows me the joining of sections", whilst Renita retorted, "I am able to learn better by seeing how all terms are linked, it is easier to remember" and Zondi reported, "Yes I will use it to revise because it helps me to understand things better when I know how they're linked".

The other theme explains that understanding is easy when notes are summarized. This is typified by the following responses: "I will use it when revising because it makes it easier for me to learn and understand when terms are summarized and made into simpler sentences" (Denelle), "It makes it easy to understand, it is less confusing than looking at chunks of notes" (Ashiel) and "It is easier because there is less to learn from but you still get a better understanding than if we had to go through booklets of notes"(Presantha).

5.3.7 Responses to whether learners preferred concept map tests to traditional tests

76% of learners prefer taking concept map tests whilst 24% prefer traditional tests. The general feeling amongst learners who prefer traditional tests gave the reason that they prefer it because they've used this format since primary school, however they claimed they liked using concept maps to revise. This is confirmed by the following comments: "I prefer writing traditional tests but I like using concept maps to learn" (Elton) and "I don't understand concept map tests, but it is easier to learn from a concept map" (Netrisha).

Learners that prefer concept map tests generally felt that they were easier to do and a fun and enjoyable way to be assessed. This is illustrated by the following comments: "It is easier than traditional tests" (Suhana) and "Yes I will use it to revise because it helps me to understand things better when I know how they linked" (Zondi). Renita wrote, "Concept maps are easier, traditional tests are complicated".

Some felt that concept map tests were a good reflection of their understanding of how concepts are linked to each other. This is exemplified by the following comments: "I learn a lot more when I do concept map tests; it shows my understanding of links between things" (Kamilla) and "Concept maps are useful for testing because it proves your understanding of where each concept fits" (Leshav).

Others liked using concept maps because it allowed them to express themselves creatively, hence making maths fun. This is shown by comments such as: "It is more enjoyable when I can be creative and express myself with colours. It makes maths fun for me" (Atish) and "Concept maps makes maths fun, when school is fun the learners will want to learn" (Mitchlin).

Whilst some indicated that concept maps allow them to retain knowledge well after the test is written. This is typified by the following comment, "It is easy to remember what I have studied, even after I had finished the exam" (Presantha).

The analysis of the concept maps helped me to discover the extent of learners' conceptual development, whilst the questionnaire revealed that learners had mixed feelings about using concept maps during a lesson. However there was overwhelming support for the use of concept maps at the end of a section as learners found it very helpful when revising. The questionnaire also revealed that learners found it easier to remember a section when it was introduced using a concept map. The interview served to clarify issues that were unclear in the concept maps and to probe ambiguous comments in the questionnaire.

5.4 SUMMARY

Analysis of the questionnaire and interview revealed that aside from enjoying concept map activities due to its creative non-competitive nature, there were positive cognitive and affective outcomes from the group work tasks. Learners appreciated the positive social factors associated with group work and reported that the support and assistance of group members helped with their learning. Learners also acknowledge that the discussion in the group made them re-evaluate their understanding of their concept maps. Analysis of the group and individual concept maps showed that concept maps revealed a more integrated and complex structure after the group work interaction. This provides further evidence that group work assists in improving learners' cognitive structures. This translates to learners gaining a more in depth understanding of concepts and cohesion of knowledge for that particular section.

Comparison of concept maps done at the beginning and end of the study show considerable increase in structural complexity and integration. This is an indication of the cognitive growth amongst learners as time progressed. The number of concepts and valid links for the latter concept map increased significantly. This indicates accuracy in understanding of concepts. Furthermore there was an appreciable increase in the number of examples quoted in the second concept map. Hence demonstrating that learners' specificity in knowledge was also enhanced as the study progressed.

The analysis of the concept maps helped me to determine the extent of learners' conceptual development, whilst the questionnaire revealed that learners displayed mixed feelings for using concept maps during a lesson. There was overwhelming support for the use of concept maps at the end of a section as learners found it an invaluable tool to revise. The interview served to explain issues related to the group-work activities and clarified parts of the questionnaire that I did not fully understand.

CHAPTER 6

DISCUSSION, LIMITATIONS AND RECOMMENDATIONS

The focus of this research was to investigate learners' conceptual development in mathematics in a grade eight class. This investigation was guided by the following key research questions:

1. What are the advantages and disadvantages of using concept maps to teach mathematics? – A literature perspective.
2. Can concept maps facilitate group-work?
3. Are concept maps an effective learning tool for mathematics for grade eight learners?
4. Can concept maps provide valid information for the teacher about learners' knowledge of mathematical concepts?
5. How can concept maps assessments be practically applied to classroom situations?
6. Do concept maps develop grade eight learners' conceptual understanding through the comparison of successive concept maps?

6.1 DISCUSSION

I will now use the above key questions as a backdrop to discuss my findings, make recommendations and list the limitations of my study. From the discussion in the previous chapter I will make general conclusions from the findings of this study and support these findings from previous research wherever possible. Within the realms of the classroom this study provided remarkable findings about the use of concept maps. Within the constraints of this study I would like to present the following conclusions.

6.1.1 Use of concept maps to assess declarative knowledge

The study revealed that concept maps was an effective tool to measure changes in learners' knowledge structure. Comparison of successive concept maps helped to determine learners' knowledge acquisition. Learners' concept maps revealed a more integrated and complex structure after the group work interaction. For example, Shival's individual concept map in Figure 5.6 showed a substantial growth in concepts and how they are linked to each other after the group-work session (see Figure 5.7 for Shival's group concept map on real numbers). This translates to learners gaining a more in depth understanding of concepts and cohesion of knowledge for that particular section when learners confer with each other in a group.

Furthermore comparison of concept maps done at the beginning and end of the study show considerable increase in structural depth and cohesion of concepts. This was apparent when examining the sample of chosen concept maps on real numbers that was done at the beginning of the section to concept maps on data handling that was done at the end of the section. The latter concept maps on data handling included many more concepts and showed integrated branching and cross-links, indicating complex cognitive growth as time progressed. Learners' latter concept maps also revealed elaborate connections and a better quality of linking words, revealing a firm grasp of concepts and a profound level of understanding.

6.1.2 Group-work using concept maps

The use of concept maps proved to be very effective in learning within a group. Learners benefited immensely from working with their peers as they assisted each other when concepts were omitted or incorrectly linked. They engaged in animated discussion about which concepts should be included and which should not be included. Most importantly even the reserved learners participated in these discussions. They enjoyed the social dynamics that group work provided and enhanced their understanding at the same time. Learners especially appreciated working in groups in this particular instance as they were working with a new technique. Novak (1990) shows that when learners work in small groups and co-operate in striving to learn the subject matter, encouraging cognitive and affective results are observed. White and Gunstone (1993) found that concept maps promote serious debate even amongst learners that generally do not participate in class discussion. They suggest that this is perhaps due to the "purposeful" and "physical acts" that building of concept maps involve. In addition they add that although the intellectual challenge of concept maps cannot be contested, concept maps do not pose the competitive threat that traditional forms of testing pose. This is probably due to concept maps not having right or wrong answers.

6.1.3 Affective Factors

Based on evidence obtained from the questionnaire during the study learners enjoyed the creativity and freedom that concept maps allowed. Generally learners enjoyed their maths lessons because concept maps introduced fun and hands on activities, which were different from traditional maths lessons, were learners worked through mundane exercises. However, according to the questionnaire there were learners that did not like using concept maps during their lessons. This might be due to the nature of the knowledge used in concept maps. Concept map tasks do not test the procedural knowledge that makes many learners nervous. It tests another aspect- the conceptual knowledge. A study conducted by Jegede, Alaiyemola and Okebukola (cited in Novak, 1990) recorded learners' anxiety levels whilst working on concept maps. They used the Zuckerman's Affect Adjective Checklist to determine students' levels of anxiety and found that students using concept mapping displayed a highly significant reduction in anxiety levels. Another author White and Gunstone (1993) believes that the friendly and non-threatening nature of concept maps allows learners to contribute freely to concept map activities yet simultaneously revealing a wealth of information of their knowledge structure.

6.1.4 Promotes Learning

Learners found concept maps to be a helpful way to learn as all the information is summarized in one simple map. They concur that concept maps could be used as a summary of their notes from which it is easier to learn rather than going through copious amounts of work which was evident from analysis of the questionnaire. Wandersee (1990) in his article *Concept Mapping and the Cartography of Cognition* also outlines the benefit of using concept maps to summarise information. These findings are consistent with work done by Novak (1990), who declared that concept maps help learners "learn how to learn". He explains further that it could be the organisational structure of the material and the easy recognition of how concepts are inter-related that helps learners make sense of new knowledge.

Some learners found that it was easier to remember information when learnt from a concept map that was designed by the educator. Learners found that it was easier to remember because they could see the relationships between the concepts, which helped them understand the section. Willerman and Harg (1991) found similar findings in their study that used concept maps to introduce a new topic (used concept map as an advanced organizer). They found that learners' achievement improved significantly when introduced with concept maps. They believe that learners retained the information better due to the visual and organisational nature of the concept maps. They add that another reason for the effectiveness of using concept maps could be attributed to the teacher designing the map. Since then the map was more complete and accurate than a learner-constructed concept map.

Other learners found that when they used concept maps, they could still remember information well after the test or exam was written. Novak (1990) report that many educators and learners are surprised to see how this simple tool facilitates meaningful learning and aids in the retention of knowledge for longer.
Although learners found concept maps helpful to revise and to use during lessons, some preferred conventional tests to concept map tests. Those that supported this view offered that they were familiar with conventional type assessments and will therefore perform better.

6.1.5 Information for the teacher

Concept maps provides a wealth of information to the educator. Examining learner maps helped me gauge misconceptions and gaps in learner understanding. This helped me to ascertain whether learner understanding was coherent with what I expected. It also helped me to judge the shortfalls in my instruction. According to Baroody and Bartels (2001) concept mapping can be an invaluable tool for assessing the meaningful learning of mathematics. They expand that it helps to determine the accuracy and depth of learner understanding. White and Gunstone (1993) claim that close inspection of concept maps can result in reconsideration of teaching styles to fill in particular gaps in learners' knowledge structure.

6.1.6. Concept map assessments

Although this study successfully established that concept maps could be used to determine learners' conceptual development, the practicality of scoring concept maps is still problematic. In South African schools educators are comfortable with assigning a score out of a total that can be subsequently expressed as a percentage. Since concept maps are unique there is a possibility that a concept map could be scored more than the criterion-referenced concept map. This is possible since there are innumerable variations to any particular concept map. For an average classroom educator the number of variations could be quite daunting to assess in terms of time and intellectually challenging to score divergent concept maps.

It is suggested that an analytical rubric be designed based on the degree of correctness for each component of the map. For example a score of one could be assigned for using a linking word, a score of two for a non-descriptive linking word and a score of three for a relevant, descriptive linking word. A maximum score of three could be given to each relevant component of the concept map. The total is achieved by adding the individual scores for each category, which can then be expressed as a percentage.

Analysis of the questionnaire shows that majority of learners prefer using traditional types of assessment as opposed to concept map assessments whilst still acknowledging the benefits of concept mapping to their conceptual development. Their reason for this preference is that they are familiar with this format since it's the only one they've been exposed to since primary school. This is a sensible reason. Hence it is suggested that more concept map activities be included in the classroom as this study and past literature indicates a wealth of value to both the educator and the learner.

6.2 RECOMMENDATIONS OF THE STUDY

For school educators, the concept map can be added to their repertoire of instructional and evaluation practices. Conventional techniques test procedural knowledge whilst concept map tasks evaluate learners' conceptual knowledge, which is based on the understanding of inter-relationships among concepts. Concept maps also serve as a heuristic for learning. Examining successive concept maps reveals the extent of learners' conceptual development.

In this study the use of concept maps as an advanced organizer proved to be an effective means to introduce a new topic. Learners found that concept maps designed by the educator presented information in an organised and visually appealing way that encouraged learner participation. Moreover learners found that they could retain information longer since the advance organizer designed by the educator gave learners better direction to their learning than individually designed concept maps.

However the value of individually designed concept maps by learners cannot be denied. They allow the educator even whilst observing the construction of concept maps, to gauge the gaps in learners' knowledge and identify their misconceptions. This allows the educator to make the necessary adjustments to instruction to remedy learner difficulties.

This study also revealed that concept maps could be used to facilitate collaborative learning. The results indicate that when learners worked in groups whilst trying to make sense of which concepts link with each other, positive cognitive and affective outcomes were recorded.

6.3 LIMITATIONS

My aim for this study was to determine learners' conceptual development. It would have been ideal to compare successive concept maps of the same topic however the constraints of completing the syllabus and assessing learners continuously did not allow me to do this. I therefore examined the structural complexity of maps constructed for different sections.

This is a small-scale study undertaken in a particular school where a class of thirty-four learners participated. The context of this school and the background of the learners are specific to this sample and might or might not be the case in other situations. Each educator is unique and would approach the teaching of concept maps differently, which will influence the outcome differently. It is a limitation that the findings of this study are specific to a particular sample of learners. This sample cannot be said to be representative of all schools and all grade eight learners in South Africa. As such the findings may not be generalised to all learners within South Africa. However I believe that when educators read this study it will assist them to use concept maps in the various outcomes discussed in this thesis.

6.4 CONCLUSION

This study examined the use of concept maps as a vehicle for exploring learners' conceptual understanding in mathematics in a grade eight class. One of the findings of this study indicates that learner' concept maps showed substantial and important changes after the group-work session. Furthermore comparison of successive concept maps indicates that the latter concept maps increased in structural complexity by way of more concepts and linkage of concepts. Since concept mapping requires learners to explicitly describe the connections between concepts, it provides educators with an invaluable tool to gauge the correctness of learners' knowledge and understanding. This study also provides support for the use of concept maps as an advanced organiser. Moreover the study revealed that learners preferred studying from a concept map prepared by the educator as they then have complete concept maps available to them for reference and reviewing during a section.

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APPENDICES

APPENDIX A LETTERS OF CONSENT

Letter of Consent: Parents

University of Kwa-Zulu Natal

Edgewood Campus

Pinetown

Dear Parent

I, Mrs Urmilla Moodley an educator at Wingen Heights Secondary, am currently undertaking a Masters course in Mathematics Education at the above University. I am undertaking research of an approach to mathematics teaching to determine whether it is beneficial to learners' understanding of mathematical concepts. Part of my study is to assess concept maps constructed by learners, learners have to answer a questionnaire and some learners will be interviewed.

I request permission to include your child in my research project. All work undertaken by learners will be used for their CASS and no tuition time will be used to collect information from them. The questionnaire will be filled during a period when one of their educators is absent.

Nor will interviews will be conducted during tuition time. They will be conducted during the breaks or after school, which ever is convenient for your child. Please note that participating in this interview is voluntary and if your child wishes to withdraw from the study at any time, he or she may do so.

Thank you.

Yours sincerely

Urmilla Moodley

Parental consent

I ______________________________, parent/guardian of _______________ grant/do not grant permission for my child/ward to participate in the above research study. I have read and understand the contents of the above letter.

____________________   ____________________

signature   date

Letter of Consent: The Principal

University of Kwa-Zulu Natal
Edgewood Campus
Pinetown

The Principal
Wingen Heights Secondary
Shallcross

Re: Request permission to conduct a study with grade 8 mathematics learners

I, Mrs U. Moodley am currently undertaking a Masters degree in Mathematics Education at the above university. I am undertaking a study into another approach to teaching and learning. My task is to determine whether the use of concept maps is beneficial to learners understanding of mathematical concepts. Part of my study is to assess concept maps constructed by learners. Learners will also be involved in filling in a questionnaire and some learners will be interviewed.

I request permission to include the learners that I teach in this study. All work undertaken by learners will be used for their CASS mark and no tuition time will be used to collect information from them. The questionnaire will be filled during a period when one of their educators is absent. Interviews will be conducted during the breaks.

Learners and parents will be informed that participation is voluntary and that the learners can withdraw from the study at anytime should they wish to do so.

Thank You
Yours Sincerely

____

U.Moodley
Letter of Consent: Department Official

University of Kwa-Zulu Natal
Edgewood Campus
Pinetown

The District Manager
Wingen Heights Secondary
Shallcross

Re: Request permission to conduct a study with grade 8 mathematics learners

I, Mrs U. Moodley am currently undertaking a Masters degree in Mathematics Education at the above university. I am undertaking a study into another approach to teaching and learning. My task is to determine whether the use of concept maps is beneficial to learners understanding of mathematical concepts. Part of my study is to assess concept maps constructed by learners. Learners will also be involved in filling in a questionnaire and some learners will be interviewed.

I request permission to include the learners that I teach in this study. All work undertaken by learners will be used for their CASS mark and no tuition time will be used to collect information from them. The questionnaire will be filled during a period when one of their educators is absent. Interviews will be conducted during the breaks.

Learners and parents will be informed that participation is voluntary and that the learners can withdraw from the study at anytime should they wish to do so.

Thank You

Yours Sincerely

____

U.Moodley

APPENDIX B INTERVIEW SCHEDULE

Interview one

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

SINDISWA : I like working in groups.

RESEARCHER: Can you tell me why you like working in a group

SINDISWA: When we do an activity in a group I understand because they explain to me when I don't understand.

RESEARCHER: Ok. Thank you.
In the questionnaire you said that you like using concept maps sometimes in your maths lessons. Can you tell me why?

SINDISWA: Yes sometimes I understand maths and sometimes I don't.
Learner did not want to say any more)

Interview Two

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

CARL: It allows people to contribute to the concept map. It gives us a chance to share ideas.

RESEARCHER: How did the group work activity help with your understanding of maths activities?

CARL: I found out what mistakes I made and my classmates helped me correct them. It also helped me to see the value of concept maps in my understanding of maths concepts.

RESEARCHER: In the questionnaire you said that you like using concept maps because it is ***"fun to do".*** Could you tell me why is it fun, what about concept maps do you enjoy so much?

CARL: I find reading my notes boring. Drawing up a concept map is creative and helps you understand the work clearly.

RESEARCHER: You also said that you will use concept maps when revising because *"it makes it easier to understand"*. Could you tell me more about why it is easier to understand?

CARL: A concept map breaks up the topic into different concepts therefore you know what the topic is made up of and hence understand it better.

Interview Three

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

SHAHIL: It is fun. I like working in groups and helping them.

RESEARCHER: How did the group work activity help with your understanding of maths activities?

SHAHIL: it made my work easier to understand. Working in a group helps me to see what mistakes I made. We can help each other to choose the concepts to include in the concept map.

Interview Four

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

KRAIG: Easier to construct a concept map with friends, you can't think when you're alone. I ask questions when I don't know and my friends help me.

RESEARCHER: How did the group work activity help with your understanding of maths activities?

KRAIG: I improved the way I summarized my work in a concept map

RESEARCHER: In the questionnaire you wrote that you will use concept maps to revise because it helps you to *"fully understand the work when you are revising.*

Could you explain to me what you mean by *"fully understand"*.

What about concept maps make you understand better?

KRAIG: It is easier to understand with a concept map you can remember everything easier.

Interview Five

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

THULISILE PORTIA NYANISA: I did enjoy it, better to work with friends.

RESEARCHER: How did the group work activity help with your understanding of maths activities?

THULISILE PORTIA NYANISA: It is easier to work in a group than alone because they help you to understand the work.

RESEARCHER: In the questionnaire you said you will use concept maps when revising,. I did not understand what you were trying to tell me. Could you explain to me again?

THULISILE PORTIA NYANISA: I was trying to tell you that concept maps helped my learning and that it is fun and easy to use.

RESEARCHER: You also said that you prefer concept map tests. Can you explain to me why?

THULISILE PORTIA NYANISA: Yes I do like concept tests because I understand it better.

Interview Six

RESEARCHER: How did you feel about the group work activity when constructing concept maps?

NKANYISO MNGADI: I feel good we can help each other in a group work. We can make sure that everybody understands the work.

RESEARCHER: How did the group work activity help with your understanding of maths activities?

NKANYISO MNGADI: Group work helps me to understand concepts because if I don't know I can ask someone who is in my group.

RESEARCHER: You wrote in the questionnaire that you will use concept maps sometimes but I did not understand your reasons. Could you explain to me again please?

NKANYISO MNGADI: because sometimes I understand concept maps and sometimes I don't.

RESEARCHER: Can you tell me when you like using concept maps? Give me just one example of when you liked using concept maps?

NKANYISO MNGADI: I liked making the poster (concept map was on data handling).

RESEARCHER: Could you give me one example of when you did not like making concept maps.

NKANYISO MNGADI: I don't like making concept maps by myself.

RESEARCHER: When I gave a concept map with blank spaces and you had To fill in the concepts, how did you feel about that activity?

NKANYISO MNGADI: That was OK but it is even easier when you give us a list of concepts and we have to make a concept map.

RESEARCHER: How do you feel about making your own concept map when I just tell you a topic?

NKANYISO MNGADI: I find those difficult.

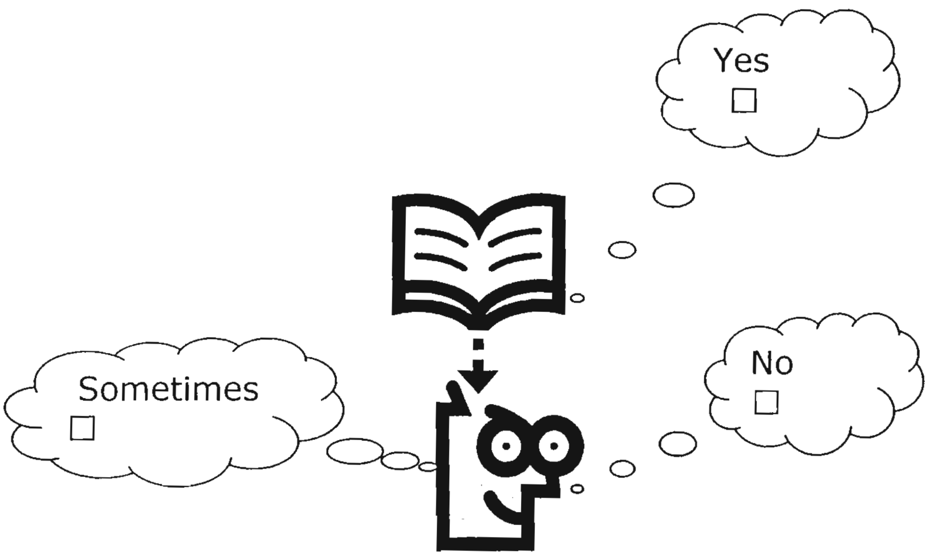
APPENDIX C QUESTIONNAIRE

Questionnaire: Learner Views About Concept Maps

Name Surname	
Male/female	

- The purpose of this questionnaire is to find out whether concept maps have helped with your understanding of mathematical concepts
  and to determine your views about concept maps.
- Work on your own as I want to know your views on concepts maps.
- Each question has its own instructions.

1. Some learners have found concept-maps very useful when learning. Do you like using concept maps in your mathematics lessons ? Put a tick (✓) in the appropriate box.



2. Give reasons for your choice above. For example if yes say why.

3. You have worked with concept maps in your mathematics lessons.

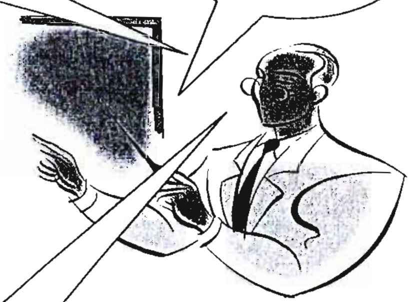
   When did you find it most helpful? Put a tick (✓) in the appropriate box for each callout (word bubble).

☐ yes
☐ no

Helpful at the end of a section

Helpful during a section

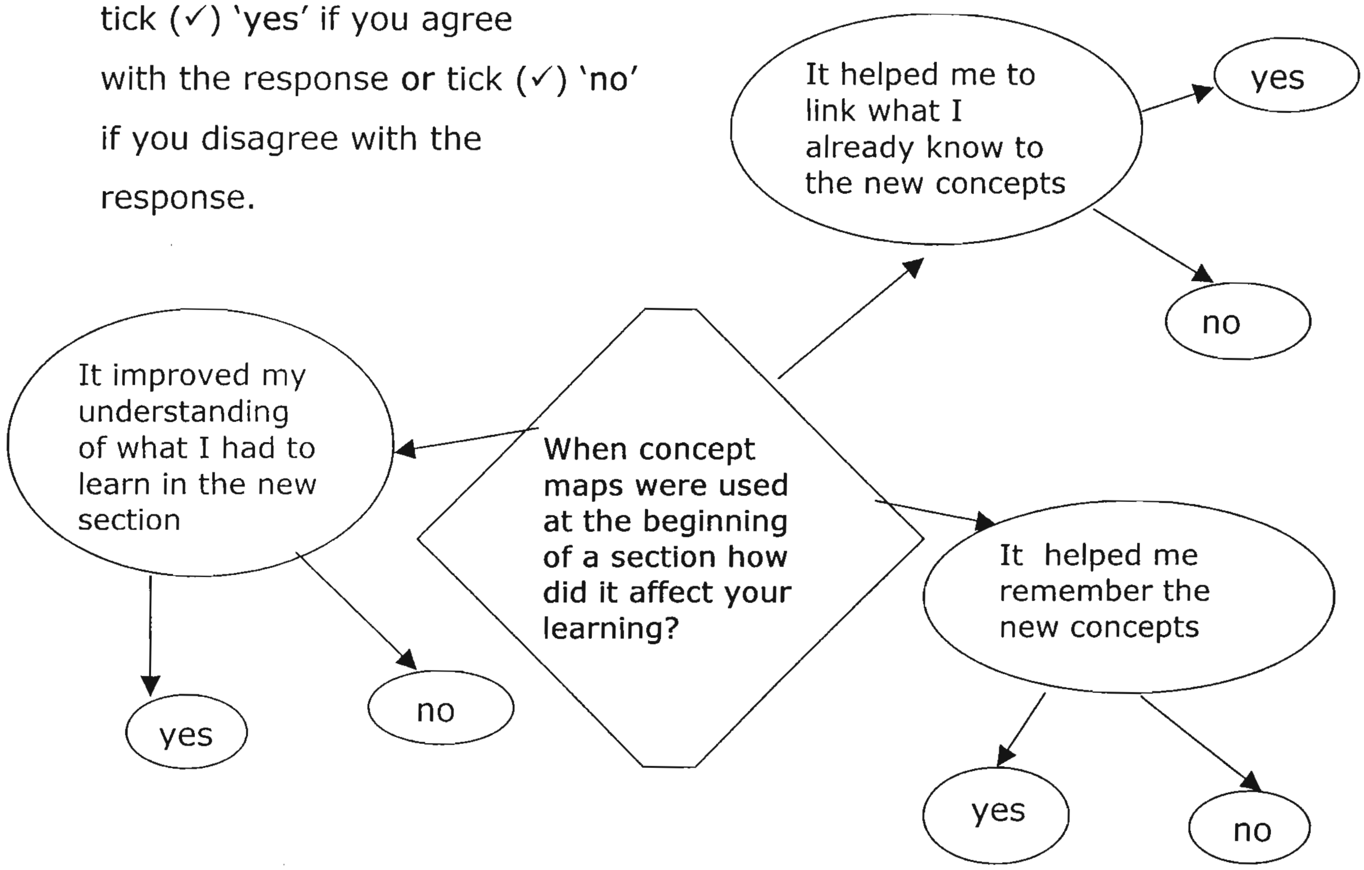
☐ yes
☐ no



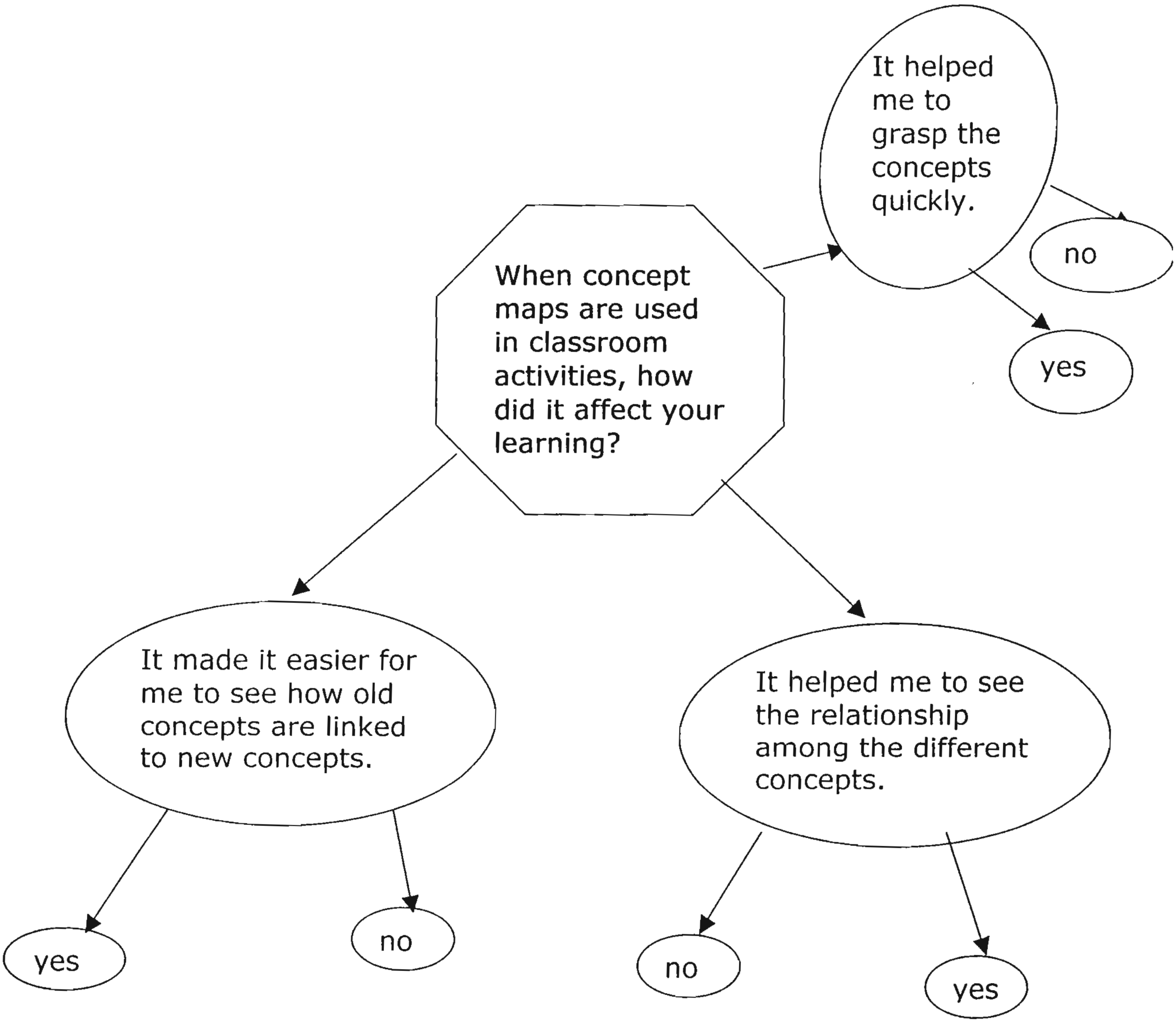
☐ yes
☐ no

Helpful at the beginning of a section

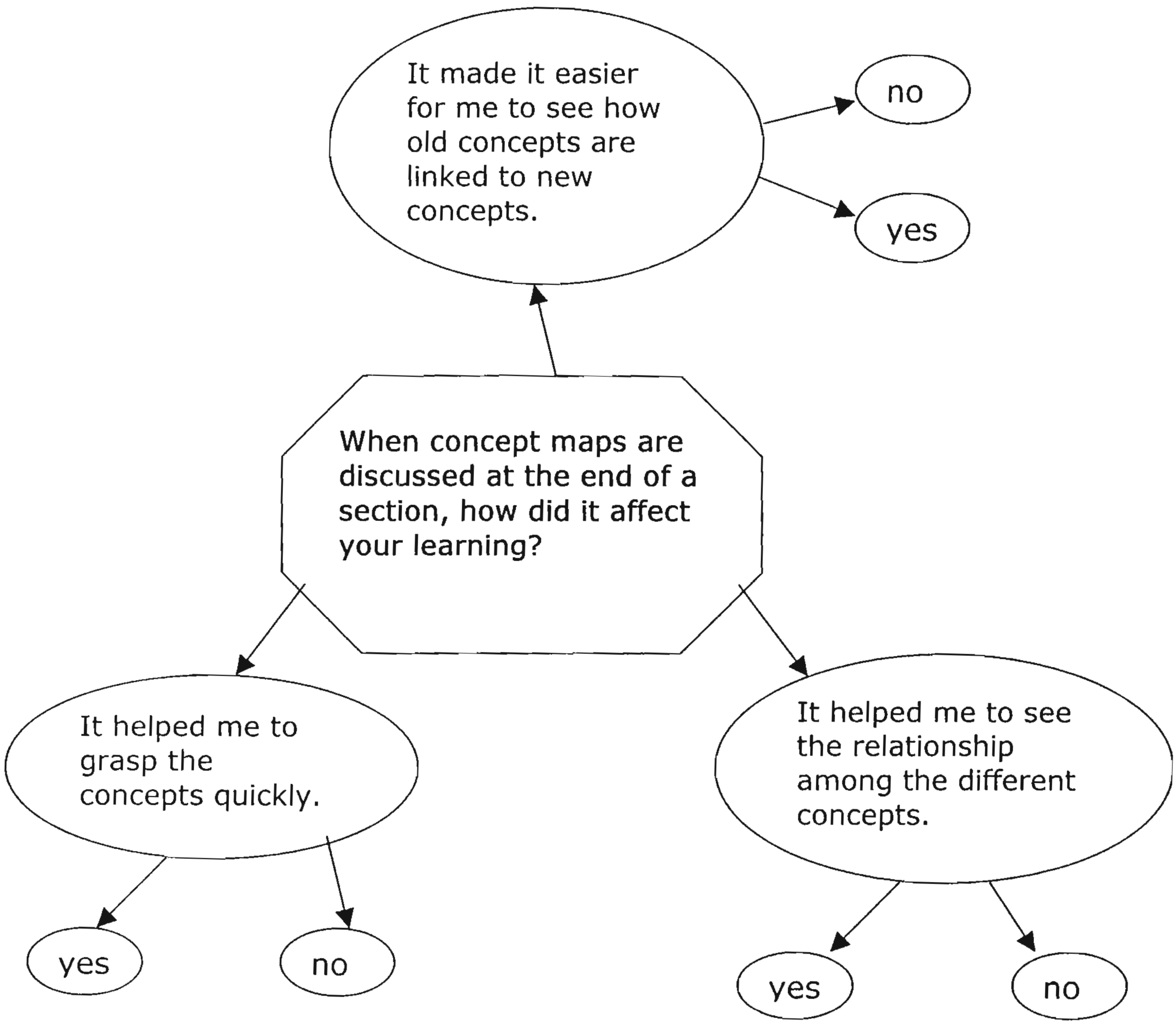
4. Consider each response and tick (✓) 'yes' if you agree with the response or tick (✓) 'no' if you disagree with the response.



5. Consider each response and tick (✓) 'yes' if you agree with the response or tick (✓) 'no' if you disagree with the response.



6. Consider each response and tick (✓) 'yes' if you agree with the response or tick (✓) 'no' if you disagree with the response.



7.1 Will you use concept maps when revising? Tick (✓) yes or no.

☐ yes ☐ no

7.2 Explain your response (7.1) above in a few words.

____

____

____

8.1 Do you prefer concept map tests or traditional tests?

8.2 Explain your response (8.1) above.

UNIVERSITY OF
KWAZULU-NATAL

RESEARCH OFFICE (GOVAN MBEKI CENTRE)
WESTVILLE CAMPUS
TELEPHONE NO.: 031 – 2603587
EMAIL : ximbap@ukzn.ac.za

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9 SEPTEMBER 2008

MRS. U MOODLEY (204515520)
MATHEMATICS, SCIENCE, COMPUTER & TECHNOLOGY EDUC.

Dear Mrs. Moodley

ETHICAL CLEARANCE APPROVAL NUMBER: HSS/0468/08M

I wish to confirm that ethical clearance has been approved for the following project:

"A study of learners' conceptual development in mathematics in a grade eight class using the concept map approach"

PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years

Yours faithfully

PXimba
....

MS. PHUMELELE XIMBA

cc. Supervisor (Dr. V Mudaly)
cc. Mr. D Buchler

RECEIVED
2008 -10- 02
FAC RESEARCH OFFICE