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CONCEPT MAPPING:
A STRATEGY TO PROMOTE
STUDENT LEARNING

By

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled CONCEPT MAPPING: A STRATEGY TO PROMOTE STUDENT LEARNING submitted by Larry Medinski in partial fulfilment of the requirements for the degree of MASTER OF EDUCATION in Secondary Education.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

The Problem

Introduction

The Science Council of Canada's report Science for Every Student: Educating Canadians for Tomorrow's World (1984) begins an analysis of the health of science education in Canada emphasizing that

> Tomorrow's citizens and decision makers are in school today - are they receiving the education they will need in the 1990s and beyond? As the rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future. (Science Council of Canada 1984, p.9)

A recurrent theme in research on classroom practice is that teaching is rarely intellectually inspiring and challenging. Lecture and recitation predominate with students passively receiving information or responding to worksheet or teacher questions that require only simple recall and comprehension of the material presented (Yager & Penick 1984; Orpwood & Souque 1985; Goodlad 1984; Tobin & Gallagher 1987).

Yager and Penick (1984) reported that a majority of students believed that not only are the things they learn in science "dull" and "no fun" but, also, have little relevance to the real world. Koballa (1985) points out that much of adolescent behaviour is guided by and in response to the individual's search for meaning. In his review of research, Hofwolt (1985) indicates that most students feel that the teacher determines course content with students having little or no input. They feel that the textbook provides the structure and organization and that they have no choice in the way they learn. He goes on to suggest that students believe that teachers value student ability to think for themselves; however, few teachers use techniques which promote the development of higher cognitive skills in their students. McMillan and May (1979) found that the most important factor associated with students liking or not liking science is the degree of active involvement and experience in the learning process.

Onosko (1990) suggests that recently educational reformers have focused their attention and emphasis on teaching for higher-order-thinking in the attempt to nurture the educational process back to productive growth. Attention and commitment to promoting higher-order-thinking skills have been spreading throughout educational circles. Lawrenz (1990) cites a 1985 Gallup poll in which teachers ranked improvement in thinking as the most important of 25 educational goals.

There seems to be considerable awareness of and agreement about the importance and value of promoting higher-order-thinking and thereby making learning more meaningful. The problem of devising effective teaching techniques has preoccupied science educators for many decades. Novak (1988) describes the typical junior high science classroom, as a place where near rote-mode learning predominates with little or no desire to deviate from teaching the basic facts. This depiction focuses our attention on the absence of meaningful learning in the traditional classroom setting. Students' perception that the teacher and the text are the main source of knowledge (Connelly, Crocker, Kass 1985) must also be examined in terms of promoting meaningful learning. The lack of elaboration and large concept load, common characteristics of school subject textbooks, creates a learning situation requiring students to memorize information without developing in-depth understanding (Lloyd 1990).

Meaningful learning cannot take place when the students' view their role in the learning process as passive consumers of information presented by the teacher or text. If we are to facilitate meaningful learning by students, we must provide them with a reason for rejecting rote-learning strategies. This implies a need to foster a change in students' perceptions of learning as a rote, arbitrary and nonsubstantive practice to one that views learning as a reconstruction of meaning. Strategies which allow the learner to accommodate new ideas within their personally constructed body of knowledge will allow for learning with understanding and personal meaning. These strategies will allow the learner to supplant the view that school learning represents the transmission of an unchangeable body of knowledge with the understanding that they are in control of and essential participants in the learning process.

Purpose of the Study

The purpose of this study is to explore the use of concept mapping by grade nine students in the science classroom. The study will examine the extent to which students are able to use the strategy of concept mapping to facilitate their learning.

Specifically, this study attempts to investigate the following questions:

1. Are grade nine students capable of constructing good concept maps? If so will students use concept maps as "answers" on science tests?
2. Do students who are considered to be low-academic achievers use concept maps as frequently as do high-academic achievers?
3. What are grade nine students' attitudes toward the construction and use of concept maps as strategies for learning?
4. What are grade nine students' attitudes toward the use of concept maps as a means of evaluation or assessment.

Significance of the Study

While the number of studies addressing the topic of concept mapping and meaningful learning has steadily increased there is still a need for contributions to the existing knowledge base. The findings, resulting from this study, are expected to augment our current understanding of the relationship between student achievement, as determined by more traditional evaluation procedures, and strategies which allow the individual to express their knowledge in an alternate format.

Information pertaining to students' perceptions of their role in the learning process, and their feelings as to the effectiveness of this strategy in terms of helping them learn, would be of value. Descriptive information detailing the influence of the concept mapping strategy in promoting meaningful learning would enhance our current understanding of this complex process.

Definitions

In this thesis the following definitions will be adhered to:

concept - a perceived regularity in events or objects, or records of events or objects, designated by a label.

concept maps - representations of meaning or ideational frameworks specific to a domain of knowledge, for a given context of meaning.

concept meaning - an idiosyncratic understanding by the individual represented by all of the propositional linkages the person could construct that include that concept.

meaningful learning - non-arbitrary, non-verbatim, substantive incorporation of new knowledge into a person's cognitive structure.

propositions - two or more concepts linked together with words which serve as the units of psychological meaning.

rote learning - arbitrary, verbatim, non-substantive incorporation of new knowledge into cognitive structure.

low academic achiever - a student who achieves 55% or less on a specific evaluation instrument or consistently scores at or below this grade on multiple evaluation instruments.

high academic achiever - a student who achieves 80% or better on a specific evaluation instrument or consistently scores at or above this grade on multiple evaluation instruments.

Delimitations

The focus of this study is limited to the concepts related to specific units of study as identified in the Junior High Science Program of Studies (Alberta Education 1990). The study population consists of grade nine students from a junior high school in a small town in west central Alberta. All students involved receive science instruction from the same teacher. The teaching methods employed, including the concept mapping methodology, will be consistent for all students. Evaluation of all assessment items with be conducted by the teacher instructing the students.

Limitations

The ability of the students to learn and apply the concept mapping strategy may depend on the student's cognitive preference and their perception of the value of the heuristic. The degree to which the students' utilize the concept mapping strategy will affect their ability to construct maps. Due to the modest study population size and involvement of one teacher conclusions and inferences resulting from the obtained data may have limited transferability.

Assumptions

1. Meaningful learning is a desirable practice which can be reflected by student thought processes and actions.

2. Concept maps serve as a mechanism to reveal the thinking processes, either the whole process or to some understood part of the process.

3. Concept maps, as drawn by the student are, a direct representation of the student's understanding of the ideational framework and relationships of the concepts making up the topic of study.

4. The drawing of a concept map aids understanding and/or recall by the learner.

5. The construction of <u>unique</u> and <u>detailed</u> concept maps constitutes a procedure which, in itself, requires higher-order- thinking skills.

6. Concept maps are able to be "scored" in some way in order to detect differences between learners and/or between the same leaner at different times.

CHAPTER 2

Review of the Literature

Over the last two decades, a vigorous search has been conducted for techniques that can lead to improvement in the quality of instruction in our schools and subsequent student learning. The objective in most cases is the promotion of learning with meaning rather than rote learning. Having a large store of accurate knowledge is a prerequisite for successful learning and problem solving; however, the structure in which this knowledge is stored is also important. According to Reif (1983) and Resnick (1983), most students have a store of knowledge that is small, not well organized and full of well-established misconceptions. The knowledge base available to successful learners and problem solvers, on the other hand, is characterized as being large and well organized (Frederiksen 1984; Smith & Good 1984).

The learning process has come to be viewed as the development of an individual's capacity to select information and to construct meaning by placing the new information and experiences in the context of what is already known, valued, and capable of being accomplished. The recent and dramatic shift of attention to cognitive psychology, with its interest and emphasis in the learner in-the-process-of-learning (West & Pines 1985), has become established as a constructivist programme which has been readily accepted by science educators

(Millar 1989).

In accordance with this constructivist perspective classroom teaching practices must recognize the unique knowledge framework which each student possesses and provide opportunities for students to expand their framework. These opportunities or classroom lessons should allow for students to examine new concepts in relation to their existing knowledge framework and reconsider their present views and beliefs which may be contradictory to information presented to them. Classroom teaching and learning can be considered as an evolving of the individual's existing knowledge framework by the assimilation of new ideas within the framework. Experiences which cause the individual to reconsider their current beliefs serve as mechanisms to clarify misconceptions or establish new strands of understanding within their knowledge framework.

A basic tenet of this constructivist model is that concept learning is understood as a reconstruction of meaning rather than simply the accretion of new ideas (Driver 1989). Concomitant with the constructivist view is the fostering of change in student learning from a rote, arbitrary, and nonsubstantive practice to one which promotes meaningful learning. Central to the issue of enhancing student learning is the issue of epistemology. If students perceive their school experience as the transmission of a body of knowledge that cannot be changed by the learner then there is little motivation or opportunity for creative involvement of the learner.

The constructivist approach to science recognizes the need to maintain the meaningful involvement of learners in learning a pre-determined body of knowledge. Brody (1987) describes learning as the comprehension and acceptance of concepts which are intelligible and rational to the learner; knowledge acquisition is an activity in which individuals participate and construct new knowledge based on previous experience. From the constructivist perspective knowledge does not arise spontaneously, nor can it be implanted. The learner is in control of the learning process and may resist outside efforts to enforce the acquisition of knowledge or correct and overthrow alternate conceptions. Lythcott and Duschl (1990) identify the primary tenets of the constructivist psychological world view:

> People impose order on the world perceived in an effort to construct meaning, meaning lies in cognition not in elements external to us, information impinging on our cognitive systems is screened, translated, altered, perhaps rejected by the knowledge that already exists in that system, the resulting knowledge is idiosyncratic and is purposefully and effortfully constructed (p. 458)

Children naturally interact with their environment from their moment of birth and begin to interact with the world at arms reach. Intuitively they develop ideas, concepts, and theories to interpret that world. Those ideas, concepts, and theories are not, in a simple inductivist way, only a part of the world of sense impressions, rather they are imaginative constructions brought to bear on the world of observation (Cleminson 1990). Concepts or theories do not follow from observation in a simple cause and effect manner. Learning takes place not only through the taking in of new information but also involves organization and restructuring of the concepts and theories that the learner already has. Learning is a process in which the learner is actively engaged in constructing meanings from text, dialogue or experimentation (Driver & Bell 1986).

Concept Mapping Heuristic

The search for teaching techniques which enhance student learning has intensified over the past two decades. Techniques which enable students to build mental bridges between what is already known and what is to be learned are considered to promote meaningful learning.

One area of contemporary interest that holds promise for meaningful learning in science is concept mapping. Concept mapping is a learning strategy that was developed first as a research tool to represent a learner's prior, relevant knowledge and later as a tool to enhance meaningful learning. J. D. Novak was the researcher instrumental in the development of concept mapping, and is described as a pacesetter in concept mapping (Pankratius & Keith 1987).

Novak's (1987, 1988) description of his early studies of learning emphasizes the influence of the "cybernetic model" of learning and an evolving "conceptual schemes" view of epistemology. Novak suggests that Ausubel's Psychology of Meaningful Learning (1963) brought about a change in the paradigm guiding his research. This new perspective of learning emphasized the individuals' role in choosing to relate new knowledge to relevant concepts and propositions they already know and stood in contrast to the common belief that learning is automatic, effortless, cumulative and continuous over life. Novak's acceptance of learning as a personal construction led to many of the changes described by Kuhn (1962), including changes in the kinds of research questions asked.

A subsequent decade of research fostered the development of an evaluation strategy called Concept Mapping. This technique was used to analyze interview data and as a direct instructional technique with students. Concept maps are described as a representation of meaning or ideational frameworks specific to a domain of knowledge, for a given context of meaning. Concept mapping is a metacognitive strategy which can be applied at any grade level and to any subject matter with the intent of facilitating meaningful learning and the understanding of knowledge acquisition (Novak 1990).

Ausubel, Novak, and Hanesian (1978) define meaningful learning as requiring: meaningful learning materials; a meaningful learning set, for example, a disposition on the part of the learner to link each concept label in the new material with concepts he or she already possesses; and relevant cognitive structure, that is, some concepts already present in cognitive structure that can be related non-arbitrarily to the new concept labels. In contrast to students who learn by rote, students who employ meaningful learning are expected to retain knowledge over an extensive time span and find new, related learning progressively easier. Concept mapping is considered to be a robust and effective heuristic which facilitates students experiencing meaningful learning.

Assimilation Theory and Concept Mapping

The development of the concept mapping heuristic, as presented in this discussion, was guided by Ausubel's (1963, 1968) Assimilation Theory. Novak (1988) suggests that the principle contribution of Ausubel's theory was its emphasis on the power of meaningful learning, as contrasted with rote learning. Ausubel's detailed description of the role that prior knowledge plays in the acquisition of new knowledge guided Novak's work.

Assimilation Theory places emphasis on cognitive processes involved in acquisition of knowledge and the role which explicit concept and propositional frameworks play in the learning process. According to the Assimilation Theory a

CONCEPT, a perceived regularity in events or objects designated by a label, is learned by way of association with other concepts. Except for a relatively small number of concepts acquired very early by children through a discovery learning process, most concept meanings are learned through the composite of propositions in which the concept to be acquired is embedded (Howard 1987).

As a pedagogical technique, concept mapping helps students see explicitly how new concepts can be related to previously learned concepts. The simplest concept map would be one concept linked to another concept using logical connecting words.

For example CANDY--------IS-------SWEET

represents a simple concept map with two concepts connected by a line containing a descriptive word. The concepts plus the connecting word(s) form a PROPOSITION or meaningful statement. A more complex concept map may begin to illustrate new meanings to students and hence to extend their concept meanings. Concepts grow in meaning as they become relatable to a wider array of concepts in specific propositions. A concept map is a schematic device for representing sets of concept meanings embedded in a framework of propositions (Novak & Gowin 1984).

In accordance with Assimilation learning theory it is recommended (Novak 1981) that concept maps be constructed hierarchically, with the most general, more inclusive concept at the top, and less inclusive concepts at the subordinate "levels". The emphasis on a hierarchical arrangement acknowledges a fundamental principle of the assimilation theory which suggests that meaning derives from perceived relationships between concepts. SUBSUMPTION, a fundamental principle of the assimilation theory, occurs when new knowledge is perceived as related to and assimilated under already known, more general relevant concepts.

Hierarchy can also show the set of relationships between a concept and other concepts subordinate to it. To construct a hierarchical concept map, one must think through what one perceives to be the most inclusive, less inclusive, and least inclusive concepts in any body of subject matter. The construction of a hierarchical concept map requires active thinking by the participant which facilitates the integration of the new knowledge into their existing conceptual frameworks. A hierarchical structure also permits later subordination of a specific concept map into a more general, more inclusive map. The concept mapping strategy enables the learner to grasp new relationships between topics that before may have appeared unrelated.

In accordance with the constructivist view of learning, meaningf l learning is a continuous process wherein new concep greater meaning as new relationships (proposi inks) are acquired. This process of PROGRESSI ERENTIATION encourages the learner to identify and describe their personal and idiosyncratic understanding of a subject which in turn allows for better understanding of what is misunderstood. Progressive differentiation is enhanced when concept maps for one topic are cross linked to concept maps for other related topics.

Associated with the discovery of new relationships is the process of INTEGRATIVE RECONCILIATION which is of great significance to meaningful learning (Novak & Gowin 1984). Facilitated by the concept mapping process, the learner may experience a substantial alteration in his or her understanding of concept meaning and relationships. This awareness of the new relationships, which are commonly displayed as cross links between sets of concepts on the map, are indicators of creative, higher-order-thinking. The process of reconciliation facilitates the incorporation of new concepts and meanings into the learners conceptual framework and the resolution of conflicting messages or meanings. Meaningful learning requires a conscious effort on the part of the student to relate new knowledge to knowledge previously acquired (Novak & Gowin 1984).

Concept maps externalize the individual's propositional frameworks and can be viewed as tools for negotiating meaning. During the construction of the concept map students and/or teachers construct their idiosyncratic understanding of the relationships between propositional statements. This process allows for the individual to become familiar, in an explicit manner, with "what they know" about a specific topic. The concept map clearly shows correct relationships but also provides the opportunities for the checking of faulty linkages or to show what relevant concepts may be missing. The act of constructing the concept map can also promote the awareness of new relationships promoting the differentiation of related concepts. Meaningful learning requires a conscious awareness of new relationships between old and new sets of concepts.

Implications of the Concept Mapping Heuristic

In the current research literature a number of studies make a variety of assertions pertaining to the use of the concept mapping strategy. Concept mapping is claimed to promote meaningful learning which is defined as non-arbitrary, non-verbatim, substantive incorporation of new knowledge into a person's cognitive structure. These characteristics of learning are opposed to rote learning which is arbitrary, verbatim, nonsubstantive incorporation of new knowledge into cognitive structure (Novak 1988). Klausmeir et al. (1974) suggests that meaningful learning enables the student to:

a) generalize to new instances or discriminate non-instances of the concept;

b) recognize other concepts in a taxonomy as supra-ordinate, co-ordinate or sub-ordinate;

c) recognize cause-effect, correlational, probability and axiomatic relationships among concepts; and,

d) solve problems involving the concept.

A number of studies have examined the effect of the concept mapping heuristic on academic achievement. Many studies (Schmid & Telaro 1990; Jegede, Alayiyemola & Okebukola 1990; Pankratius 1990; Bodolus 1986; Abayomi 1988; Spalding 1989) reported an increase in achievement, as indicated by higher mean scores on post-test instruments. The conclusions of many research studies indicate that concept mapping is effective in bringing about meaningful learning in science (Okebukola & Jegede 1988; Heinze-Fry & Novak 1990; Okebukola 1990). These studies made specific reference to the evaluation instruments which were constructed to assess the extent of meaningful learning (a portion of the test questions were at the application level or above).

While the majority of studies cited suggest that concept mapping enhances student achievement and meaningful learning, the students which benefit most from the learning aid may be those having lower abilities (Schmid & Telaro 1990; Spalding 1989). Novak, Gowin and Johansen (1983) point out that in general, students of any ability level can be successful in concept mapping and that other factors, such as motivation, were important. The correlation between ability, as determined by traditional evaluation instruments, and concept mapping strategy was found to be very low.

Lehman, Carter and Kahle (1985) indicate no significant difference on an achievement test designed to assess meaningful learning. They suggest, however, that the similarity of the treatments used in their study, outlining and concept mapping, might have contributed to the difficulty in identifying achievement differences. Other factors which might have prevented achievement differences were the students' and teachers' lack of familiarity with concept mapping in comparison with outlining as well as the difficulty of the evaluation instruments. Stensvold and Wilson (1990) report that high-ability students performing concept mapping achieved lower scores on a comprehension test than similarly able students who did not construct concept maps. The authors suggest that high verbal ability students may prefer to use a rote style of learning very different from that required to construct an articulate concept map. Spalding (1989) states that students with higher CTBS (Comprehension Test of Basic Skills) scores who used the practice of defining concepts did better on a post-test instrument than similar students who were part of the treatment group using the concept map heuristic. This supports the suggestion that high-ability students may prefer rote learning styles.

While student achievement and meaningful learning have been the focus of the majority of studies involving the concept mapping heuristic, other factors such as anxiety (Jegede, Alaiyemola & Okebukola 1990), attitudes (Novak 1981), cognitive preference and learning mode (Okebukola & Jegede 1988), effects of mapping on learning (Heinze-Fry & Novak 1990), locus of control (Sherris & Kahle 1984), and gender

(Bodolus 1986) have been examined from a correlational perspective.

If students are to be able to meet the intellectual demands required of citizens of the 21st century it would seem to be imperative that they be equipped with strategies and learning aides which empower them to be active learners. Novak (1988) claims that very high-performing students (students earning high grades) are learning primarily by rote and experience frustration in their studies. This frustration may be the result of students' perception that the learning strategies they are taught may not be effective. Learning strategies frequently employed in schools promote learning as the process of memorizing isolated facts which frequently results in superficial, short term learning.

Students' efforts and attitudes towards learning represent long standing areas of concern in our educational system. Novak (1988) makes reference to studies which show relationships between students' epistemological commitment (empiricist/positivist as opposed to constructivist) and their ability to perform on complex problem-solving tasks. The studies cited support the value of heuristics designed to encourage students to re-examine their understanding of the learning process.

The suggestion that negative feelings are associated with cognitive involvement in rote learning practices and positive feelings arise when involvement is meaningful is supported by the work of Robertson (in Novak 1988). Robertson's study implies that student motivation and meaningful learning may be augmented by helping the student organize new concepts and propositions into a whole, existing, relevant framework. It is suggested that concept mapping serves as a learning aid which enhances, in both a qualitative and quantitative way, the learner's knowledge structure. It is also suggested that concept maps may be useful aids which assist students' learning and the retention of new information in a more meaningful way.

CHAPTER 3

Methods and Procedure

Introduction

This chapter presents an overview of the research procedures used in the pilot study (Medinski & Brouwer 1993) and a detailed description of the design of the main study. The procedures used in the pilot study and subsequent results served to shape the design of the main study.

The Pilot Study

Study Design

The purpose of the pilot study was to examine the effect of the use of concept mapping on student learning in the junior high science class. Specifically the objectives were to determine whether Grade 9 students could construct concept maps and to determine the effect of concept mapping on students' academic achievement. Students' attitudes towards concept mapping and the learning of science were also examined.

The study involved four classes of Grade 9 students from one school in a central Alberta town. The classes comprised students with a heterogeneous mixture of ability levels. Control and treatment classes were selected randomly with the same teacher teaching all classes. The teacher followed the

Junior High Science Program of Studies (Alberta Education 1990) and used identical reference texts, resource materials, and methods of instruction.

At the beginning of each of the six units to be studied, students completed a pretest consisting generally of 35 multiple choice questions and a few numerical response questions. The test instruments used were part of the Grade 9 Science Field Test battery produced by the Student Evaluation Branch of Alberta Education and tested students' knowledge, comprehension, and other higher-mental skills in each of the science content areas. Results of the pretests were not passed on to the students.

After completing each unit of study the unit pretest was administered again, functioning as a posttest. The students' pretest and posttest scores indicated each student's level of achievement. The student's score on the multiple choice portion of the test were used to identify high-achieving and low-achieving students for this specific test instrument. Students scoring between 45%-55%, on the multiple choice portion of the test, were considered as low-achievers and students scoring above 80% were identified as high-academic achievers. The class averages on the unit pre and posttests allowed for a comparison of the classes.

All students were requested to complete the Student Attitude about Science and Learning Science Survey prior to the identification of the treatment and control classes.

Student responses were tabulated.

The Concept Mapping Strategy

Classes selected to learn concept mapping were introduced to the strategy through a variety of activities which involved the use of memory and establishing relationships between concepts. Activities included displaying number groups having regular patterns for approximately 15 seconds using an overhead projector and then asking students to recall as many as possible. Word lists related to a common theme, such as parts of a tree, were displayed for short intervals and students were to recollect as many as possible. Random number groups and unrelated word lists were presented to the students for set periods of time after which the students were expected to write down as many as could be remembered. After these types of activities class discussions were conducted which served to allow students to discuss their abilities to remember the various items in the different lists. The class discussions served to identify common strategies employed by individuals to help them remember. Through class discussions the limitations associated with attempts to memorize were clearly expressed by many students. The advantages associated with attaching or linking words and grouping words, which shared some type of relationship, were expressed by the students.

Additional activities were used to illustrate the importance and common practice of organizing ideas and linking them to what is already familiar. These included having the students construct definitions or descriptions for common words such as dog, fruit, metal, and friend. The students shared their results, and through class discussions they became aware of the idiosyncratic nature of meanings associated with concepts.

Teacher-prepared concept maps were used to introduce students to the basic components of concept maps. These maps illustrated the arrangement of the **propositions** to form **hierarchical levels**. The grouping of related concepts to form **branches** and the establishment of **crosslinks** were explained and illustrated. Students were provided opportunities to practice constructing concept maps as individual and whole class activities. Feed back was provided to students emphasizing the uniqueness, yet correctness, of individual maps. Students were assigned a variety of exercises including word searches, summary paragraphs and readings from their textbook, as starting points for constructing concept maps.

During this period of practice the students' concept maps were not formally graded. The marking scheme to be used later was described and explained to the students using concept maps constructed during class (Appendix 1).

Data Collection

For this pilot-study the unit **Chemical Properties and Changes**, described in Alberta Education's Junior High Science

Program of Studies (1990) was selected as the content focus. All classes completed the appropriate pretest and received the same instruction in terms of teaching strategies, assignments and laboratory activities. All classes were provided identical summaries for each of the topics identified within the primary text resource Science Directions 9 (1992) (Appendix 2).

The classes forming the control group were expected to copy the summaries as notes. These summaries were discussed in class and identified as review materials for future tests. The treatment group were provided with the summaries and requested to construct a concept map or maps incorporating the main concepts from the summary. Student concept maps were evaluated according to the teacher prepared maps (Appendix 3). Student maps were returned to the students and they were encouraged to review their maps. Upon completing the unit Chemical Properties and Changes all students wrote the posttest. Individual student pretest/posttest raw scores as well as percent gain were tabulated. Class results were expressed as mean pre- and post-test scores and standard deviations.

During the unit of study the teacher held informal and semi-structured interviews with 10 participants in the treatment groups. The students interviewed included 3 high-achieving males, 2 low-achieving males, 3 high-achieving females and 2 low-achieving females. Five of the student interviews, 2 high-achieving females, 1 low-achieving female, 1 high-achieving male and 1 low-achieving male, were recorded and transcribed while anecdotal records were made during the other interviews (Appendix 4). Stemming from the interviews a Concept Mapping Student Survey was constructed to provide a broader sample of data. Upon completion of the post-test for the unit **Chemical Properties and Changes** and prior to receiving their marks on the post-test students completed the Concept Mapping Student Survey. The results of the survey were tabulated.

The Main Study

Study Design

The purpose of the main study was to continue the examination of the use of the Concept Mapping strategy as a means of promoting understanding or meaningful learning of science by junior high school students. The pilot study indicated that students were able to construct concept maps of varying degrees of quality or completeness. Findings resulting from the pilot study, including results of the Concept Mapping Student Survey and student responses provided during the interview sessions, indicated that some students felt that concept mapping provided a desirable alternative method for students to express their understanding of a topic.

Guided by the outcomes of the pilot study the objectives of the main study were formulated. The overall goal of the main study was to allow grade nine science students to develop an understanding and familiarity with the concept mapping strategy and to provide opportunities to use concept maps as answers to evaluation items. Specifically the focus of this study was:

1. To examine the frequency of use of concept maps as answers on test questions,
2. To compare the academic achievement levels of the students using concept maps with students using paragraph answers;
3. To survey students feelings towards the use of concept maps.

The main study provided a means to gain information on whether students would willingly choose to use the concept mapping strategy, as a means of expressing their understanding of a topic, during evaluation sessions. The assumption that students would use the strategy which they felt would be most effective, the one they felt most comfortable with, and would allow them to produce the best answer guided the procedures in the main study. Students' preference for using concept maps as opposed to traditional paragraphs, as answers on evaluation instruments, was appraised by determining frequency of use of concept mapping and paragraph writing.

The main study functioned as a mechanism to explore whether high-achieving students would prefer to use the concept mapping strategy, to express their knowledge on test questions, more frequently than low-achieving students. Student achievement on the multiple choice portion of the test served to identify high and low-achievers. Information pertaining to frequency of completion, of concept mapping assignments and their associated ratings was also obtained for the student population participating in this study.

This study was conducted in one junior high school located in a central Alberta town. Three classes of grade nine students, representing two-thirds of the grade nine population, were involved. The classes participating in the study were comprised of students with a heterogeneous mixture of ability levels and totalled 94 students.

All students participating in the study were taught by the same teacher and received the same instruction in science in terms of resource materials, teaching methods, and assessment activities. The six units of study identified within the Junior High Science Program of Studies (Alberta Education 1990) served as the course content and were taught to the grade nine science classes. The principal textbook reference used was Science Directions 9 (Winter et al., 1990).

During the first two units of study the concept mapping strategy was not formally introduced. This time period, of approximately three months (September to December), provided the opportunity to establish a variety of classroom procedures and the development of convivial teacher-student relationships. Teaching strategies and practices instituted during this introductory phase of the study were incorporated throughout the study.

The main reference textbook Science Directions 9 (Winter et al., 1990, regularly divided each Unit of study into a series of six Topics. Since this textbook served as the main reference for this course this organizational pattern was followed as a way of delineating subject material for instructional purposes.

All Units were introduced to the students through the use of demonstrations which frequently incorporated an object, process or phenomenon which was central to the concepts presented in the unit. This introductory event served to focus student attention on the domain to be studied, to elicit student discussion about the field of study, and to provide a brief overview of the content comprising the unit. Each of the Topics included within the Unit were introduced in a consistent manner, frequently using a question or series of questions designed to initiate student discussion. Key concepts, pertaining to the topic, were identified, defined, and explained. Concept understanding was promoted by students completing various hands-on activities, written assignments, and note taking assignments which were hoped to consolidate the information in a concise, succinct manner.

Prior to the introduction of the concept mapping strategy all students completed a Student Questionnaire assessing the students' feelings about science class, learning science, and science in general. The results of the survey were tabulated.

The Concept Mapping Strategy

The students were introduced to the concept mapping strategy, after the introductory period, through a variety of activities designed to have students become aware of the methods or strategies they used to retain and recall data or facts. The initial activities included presenting lists of words and number sequences which were unrelated, using an overhead projector. After a brief exposure to the word or number lists, (usually 15 to 20 seconds) students were asked to recall and write as many as possible. Class discussions followed with the students describing the methods they used to help them remember the word or number lists.

Subsequent activities used number and word lists in which the numbers followed a pattern or sequence and the words were related. Again students were exposed to these number and word lists for a brief period and then expected to recall and write down as many as possible. In the class discussions which followed many students expressed their ability to recall more numbers or words, presented in the lists, by identifying or establishing patterns or relationships within the number or word lists. These activities were intended to make students aware of the benefits arising from the establishment of connections between concepts.

An exercise which became a consistent practice throughout the study was to have students develop their own definitions for the key concepts, presented in the textbook, within the Topic of study. The teacher demonstrated the process by selecting 4 or 5 key concepts (commonly words which were in bold type, italicized, or formed subheadings) from the Topic. The teacher then interpreted each term using uncomplicated, familiar words. This activity served to identify the principal concepts and to encourage the students to organize or link new ideas or concepts to what is already familiar to them. Through presentation of students' definitions of concept terms it became apparent to the students that there was a great variety of acceptable definitions for any given term.

The basic elements of and the structure associated with concept maps were illustrated using teacher-prepared concept maps that included concepts currently being studied in class. The elements identified include: **propositions** (two related concepts linked by a line and a word or words establishing the relationship); **hierarchical levels of concepts** (the most general concept being found at the top of the map and more specific concepts located further down); **branching** (distinct concept groups form branches from a common concept); and **cross links** (connecting concepts from different branches of the map.

The Concept Mapping strategy was introduced and explained within the context of the unit on **Controlling Heat** as presented in Science Directions 9 (Winter et al., 1990). Various concepts presented within the first three Topics of this unit were incorporated into the activities associated with teaching students about concept mapping including the use of teacher prepared concept maps. Students were requested to copy the concept maps and encouraged to construct their own maps, as practice, using similar concepts identified in the teacher-made map. Students were given various opportunities to practice constructing concept maps, sometimes as whole-class activities and sometimes as individual assignments.

In addition to concept maps the teacher continued to provide the students with paragraph-summaries or notes as a way of summarizing a given topic. Concept mapping and paragraph-summaries were presented as alternate ways of expressing information about science topics. The teacher made a conscious effort to utilize each method, concept mapping and paragraph-summaries, on a regular basis. The teacher emphasized the effectiveness of each method and provided all students with an outline for the students to refer to when constructing paragraph-summaries or concept maps (Appendix 5).

Data Sources

Three units of study, Controlling Heat, Using Electricity and Understanding Chemistry, as presented in Science Directions 9 (Winter et al., 1990) provided the subject content for this study. The teacher made conscious efforts to utilize consistent teaching methods and evaluation procedures for all classes involved in the study. During each of the Units of study the students were requested to copy teacher-made concept maps and complete various concept mapping assignments. The copying of teacher prepared maps provide students with an overview of the structure of maps in terms of concept hierarchy, levels of relationships, and branching. Assignments provided opportunities for student practice of map construction with assignments frequently submitted to the teacher for examination and evaluation. The evaluation system for the concept maps, which was explained to the students, rated the student maps as Attempted, Satisfactory, or Good.

The criteria for each of these categories focused on the basic requirements for effective concept maps including number and of correct propositions, connecting concepts to form branches, establishing levels, and identifying cross links (relationships between concepts in adjacent branches) (Appendix 6). The rating assigned to nine different concept maps assignments (3 from the unit **Controlling Heat**, 3 from the unit **Using Electricity** and 3 from the unit **Understanding Chemistry**) completed by the students in the study were recorded and tabulated. This data provided information on individual students competence and overall rates of completion. The evaluation system functioned to provide feedback to the students regarding the quality of their map. The students were encouraged to redraw maps to improve upon the overall completeness and usefulness of their maps.

All students were also required to record a number of paragraph-summaries for each the Units of study. The paragraph-summaries were customarily discussed in class and student questions were clarified by the teacher. The teacher-made concept maps, paragraph-summaries and student-made concept maps served as the primary modes of recapitulating the main concepts presented within the Units of study. Throughout each of the Units students also participated in hands-on activities, completed a variety of written assignments and viewed audio-visual presentations pertaining to the topics being studied.

At predetermined intervals the students were tested on the subject material studied during the preceding segment of time. The tests or examinations consisted of multiple choice questions, and a Paragraph/Concept Map question(s). The Paragraph/Concept Map questions examined the students higher-order-thinking skills in that they required students to select and organize their existing knowledge into a coherent response. The Paragraph/Concept Map questions functioned to allow students to choose between the more traditional approach of using a paragraph to present their knowledge or the alternative concept map strategy.

Paragraph/Concept Map Questions

Paragraph/Concept Map Question 1 was part of the final unit exam on Heat Energy. This represented the first test question which the students had an opportunity to use concept mapping as an answer. The students had not been required to respond to this question in paragraph or concept map form prior to this exam.

Question 1: The three methods of heat transfer include conduction, convection and radiation. Use a Concept Map or Paragraph to explain how each of these methods of heat transfer occurs and the differences between each of these methods.

Paragraph/Concept Map Question 2 was part of a Term Final exam. This question contained two parts, A and B, with the students being required to answer each part. Part A required students to apply the principles they had learned in the unit **Controlling Heat**. Part B was based on the first two Topics, **Electricity - Static and Current** and **Cells and Batteries**, covered in the unit **Using Electricity**. Prior to answering these test questions all students had copied paragraph summaries of each Topic and completed a mapping assignment related to the Topics. Teacher made concept maps had been employed in the class to explain the topics. Students had not been required to answer either part A or part B of question 2 prior to the test, using any format.

Question 2 Part A: You are to design a container which will prevent a large ice cube from melting for as long as possible. Your container can be made of any common types of material however you are not to use electricity. The container, with the ice inside, will be placed outside in the bright, hot summer sun.

Part B: Jennifer was wearing wool slippers and walked across her carpeted bedroom floor to turn on her stereo. When she reached out and touched the stereo controls she received a shock. Explain why Jennifer received the shock and how she could prevent this in the future.

Paragraph/Concept Map Question 3 was part of the final exam on the unit **Using Electricity**. This question consisted of two parts each of which focused on specific topics within the Unit. Each part of this question included lists of key concepts from the relevant topics. These concepts were included to examine what affect the lists would have on the students' selection of either paragraph or concept map format as answers. The concept list was also viewed as a means to focus the students' attention on the key concepts to be incorporated into their answers. Students had not been required to answer either parts of question 3 prior to the test.

Question 3 Part A: Bill noticed that his portable CD player was not able to play at high volume. Bill said to his friend Jack that his batteries were out of juice. Jack laughed and suggested that Bill squeeze the batteries to get more juice. Using the terms below and any others you wish, explain how batteries/cells produce electricity.

direct current	electrodes	chemical reaction	zinc
battery positive	electrolyte	electron flow	
chemicals	carbon	negative	cell

Part B: Janet asked Susan to help her with a project she was working on. Janet explained how she wanted to make a device which would control her bedroom light brightness and her stereo volume from the same switch. Susan suggested they first draw a circuit diagram to help them understand how to connect the different parts of the circuit. Using the terms below and any others you wish explain what a circuit is and the parts of a circuit.

parallel	load	bulb	switch
conductor	open	source	series
control	closed	fuse	circuit breaker

Paragraph/Concept Map Question 4 was part of the final exam on the **Understanding Chemistry** unit. The question consisted of two parts with part A focusing on concepts covered in Topics one and two which dealt with the **Structure of Matter**. A list of 9 key concepts were provided as part of the question. Part B dealt with the concepts provided in Topics three, four, and six; particularly **Physical and Chemical Changes**. This question did not include a list of the key concepts identified within the pertinent Topics. Concept lists were included in question 4 part A and not in part B to examine how this would affect the numbers of students selecting either the paragraph format or the concept map.

Question 4 Part A: Matter can exist as mixtures or pure substances. Explain what the differences are between mixtures and pure substances and give examples of each. Use the terms or concepts listed below in your answer and include any other terms you wish.

elements	pure substances		density
molecules	properties	atoms	
compounds	state	mixtures	

Part B: Jack had bought a used car which had recently been painted. The following year Jack noticed a large number of rust patches along the fender line. Jack's girlfriend Barb, explained that the rusting was a chemical change and that the new paint job simply covered over the rust. Jack thought the rust was a physical change because it ruined the appearance of his car. Use a paragraph or concept map to explain what types of changes matter can undergo, describe these changes using examples and describe how you know when they occur.

After completing the unit test on **Understanding Chemistry** the students completed the Concept Mapping Student Survey. The survey included two open-ended questions: What do you like about making and using concept maps? and What don't you like about making and using concept maps? Results of the survey were tabulated.

Semi-structured interviews were conducted with eight students after the students had completed the unit test on **Understanding Chemistry**. Students selected for the interviews represented high-academic achievers and low-academic achievers of both genders. In all interviews the following questions were asked:

1. Are you able to make or construct concept maps?
2. What do you find hard about making concept maps? Are there some parts of making a map that are more difficult?
3. Are there things you like about making concept maps?
4. Do you think that making concept maps help you to learn science?
5. It seems some students have problems or find it difficult to make concept maps. Could you suggest some reasons why this might be?
6. Do you like being able to use concept maps as answers to test questions?

Five of the interviews were recorded with an audio-cassette recorder and transcribed.

Chapter 4

Presentation of Findings and Interpretation

Pilot Study Results

The pilot study employed qualitative and quantitative measures to determine whether Grade 9 students could construct concept maps and to assess the effects of concept mapping on student achievement. Students' attitudes toward learning science and concept mapping were also examined using Likert scale surveys and semi-structured interviews.

Student Attitudes About Science and Learning Science

The Student Attitude About Science and Learning Science survey (Appendix 7) afforded a glimpse into students attitudes toward school science in general and the process of learning science. Student responses directly related to these attitudes are presented in Table 1. These responses indicate that these students felt they are capable of learning science providing it is taught properly. Students also felt that one does not have to be smart to understand science.

The majority of students indicated that science is a difficult subject to learn, that there are too many definitions to remember and that one requires a good memory to do well in science. Most students indicated that science was boring. The survey results suggest that students have difficulty understanding the material presented in class and that they do not feel able to learn science on their own. Students indicated a preference for having the teacher identify the important facts.

Table 1. Student Attitudes About Science and Learning Science Survey. The results in each category are expressed as a *percentage* of the total (N = 96).

SA = strongly agree; A = agree; U = undecided; D = disagree; SD = strongly disagree.

	SA	A	U	D	SD
All students can learn science if the subject is taught properly.	32	46	9	9	4
You have to be smart to understand the work in science class.	9	28	14	36	13
Science is a difficult subject to learn.	23	37	20	14	6
There are too many definitions to learn in science class.	19	41	17	20	3
A person has to have a good memory to do well in science.	12	37	17	27	7
Science is boring.	34	21	24	17	4
The information presented in science class is easy to understand.	3	22	33	40	9
I am able to learn science on my own.	6	20	29	33	12
My teacher should tell me the important science facts in class.	21	36	33	7	3

	SA	A	U	D	SD
I learn the most in science class when I do experiments or other hands-on activities.	30	42	10	12	6

	SA	A	U	D	SD
Diagrams and pictures help me to understand science topics.	12	58	19	9	2

	SA	A	U	D	SD
The topics covered in science class help me to understand the world around me.	15	43	25	12	5

The performing of experiments and other hands-on activities and using of pictures and diagrams were consistently indicated as ways of improving the understanding and learning of science. The students also felt that school science contributes to their understanding of the world around them.

Student Achievement

The effects of concept mapping and student achievement were examined using a multiple choice/open-ended numerical response test instrument in a pretest/posttest format. The test instrument used in this study was designed to test for a variety of levels of thinking. The test, designed as a Field Test for the Grade 9 Science Program by the Student Evaluation Branch of Alberta Education consisted of 31 multiplication items and 4 open-ended, numerical response questions. Of the 31 multiple choice questions 5 questions were identified, by the creators of the test, as assessing concept knowledge, 23 questions were identified as assessing comprehension/application of the concepts, and 3 questions were identified as assessing higher-mental abilities. Three of the four open-ended, numerical response questions were identified as assessing comprehension/application and one was assessing higher-mental abilities.

The individual students' pretest and posttest student scores (Appendix 8) provide evidence of the tremendous range of change exhibited by the students in this study. The greatest individual change of 51.5% was exhibited by student 309, a member of the control group. The second largest individual change was shown by student 106, a member of Treatment Class 1, which equalled 40%. Treatment Class 1 showed the greatest overall change of 14.03% and this class also presented the highest mean posttest score. It was also interesting to note that this was the only class which did not show any negative gains from pretest to posttest.

Table 2. Mean pre- and posttest scores (maximum 33) and standard deviations for the concept mapping classes 1 and 2 and non-mapping classes 3 and 4 (N = 51 mapping students; N = 53 non-mapping students).

	Pretest		Posttest		
Class	x	SD	x	SD	Gain
1	10.8	5.02	15.7	6.44	4.9
2	11.3	4.12	14.9	5.44	3.6
3	8.7	3.27	13.1	5.03	4.4
4	11.6	4.20	15.2	5.30	3.6

The pretest and posttest student scores expressed by class, in Table 2, show that both the control and the experimental classes improved in their performance after receiving instruction however there were no significant differences in test score gains between the two groups.

Student Concept Maps

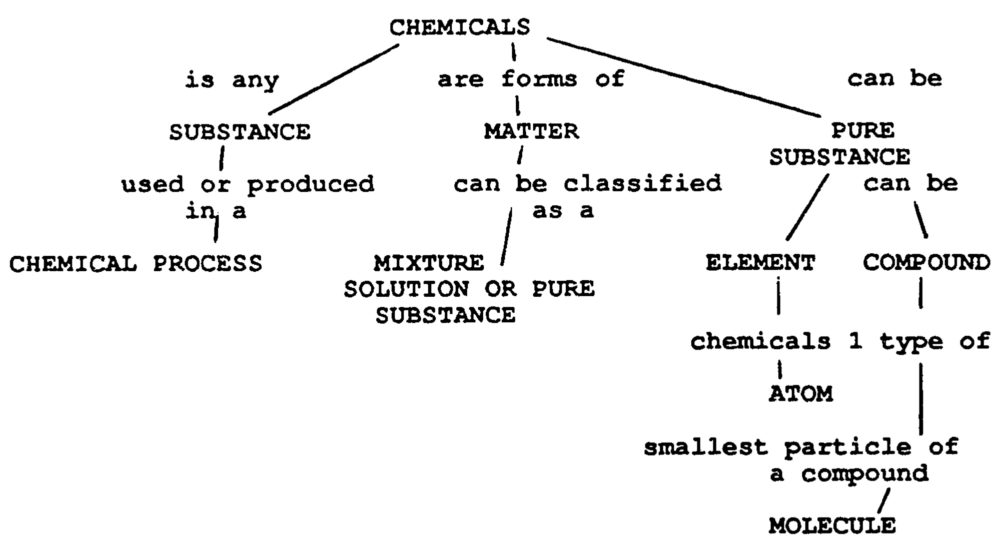
The concept maps constructed by the students varied greatly in terms of the number of concepts incorporated into the maps, the arrangement of the concepts to form correct propositions, and the overall organization of the concepts to form a meaningful concept map. A sample of concept maps constructed on the topic of Chemicals is presented in Table 3. These maps were produced by the students after reading a paragraph summary provided by the teacher on the topic.

The map constructed by student 103 contains all the important concepts, presented in the summary, linked as correct propositions. The concepts are clearly arranged into a hierarchical structure of distinct and related levels. The more general concepts are found at the top of the map with more specific concepts found at lower levels. The propositions found in this map are established in a clear and concise manner. The indication that both elements and compounds can be identified by specific properties represents a cross link. Cross links, showing relationships between concepts in adjacent branches, suggests the student has a more complete or meaningful understanding of the topic.

The map constructed by student 111 includes most of the main concepts, linked as propositions, presented in the paragraph summary with the exception of those related to properties of elements and compounds. In this map the hierarchical relationship between the various concepts is not clearly established. This student grouped the forms of matter (mixture, solution and pure substance) as a single concept and may not have understood the distinctiveness of each form. The proposition, formed by linking the concepts atom and molecule, is not proper as the linking words do not identify the relationship.

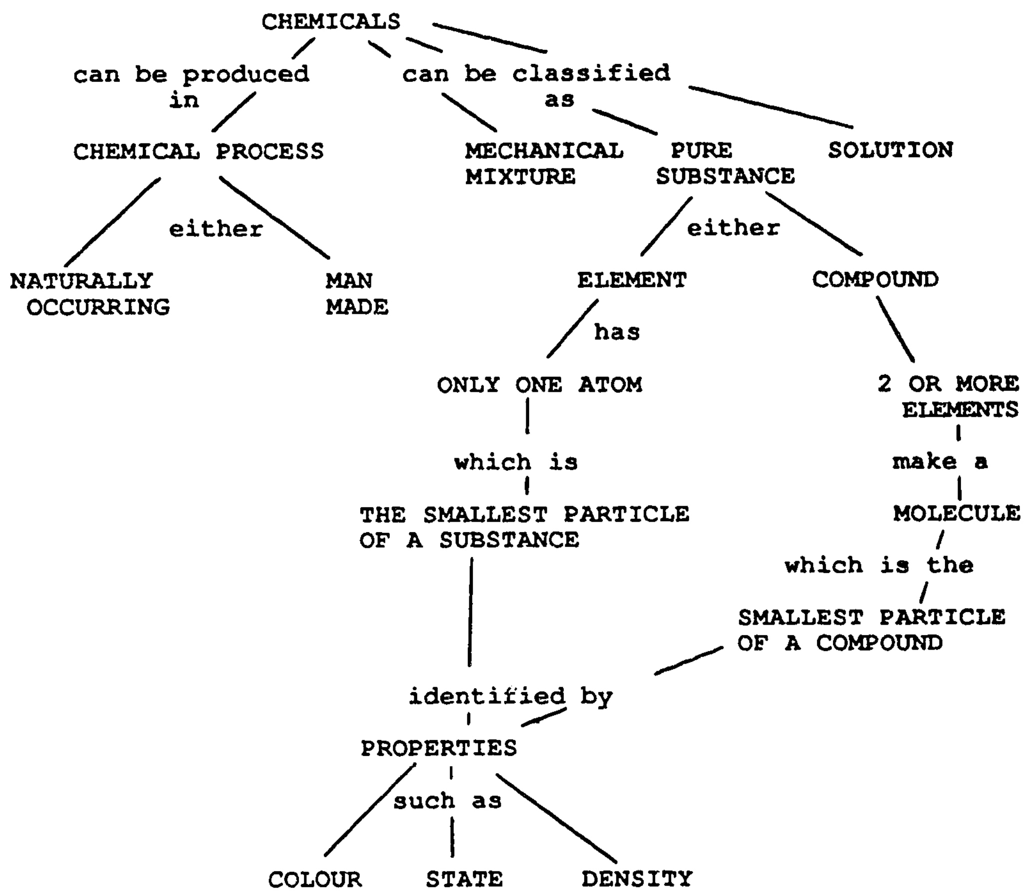
Table 3. Concept maps produced by student 103 (high-achieving student) and student 111 (low-achieving student) based on a summary paragraph on the topic Chemicals provided by the teacher.

Student 111 Map



Levels = 2   Propositions = 9   Cross links = 0

Student 103 Map

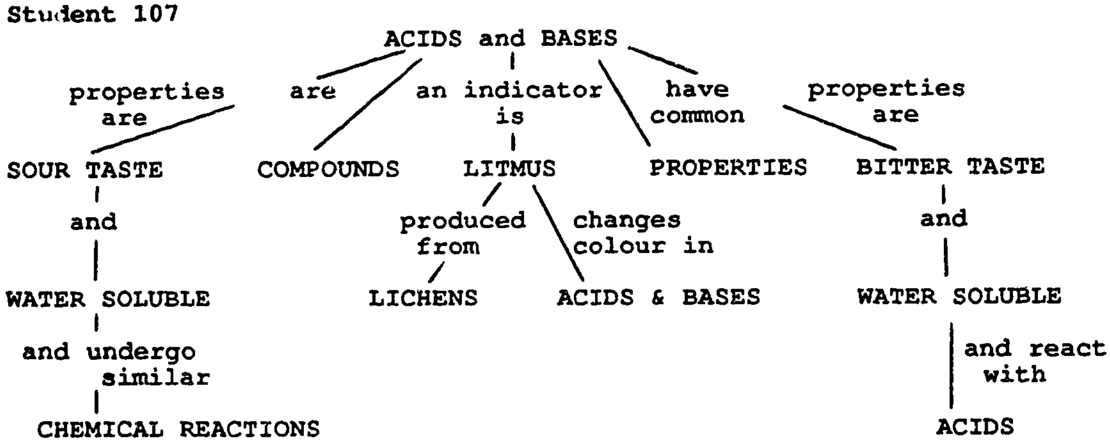


Propositions = 17 Levels = 4 Cross links = 1

The maps shown in **Table 4** were produced by students using a paragraph summary on the topic Acids and Bases provided by the teacher. These maps illustrate that while concept maps tend to be relatively unique and students establish priority and relationships between concepts in a personal manner, maps illustrate common patterns of thinking. The map drawn by student 107 shows the common tendency to cluster concepts and establish propositional relationships directly to the main ideas or most general concepts. The propositions formed by clustering suggest more of a rote form of learning in that discrete facts are isolated from each other.

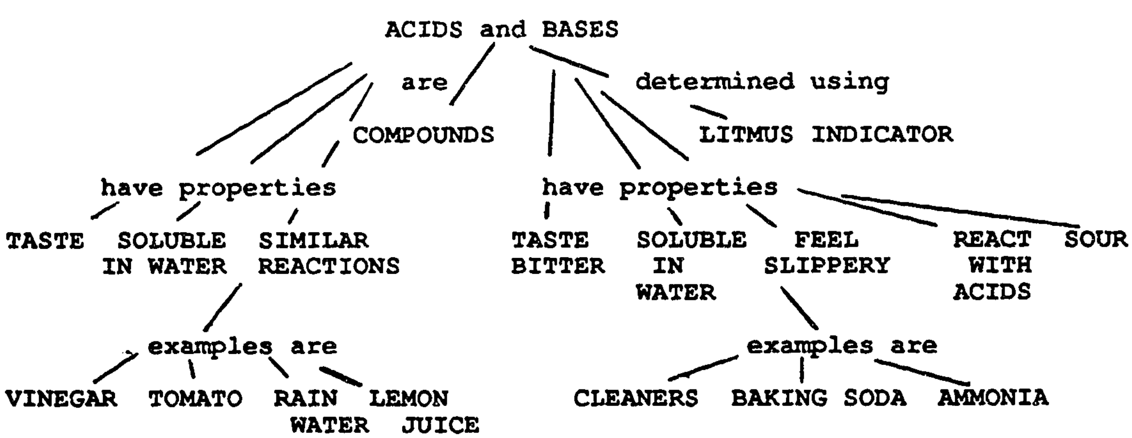
Table 4 - Concept maps produced by students 107 (low-achieving student) 222 (average-achieving student), and 122 (high-achieving student). The maps were constructed using a summary paragraph on the topic Acids and Bases provided by the teacher.

Student 107



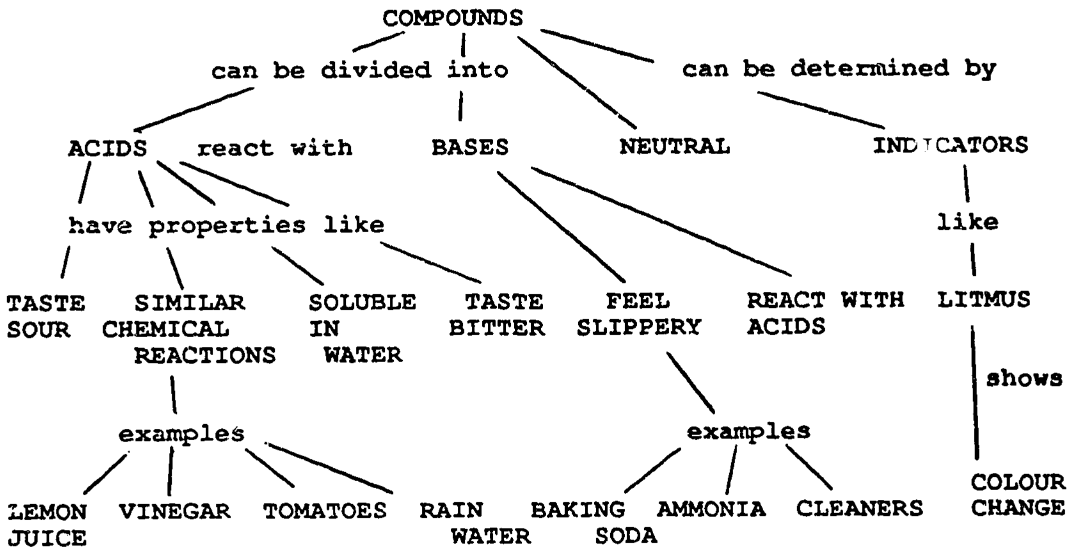
Levels = 3 Propositions = 11 Cross links = 0

Student 222



Levels = 3 Propositions = 16 Cross links = 0

Student 122



Levels = 3 Propositions = 21 Cross links = 2

In these types of maps the students identifies all the concepts as having equal importance and is not able or does not attempt to develop an understanding of the relationships between the various concepts.

The map drawn by student 222, using the same teacher summary paragraph illustrates a greater degree of arranging concepts into branches and levels. This arrangement shows, more clearly, the definite relationships between concepts and identifies the more general, encompassing concepts. This map includes nearly all the significant concepts identified within the summary arranged in correct propositional form.

The concept map drawn by student 122 shows a multilevel organization with three distinct strands and arrangement of related concepts into discrete levels. The map shows cross link relationships between acids and bases on two levels; their sharing of similar properties and their ability to react with each other. This student was able to use uncomplicated linking words to establish the greatest number of correct propositions.

Concept Mapping Student Survey

The Concept Mapping Student Survey provided the students the opportunity to express their feelings about the concept mapping strategy in an anonymous setting. Student responses to the survey presented in **Table 5** indicate that a significant number of students felt capable of making concept maps. Survey results indicate that the constructing of concept maps encourages students to think about the topic, helps students to remember the topic, and assists in the learning of science.

The suggestion that concept mapping encourages students to be actively involved in the learning process is supported by the survey results. The majority of students indicated that concept mapping helps students learn on their own and the strategy allows students to use their own words to explain science topics. The substantial number of students agreeing that concept mapping allows them to organize information in their own way supports the notion that concept mapping facilitates learning as an idiosyncratic process. In this view learning requires the individual to make meaning by establishing connections with what is already known. An additional feature, inherent in the mapping strategy, is the opportunity for the individual to readily identify those areas which may be confusing or poorly understood. Students indicated their consensus with this assertion with their support for the statement that making concept maps is a good way to find out what you don't know about a topic.

TABLE 5. Concept Mapping Student Survey, student responses expressed as per centage of total response (N=47).

SA = strongly agree A = agree U = undecided
D = disagree SD = strongly disagree

	SA	A	U	D	SD
1. I am able to make a concept map.	22	41	16	7	14
2. Concept maps are difficult to make.	16	33	19	27	5
3. Making concept maps helps me to understand the topic I am learning.	11	38	19	27	5
4. Concept maps let me organize the information in my own way.	16	35	22	11	16
5. I prefer making concept maps on a topic rather than taking notes.	41	24	11	11	13
6. I find it hard to decide on which concepts to use in a concept map.	11	38	19	24	8
7. I don't like making concept maps.	22	19	24	30	5
8. Making concept maps help me to remember the topic better.	13	41	19	11	16
9. I would not make concept maps if I didn't have to in class.	38	27	22	13	0
10. Making concept maps makes me think about the topic.	16	46	14	16	8

Item	Statement	SA	A	U	D	SD
11.	Concept maps let me use my own words to explain the science topic.	19	43	13	14	11
12.	Selecting linking words to connect concepts is hard.	19	22	13	35	11
13.	I would like to be able to use concept maps as answers on tests.	1[illegible]	22	16	24	22
14.	Choosing which concept to start the map is usually hard to do.	16	33	19	22	10
15.	I get confused when I try to make a concept map.	24	30	13	27	6
16.	If I redo a concept map I find it is easier the second time.	16	41	13	13	17
17.	A concept map gives me more useful information than do notes.	11	32	24	22	11
18.	Concept maps help me to learn science topics.	11	43	16	13	17
19.	You have to think too much to make a concept map.	16	17	30	27	10
20.	You have to be smart to be able to make concept maps.	6	13	10	51	20
21.	Concept maps should be used in other school subjects.	11	32	11	13	33
22.	Concept maps do not include enough details about a topic.	6	13	22	38	21
23.	Concept maps take too much time to make.	13	11	32	32	12
24.	Making concept maps help me to learn on my own.	11	41	13	19	14
25.	Making concept maps is a good way to find out what you don't know about a topic.	16	38	13	19	14

This sample of students indicated a strong preference for the making of concept maps as opposed to the recording of traditional notes. This suggests that the mapping strategy should be considered as an additional method of conveying information in the classroom. While less than half of the students surveyed indicated a dislike for making concept maps a majority of students indicated they would not make concept maps in class if they did not have to. A possible explanation for student discomfort with the mapping strategy is indicated by the substantial support for the statement that students become confused when they try to make a concept map.

Student Interviews

In the pilot study the student interviews were conducted with students who had completed at least 3 of the 6 concepts maps assigned during the unit. This criteria was used as a measure to identify students who attempted to learn and use the concept mapping strategy. These interviews were considered as an additional opportunity for the students to express their feelings about the concept mapping strategy in an alternate format or mode. The transcriptions of 5 of these interviews are presented in Appendix 4 and represent students identified as high and low-achievers in science and of both genders.

These interviews indicated that the students, both high-achieving students and low-achieving students, found concept mapping initially a difficult strategy to use. Rhonda, a high-achieving student, said "I found concept mapping hard to do at first because I wasn't sure what was expected, what the teacher wanted." This statement suggests that high-achieving students may pay close attention to what their teachers indicate are the correct or best way to respond or provide answers. High-achieving students frequently identified concept mapping as a useful strategy that helped them to display their knowledge in a concise format. The advantage derived from the orderly structure of maps is described by Dean, "I know the stuff and I have the ideas in my head but mapping helps me to organize it." When a person possesses a well organized body of knowledge the learning of new, related concepts is greatly enhanced.

Low-achieving students expressed less confidence in their ability to construct concept maps. A common feeling by low-achieving students was that concept mapping was a difficult task to complete on their own. The response by Nola suggests these feelings when she says, "when we do them in class they [maps] help me to understand but when I do them on my own it's not that clear to me." These feelings of inadequacy, by low-achieving students, may stem from their lack of understanding of the topic or the requirement to use thinking processes which prove taxing.

The construction of concept maps as whole class activities or with partners may prove a valuable way of assisting the low-achieving student to improve their learning of science.

This is supported by Brian's comment that, "I like maps when we do them in class or with a partner, then they're fun and they work out better." The constructing of concept maps can serve to increase the low-achieving student's understanding of a topic and promote the use of higher-order thinking skills well beyond that associated with the recording of notes. The completion of concept maps as partner or group activities encourages all students to be engaged in the thinking process, places value on their unique, personal knowledge, and reduces the threat of being singled out for existing misconceptions.

A majority of students interviewed indicated that they experienced difficulty in identifying key concepts or starting the concept map. While this condition was identified in association with using concept mapping, it represents an impediment to learning science in general. Students' find it difficult to assimilate the large number of concepts, which are integral to the learning of science, in a meaningful manner. The use of the concept mapping strategy provides constructive exercise, for those students who attempt to learn the strategy, aimed at improving significant learning.

The pilot study findings indicate that these students were capable of constructing concept maps of varying degrees of quality and that high-achieving students viewed maps as helpful in learning science. These students indicated that constructing concept maps is a difficult task initially, for a variety of reasons, but becomes easier with practice. The use of concept mapping did not appear to produce significant increases in student achievement, as measured by the pretest/posttest instrument, nor did it appear to impede student learning. Some students indicated a preference to use concept maps as answers on test questions.

The Main Study Results

The focus of this study was to examine the use of concept mapping by students as an alternate means of expressing their understanding of science topics in an evaluation setting. Students were provided the opportunity to learn and use the concept mapping strategy in order to appraise the overall ability of grade nine students to construct good quality concept maps. The main objective was to provide students the opportunity to use concept maps or explanatory paragraphs as answers to test questions. These test questions required answers which included many related concepts organized and presented in a correct, coherent fashion. The frequency of use of concept maps as answers as well as the comparison of use by high-achieving students compared to low achieving students was also assessed. Students attitudes toward learning science and concept mapping were also examined using Likert scale surveys and semi-structured interviews.

Student Attitudes Towards Science and Learning Science

Prior to the introduction of the concept mapping strategy all students participating in the study were requested to complete a Student Questionnaire consisting of 30 questions. The Questionnaire employed a Likert scale with the statements eliciting students feelings about science a a subject, methods of learning science and evaluation in science class. The results of the Questionnaire are presented in Table 6.

The results of the Questionnaire suggest that these students enjoyed science and felt confident that all students could learn

science if the subject was taught properly. A large majority of these students felt comfortable in science class and that the topics covered in science assist the individual in understanding the world around them. Slightly over half the students felt that science was a difficult subject to learn while approximately the same number indicated that you do not have to be smart to understand the work in science class.

Table 6. Student Questionnaire, total student responses in each category expressed as raw score. (N = 100)

KEY: SA = strongly agree D = disagree
A = agree SD = strongly disagree

		SA	A	D	SD
1.	You have to be smart to understand the work in science class.	5	39	45	11
2.	Science is an enjoyable school subject.	8	52	32	8
3.	All students can learn science if the subject is taught properly.	45	40	8	7
4.	I feel comfortable in science class.	14	62	20	4
5.	Science is a difficult subject to learn.	10	43	37	10

		SA	A	D	SD
6.	I learn the most about science by listening to my teacher's explanations.	8	42	39	11
7.	A person has to have a good memory in order to do well in science.	10	48	38	4
8.	There are too many definitions to remember in science class.	16	46	34	4
9.	The information presented in science class is easy to understand.	5	46	42	7
10.	Reading over my class notes helps me to understand the material in science class.	11	50	33	6
11.	Science is boring.	16	30	42	12
12.	When I study for a science test I usually do quite well.	4	48	33	15
13.	I often get confused when I try a and study for a science test.	17	41	33	8
14.	I feel a lot of stress and pressure when I study for a science test.	18	45	34	3
15.	Reading my textbook helps me to understand the material covered in science class.	18	61	20	1
16.	I often use the information I learn in science class in my everyday activities.	3	41	50	6
17.	I don't know how I learn things in science class.	2	33	49	16
18.	I learn the most in science class when I do experiments or other hands on activities.	34	48	14	4
19.	Science tests are hard because the questions usually have only one right answer.	20	43	32	5
20.	Copying notes about science topics helps me understand the topics.	9	46	30	15

		SA	A	D	SD
21.	Diagrams and pictures help me to understand science topics.	29	59	11	1
22.	I find it difficult to know what information is important in science class.	10	57	3	0
23.	It helps me to learn science when another student explains the topic.	16	49	29	6
24.	Science readings are difficult to understand.	9	39	50	12
25.	The topics covered in science help me to understand the world around me.	15	67	16	2
26.	My science teacher should tell me the important science facts in class.	22	59	16	3
27.	I am able to learn science on my own.	7	43	46	4
28.	I often try to use my own words when answering questions on science tests.	14	65	20	1
29.	I remember science facts best by memorizing each fact separately.	11	39	43	7
30.	I prefer answering science questions using one or two word answers than paragraph.	35	34	26	5

A majority of survey respondents agreed that a good memory helps a person do well in science class; while only 50% supported the claim that memorizing facts separately is the best way to remember science facts. A minority of these students felt that science was boring.

Approximately two-thirds of those responding suggested they understood how their learning occurred in science class however half the students indicated they could not learn science on their own. Over 80% of these students felt that their teacher should tell them the important science facts and that they learned the most when they completed experiments or other hands-on activities. Over three-quarters of the students claimed that the use of diagrams or pictures helped them learn science. A substantial majority indicated that reading their textbook and their class notes helps them to understand material covered in science class. Approximately two-thirds of the students suggested that explanations by other students helped them learn science. A slight majority felt that copying notes helped them understand science topics.

Less than one-half of these students supported the claim that studying for a science test assured them they would do well. A significant majority indicated they feel stress and pressure when studying for a test. Over 60% of those responding felt that there were too many definitions to remember in class and that it was difficult to know what information was important. The majority of these students viewed science tests as difficult because the questions usually have only one right answer. Nearly 80% of the responses expressed a preference for using one or two word answers as opposed to paragraphs and they attempt to use their own words when answering questions on science tests.

Student Concept Maps

For each of the units of study the students were required to complete 3 concept maps pertaining to specific topics within the unit. Each of these maps were evaluated according to the criteria identified (Appendix 9) and rated as Attempted, Satisfactory or Good. A numerical equivalency for the descriptive ratings would be: NA (Not Attempted) no mark, A (Attempted) = 5-6, S (Satisfactory) = 7-8, and G (Good) = 9-10. The descriptive rating was used to downplay the evaluative function and thereby encourage students to complete the map assignments, to provide general feedback as to the quality of the map, and encourage students to review the criteria used to assess the maps.

The information provided in **Table 7** summarizes the results for the student maps constructed for the unit on **Controlling Heat**. **Map 1**, on the topic of **Temperature**, was constructed using a teacher prepared paragraph summary as well as the information presented on pages 122-123 in <u>Science Directions</u> (Winter et al., 1991). **Map 2**, on the topic **Microwave Cooking**, was constructed using the information presented on page 139 in <u>Science Directions</u> (Winter et al., 1991). **Map 3**, on the topic **Greenhouse Effect**, was constructed using a teacher prepared paragraph summary as well as the information presented on page 146 in <u>Science Directions</u> (Winter et al., 1991).

Table 7. Summary of map ratings assigned for maps 1, 2, and 3 on the unit Controlling Heat. NA (Not Attempted), A (Attempted), S (Satisfactory), G (Good). (N=100)

	MAP NUMBER 1	2	3
Map Rating	Number of ma	assigned rating	
NA	12	13	15
A	57	55	54
S	19	21	20
G	12	11	11

The data in Table 7 illustrates that the majority of students attempted constructing concepts as assigned. Approximately one-third of the maps were rated as Satisfactory or Good which suggests a considerable number of students were capable of understanding the process of concept mapping and applying it in a successful manner. Included in the rating of NA are the maps which did not identify at least a minimum number of propositions in their maps (minimum number of propositions required for each assignment were expressed to students) as well as the number of students who did not attempt the assignment.

The maps receiving a rating of G (Good) contained the greatest number of correct propositions, arranged in two or more branches, and frequently arranged in more distinct levels. A significant feature is that these types of maps often contained one or more cross links. These maps were most often constructed by students identified as above-average or high-achieving students in science.

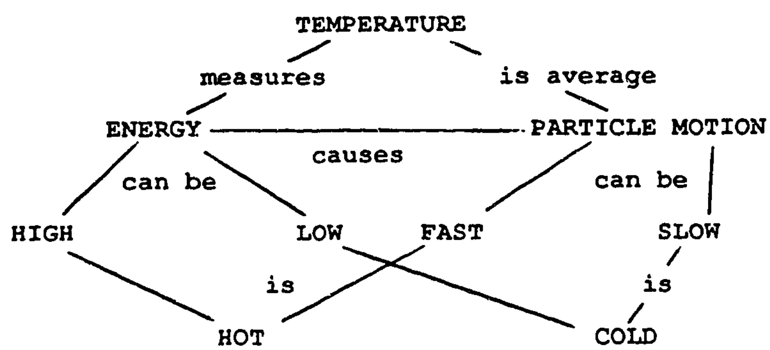
Table 8 includes examples of concept maps constructed by students on the topic **Temperature**. In this assignment students were required to identify the key concepts, presented in the readings, and connect them to form correct propositions. While the number of correct propositions displayed in each map varies only slightly the map by student B26 contains cross links. These cross links establish relationships between energy levels and temperature measurements and are considered to show a more thorough understanding of the topic.

The map constructed by student D28 also identifies propositional relationships, between energy and temperature, but relies on a more linear display. Related concepts are arranged in discrete branches, each having relatively few propositions. In the map constructed by student D11 we see a map which is distinctively linear in design. The lack of branches suggests that the student may not see the variety of relationships which occur between the different concepts.

A linear map, such as the one created by student D11, may indicate a preference for rote learning where individual bits of information are memorized as units. The organization of the concepts in terms of hierarchy, general to specific, is not as well established in maps rated as A (Attempted). A more substantial understanding of the topic is characterized by multiple connections between concepts which is more common in maps rated as S (Satisfactory), and G (Good).

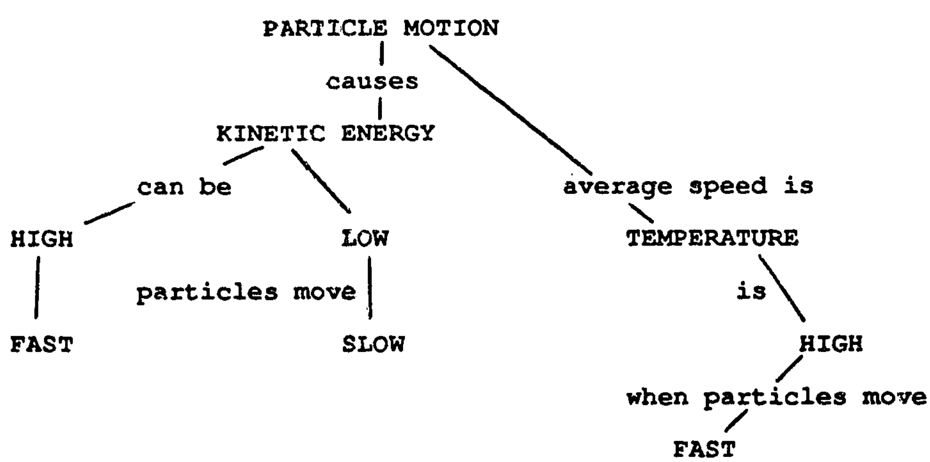
Table 8. Examples of concepts maps on the topic Temperature which received a rating of G (Good), S (Satisfactory) or A (Attempted). Students are identified by class (B, D, F) and number (1 to 34).

Student B26 - Concept map rated as G (Good)



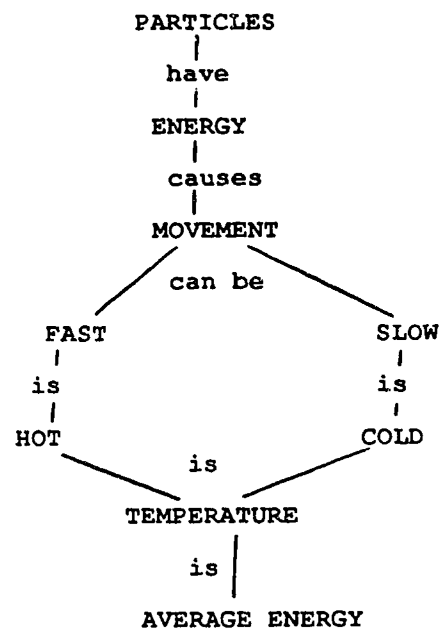
Levels = 3 Propositions = 11 Cross links = 2

Student D28 - Concept map rated as S (Satisfactory)



Levels = 3 Propositions = 8 Cross links = 0

Student D11 - Concept map rated as A (Attempted)



Levels = 2 Propositions = 9 Cross links = 0

The information provided in Table 9 summarizes the results for the student maps constructed for the unit on Using Electricity. Map 1, on the topic of Static Electricity, was constructed using a teacher prepared concept list as well as the information presented on pages 169 and 171 in Science Directions (Winter et al., 1991). Map 2, on the topic Current Electricity, was constructed using the information presented on page 172 in Science Directions (Winter et al., 1991) and a teacher prepared summary on the topic. Map 3, on the topic Electric Motors, was constructed using the information presented on page 190 and 191 in Science Directions (Winter et al., 1991).

Table 9. Summary of map ratings assigned for maps 1, 2, and 3 on the unit Using Electricity. NA (Not Attempted), A (Attempted), S (Satisfactory), G (Good). (N=94)

	MAP NUMBER 1	2	3
Map Rating	Number of maps assigned rating		
NA	11	13	17
A	56	51	50
S	18	20	18
G	9	10	9

The summary of map ratings provided in **Table 9** indicate that a large majority of students were willing and able to use the concept mapping strategy to present their understanding of the various topics. The students were able, in varying degrees, to identify and organize concepts in a purposeful manner to convey their understanding of the specific topic. The majority of maps, in each of the three map assignments, received a rating of A (Attempted) and there was a decline, as compared to the previous rating summary, in the number of maps rated G (Good). This suggests that the students had some difficulty with this topic and may indicate that the students did have a good understanding of the concepts related to the topic. The map results provide a sign, suggesting a need to review the concepts associated with these topics and perhaps the unit in general. A significant advantage of concept mapping is that the areas of misunderstanding or poor understanding are visibly displayed.

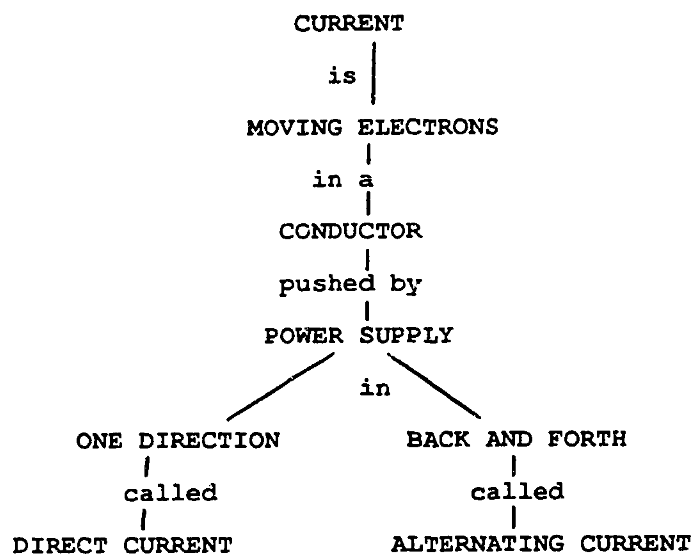
Examples of student maps on the topic **Current Electricity** are displayed in **Table 10**. These maps were constructed using a teacher prepared paragraph summary as well as background information presented in the textbook (Science Directions 9). As with the previous unit, the maps which received a rating of S (Satisfactory) or G (Good) were generally constructed by students identified as above-average or high-achieving students. The maps receiving a rating of A (Attempted) were commonly the work of students of average or limited academic ability in science.

The map constructed by Student B5 illustrates the typical map design employed by students having a limited understanding of the topic. This map has few branches and concepts tend to be strung together rather than clustered in levels of related generalization. The maps prepared by students D12 and F11 were both rated as S (Satisfactory).

These maps illustrate the considerable variety of forms maps can take and still present similar types of information. This variety of form illustrates the expanded opportunity mapping provides to the students to display their understanding of a topic. The map constructed by student F20 portrays a more comprehensive understanding whereby cross links are established between concepts in adjacent strands to identify meaningful relationships.

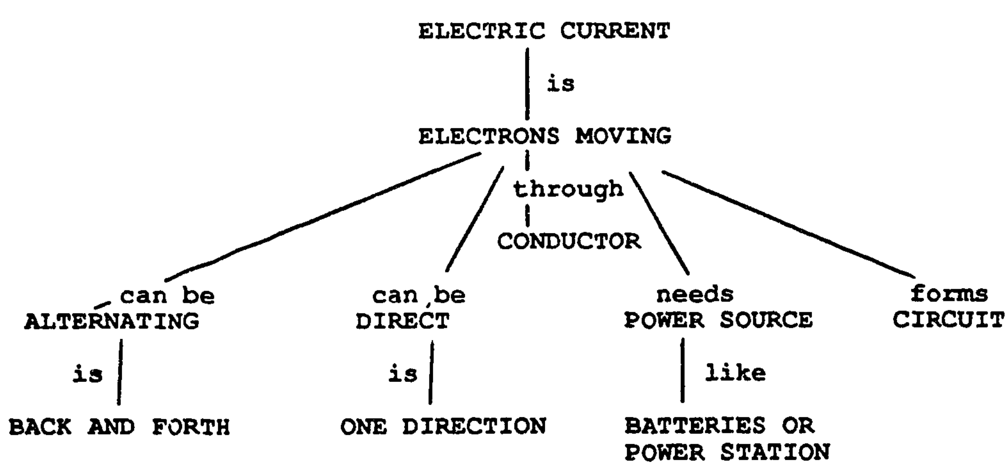
Table 10. Examples of concepts maps on the topic Current Electricity which received a rating of G (Good), S (Satisfactory) or A (Attempted). Students are identified by class (E, D, F) and number (1 to 32).

Student B5 - Concept map rated as A (Attempted)



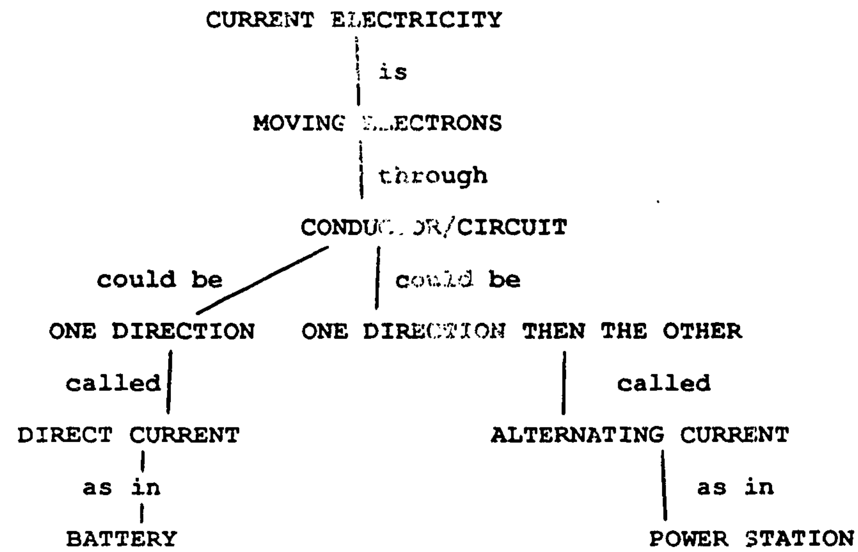
Levels = 2 Propositions = 8 Cross links = 0

Student D12 - Concept map rated as S (Satisfactory)



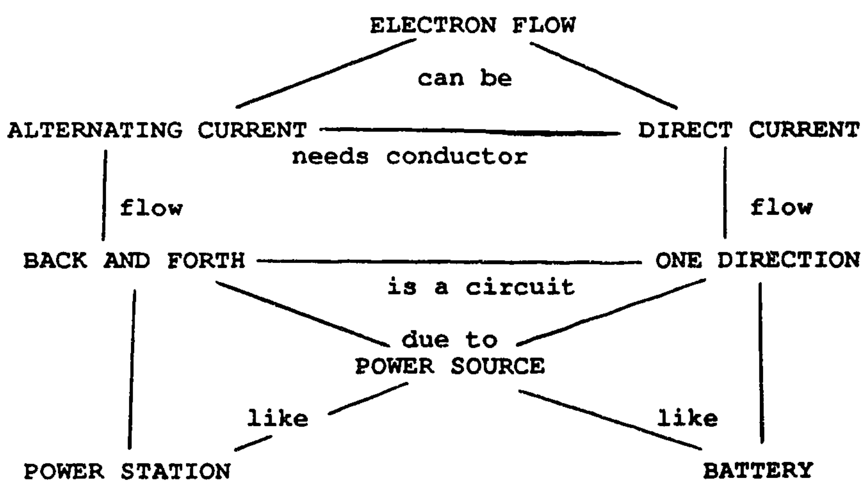
Levels = 3 Propositions = 10 Cross links = 0

Student F11 - Concept map rated as S (Satisfactory)



Levels = 4 Propositions = 8 Cross Links = 0

Student F20 - Concept map rated as G (Good)



Levels = 3 Propositions = 10 Cross links = 2

The information provided in **Table 11** summarizes the results for the student maps constructed for the unit on **Understanding Chemistry**. **Map 1**, on the topic of **Chemicals**, was constructed using the information in a teacher prepared summary paragraph. **Map 2**, on the topic **Types of Changes**, was constructed using the information presented in a teacher prepared summary paragraph. **Map 3**, on the topic **Acid and Base Indicators**, was constructed using the information presented in a teacher prepared summary paragraph.

The map rating summary in **Table 11** presents a similar distribution of map scores, in each of the rating levels, as presented in previous rating summaries. These results may indicate that each student approaches each map assignment as a unique or novel exercise and consistently utilizes spontaneous practices of concept association.

Table 11. Summary of map ratings assigned for maps 1, 2, and 3 on the unit Understanding Chemistry. NA (Not Attempted), A (Attempted), S (Satisfactory), G (Good). (N=96)

	MAP NUMBER		
	1	2	3
Map Rating	Number of maps assigned rating		
NA	13	12	14
A	53	50	51
S	19	21	18
G	11	13	13

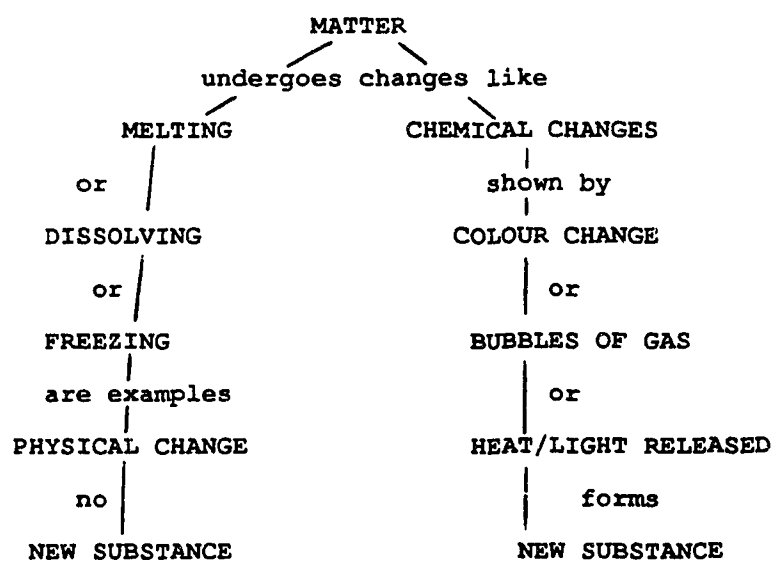
The large number of maps, in this unit, receiving the rating of A (Attempted) frequently displayed a similar linear appearance. A possible explanation for this consistency in map design may be due to students' instruction in conventional styles of information presentation. When presented with new and unfamiliar concep · a majority of low-achieving students may unknowingly emplc strategies of association which have been regularly employed and used for classroom instruction. Textbooks, note-taking, and paragraph writing display concepts in a linear, segmented manner. In these traditional modes of information presentation concepts are introduced separately and sequentially.

The concept mapping strategy involves concepts being linked and arranged in clusters or levels where relationships can be established. The concept mapping strategy requires the individual to break away from the traditional linear perspective and seek an expanded view of concept connections. In those maps rated as G (Good) the tendency to establish relationships between concepts in adjacent branches is evident. While this new way of perceiving concept associations may be achieved through prolonged practice it may be limited by the individual's cognitive state.

The student maps presented in **Table 12** display the features which are frequently exhibited by those maps receiving Attempted ratings. The concept map of student B19 illustrates the tendency of some students to construct linear maps where the most general concepts are not positioned near the top of the map. This map also displays the common practice of connecting related concepts to form linear strings rather than interrelated clusters. The reduced number of propositions, common to maps rated as Attempted, may be due to students having difficulty in fitting all concepts within their personally constructed map framework. The absence of cross links suggests a limited understanding of the relationships between the various concepts.

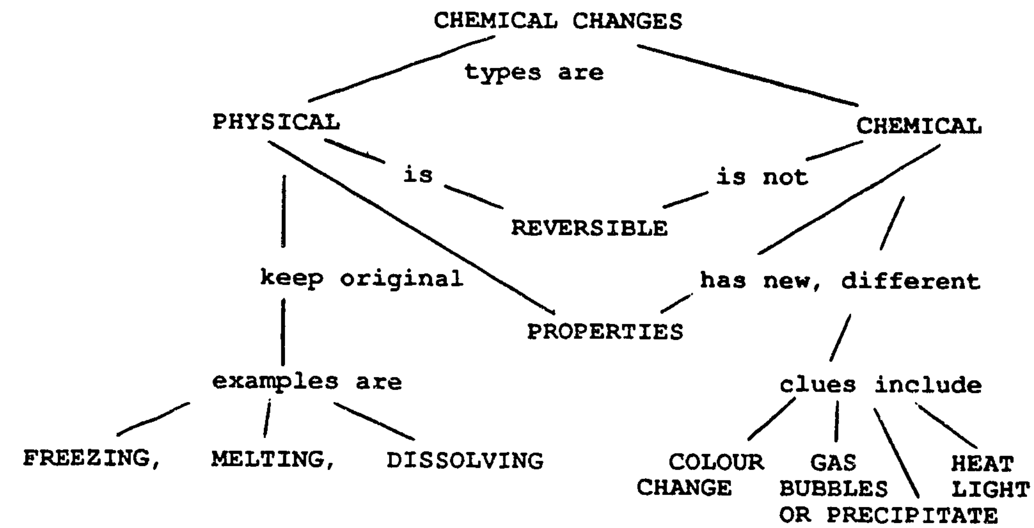
Table 12. Examples of concepts maps on the topic Chemical Changes which received a rating of G (Good), S (Satisfactory) or A (Attempted). Students are identified by class (B, D, F) and number (1 to 32).

Student B19 - Concept map rated as A (Attempted)



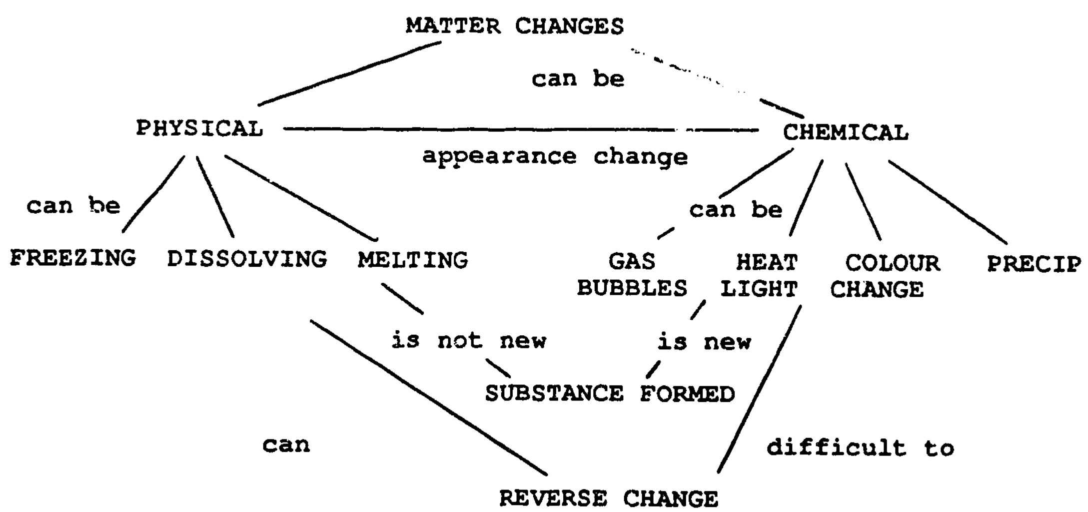
Levels = 2 Propositions = 10 Cross links = 0

Student D28 - Concept map rated as G (Good)



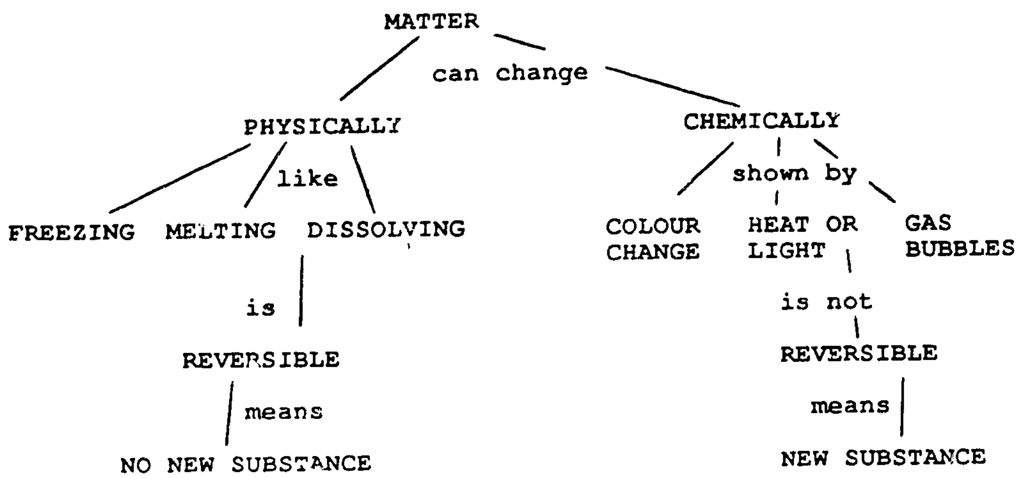
Levels = 3   Propositions = 13   Cross links = 2

Student D2 - Concept map rated as G (Good)



Levels = 3   Propositions = 14   Cross links = 3

Student F31 - Concept map rated as S (Satisfactory)



Levels = 2 Propositions = 12 Cross links = 0

The concept maps completed by students D2 and F31, both rated as G (Good) exhibit the composition which indicates a more substantive awareness of the variety of relationships existing within the given topic. The more general concepts are consistently identified and located at upper levels of the map.

The maps completed by students D2 and F31 include specific concepts or examples which help define a general concept are located at lower levels. A greater number of propositions, a characteristic of maps usually fashioned by higher-achieving students, suggests an enhanced ability to identify and establish concept relationships. The establishment of cross links serve to identify those qualities which are shared between affiliated concepts and indicate a richer understanding of the topic.

Paragraph/Concept Map Questions Results

The paragraph/concept map questions were components of unit tests or term-final exams. Their function was to provide students the opportunity to utilize the concept mapping strategy as a means of displaying their understanding of a given topic. Question 1 formed part of a term-final exam which focused on the unit of **Controlling Heat**. Prior to this term test the students had completed at least three concept maps independently. The students had copied or been provided with a least six summary paragraphs pertaining to the main topics as identified in Science Directions (Winter et al., 1990) and copied three different concept maps on various unit topics. The students had not been requested to complete this question prior to the unit test. This question did not include a list of concepts to assist students in completing their paragraph or concept map.

The results to **Question 1**, presented in **Table 13**, indicate that a majority of the students, completing the question, choose to use the concept mapping strategy to convey their ideas on the topic. The averages of the grades assigned to the concept maps and the paragraph answers varied only slightly. Students identified as high-academic achievers, as indicated by their scores on the multiple choice section of the test, showed a slight preference for using paragraphs. Those students identified as low-academic achievers, as indicated by their scores on the multiple choice section of the test, showed a preference for using concept maps.

Table 13. Results to the Paragraph/Concept Map question #1 on describing the Methods of Heat Transfer. (N = 100)

Number of students using: Concept Maps = 47   Paragraphs = 38
Average grade: Concept Maps = 5.9   Paragraphs = 5.4

Number of students not attempting question = 11

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 7
Used paragraphs = 8

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 15
Used paragraphs = 11

The relatively high frequency of use of concept mapping on this test question may be due to the format of the question. This question required students to present a summary of their understanding of this topic. The concept mapping strategy lends itself to the orderly display of a person's personal understanding of a topic. The hierarchical organization of concepts, starting with most general concepts, may assist the individual in recalling additional concepts. Students indicate, during class discussion, that the more general concepts often act as organizers or mental hooks which assist them in recalling relevant concepts.

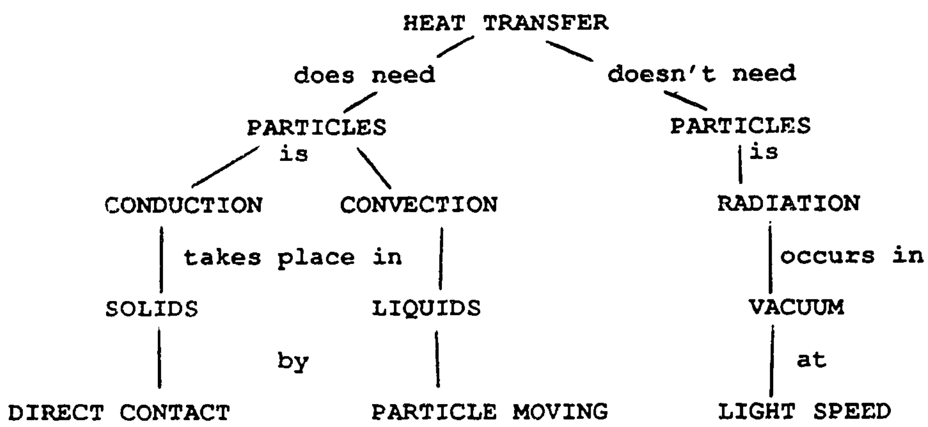
Those students who used concept mapping may have felt this method reduces the need for description employing conventional sentence structure format. Low academic achievers may have viewed concept mapping as an opportunity to express their ideas in a simpler, direct manner. For those students who become confused or frequently present mixed-up answers when they attempt to convert their in-the-head understanding to a written format, concept mapping may prove an effective alternative.

The concept maps exhibited in Table 14 were constructed by high-achieving students using the same reference materials on Heat Transfer. The map constructed by Student D9 displays a much fuller understanding of the topic, as indicated by the greater number of propositions, especially in terms of heat transfer by radiation. The identification of distinct branches, for each method of heat transfer, and the use of distinct examples results in a much greater number of relevant terms included in this map.

The map constructed by student F9 suggests this student has a general understanding of the processes of heat transfer but lacked detailed understanding of each method. The absence of propositions related to heat transfer by radiation suggests a limited knowledge of this area. Concept maps serve to clearly display the scope and depth of a student's understanding of a topic.

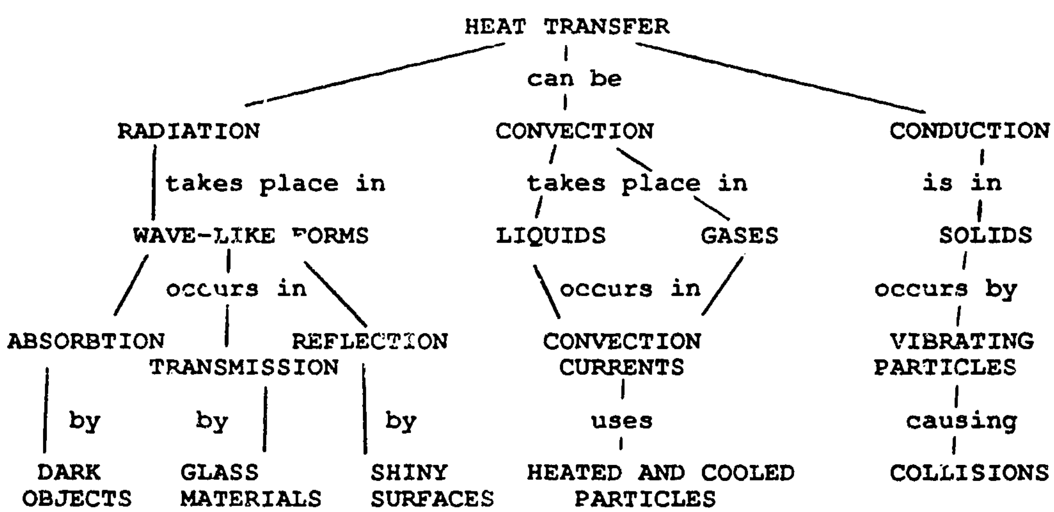
Table 14. Examples of student concept maps used to answer question #1 on Heat Transfer.

Student F9 - Concept map rated as Satisfactory (7/10). Constructed by high-achieving student.



Levels = 3 Propositions = 11 Cross links = 0

Student D9 - Concept map rated as Good (9/10). Constructed by high-achieving student.



Levels = 3 Propositions = 17 Cross links = 0

The results presented in Tables 15 and 16 display the findings for questions 2A and 2B. Questions 2A required the students to apply their understanding of heat conduction. This question was used to test students' higher-order thinking abilities as opposed to examining only their knowledge and comprehension of this topic. The vast majority of students chose to use the paragraph format to answer question 2A. Many of the students who used paragraphs to answer this question included a diagram to support and elaborate their explanation in paragraph form.

Table 15. Results to the Paragraph/Concept Map question #2 part A. (N = 94)

Question #2 - Part A. Describe the design of a container to reduce the melting of an ice cube when placed in the sun.

Number of students using: Concept Maps = 5 Paragraphs = 69
Average grade: Concept Maps = 5.8 Paragraphs = 6.2

Number of students not attempting question = 20

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 4
Used paragraphs = 10

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 0
Used paragraphs = 19

Paragraph answers to Question 2A, describing the insulating structure, commonly described the outermost layers first and then the inside layers. This sequential description rarely included the identification or discussion of relationships which existed between concepts used in earlier "layers" or sections of the paragraph. The paragraph answers routinely detailed specific concepts first rather than establishing any form of hierarchical relationships. The more general, encompassing concepts may not have been distinguished in the paragraph answer. This omission of overarching concepts reduced the opportunity to establish interrelationships between related concepts and thereby establish a broader understanding.

The students who selected to make concept maps were required to perform higher-order thinking processes, including application of relevant concepts as well as the synthesis of these concepts into a meaningful concept map, and the evaluation of their effectiveness. The extremely low number of students who employed the use of concept mapping, in this instance, suggests that students did not feel confident in using this strategy to answer this type of question. This requirement, to operate at a higher conceptual level, may have proven too difficult a task even for the high-achieving students. While concept mapping is useful and effective in displaying students knowledge and comprehension of a topic this strategy may not be easily employed to communicate ideas incorporating more creative, higher-order thinking.

Question 2B also required students to apply their understanding, in this instance the topic was **Static Electricity**, in order to effectively answer the question. The results presented in **Table 16** show that very few students used the concept mapping strategy. The low number of concept maps used in this situation lends support to the proposal that these students found it difficult to use the concept mapping strategy to answer questions requiring the application, synthesis, and evaluation of conceptual knowledge. The majority of students chose to express their answers in a paragraph format which allowed them to identify and explain individual concepts in a sequential manner. Diagrams were not commonly included with the paragraph answers. The paragraph answers tended to explain static electricity as a "bottom up" phenomenon. Little generalization was included within the paragraph answers; the focus was on each of the events which contributed to the production of the discharge.

Table 16. Results to the Paragraph/Concept Map question #2 part B. (N = 94)

Question #2 - Part B. Explain why Jennifer received a shock when she touched her stereo.

Number of students using: Concept Maps = 4 Paragraphs = 72
Average grade: Concept Maps = 5.5 Paragraphs = 6.1

Number of students not attempting question = 18

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 3
Used paragraphs = 13

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 0
Used paragraphs = 21

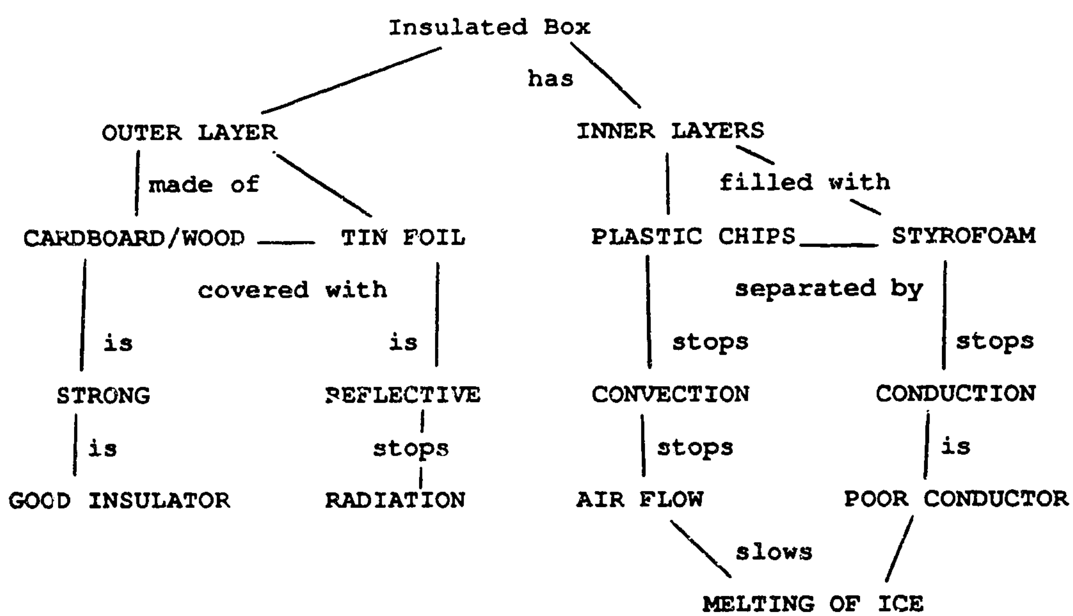
The examples of a paragraph answer and a concept map answer presented in **Table 17** illustrates the different approaches used by two high-achieving students. Both answers incorporate a description of the layers which form their container and the

Table 17. Examples of a student paragraph and concept map used to answer question #2A.

Student F20 - A paragraph answer to question 2A on heat transfer by a high-achieving student. The paragraph was rated as Good (9/10).

An umbrella shades the ice box and keeps the sun off the box. The first (outermost) box is white, made of cardboard and reflects any heat away. The air spaces in the cardboard helps prevent heat transfer. The dead air space created with the wood blocks (second layer) prevents heat transfer in or out. The second cardboard box (third layer) prevents convection currents. The air space in the second cardboard box allows for heat to build up in the air (if there is any) and keep the heat away from the ice. An inside layer (fourth layer) of tin foil reflects heat way from the ice. The saran wrap around the ice is an insulator to stop the heat from getting to the ice.

Student D25 - A concept map used to answer question 2A on heat transfer by a high-achieving student. The concept map was rated as Good (9/10)



Levels = 3 Propositions = 17 Cross links = 0

materials used to reduce heat transfer. The paragraph answer, by student F20, details the layers from the outside inwards in a sequential and distinct manner. The paragraph answer includes most of the main concepts associated with this topic however their organizational capability is not identified or utilized.

The concept map, by student D25, presents the ideas or concepts in a more generalized display. Exact numbers of layers are not specified rather the types of materials used, and their properties are identified. This map includes a large number of correct propositions which are organized into branches and levels.

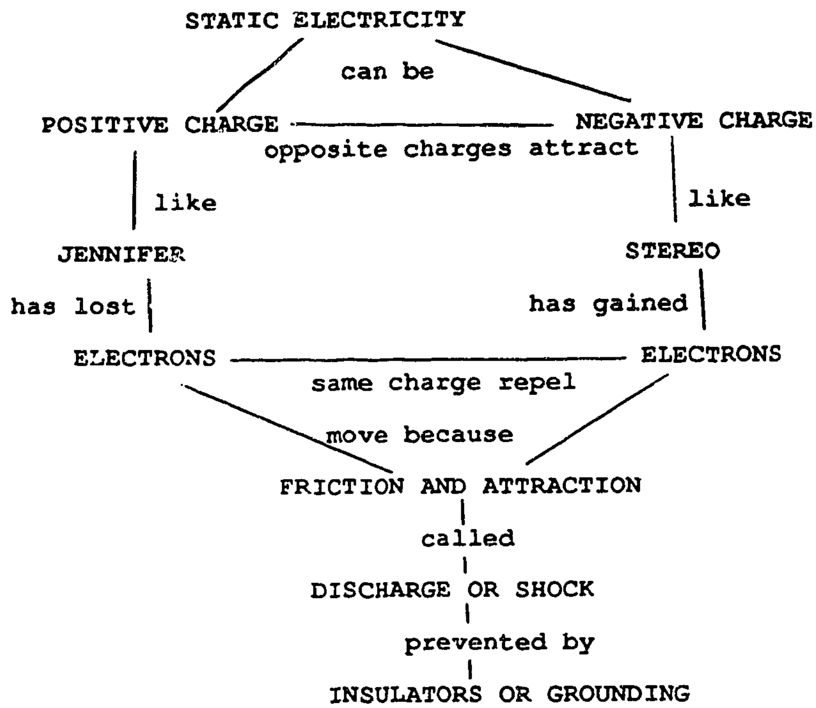
The levels of related concepts, displayed in the map, present numerous possible relationships between the concepts identified in each level; however cross links were not indicated. Key overarching concepts are identified and serve as organizers for related concepts.

Table 18. Examples of a student paragraph and a concept map used to answer question 2B.

Student F9 - A paragraph answer to question 2B on static electricity by a high-achieving student. The paragraph was rated as Satisfactory (8/10).

When Jennifer walked across the carpet with her slippers on she developed a charge of static electricity. When she touched the stereo she released the charge through a discharge. This discharge is called a shock. Her slippers made of wool became charged easily by rubbing against the carpet. The charge she had received was the opposite of the charge c the stereo. When she touched the stereo the opposite charges attracted and electrons moved. To prevent this from happening she should wear slippers made from a material which is an insulator like wood.

Student D28 - A concept map used to answer question 2B on static electricity by a high-achieving student. The concept map was rated as Satisfactory (7/10)



Levels = 4 Propositions = 11 Cross links = 1

The answers presented in Table 18 were completed by high-achieving students and were each rated as Satisfactory. The paragraph answer by student F9 provides accurate information pertaining to the question in a partially organized manner. Starting with the general concept of static electricity, student F9 goes on to discuss the concepts of discharge, charge, electron movement, and grounding. Though each concept is discussed hierarchical relationships are not clearly established.

The concept map by student D28 establishes a rather limited number of propositions but is able to show considerable understanding of the topic. The consolidation of concepts into a common strand, to form the bottom one-half of the map, establishes a propositional flow following hierarchical relationships. Starting at the top of the map, the general concept Static Electricity is used, followed by propositions detailing charge, electron flow, discharge and grounding. This map employs the use of multiple levels as opposed to numerous branches to convey an informative answer to this question. The great variety of ways of displaying correct answers, using concept mapping, continues to support the notion that learning is idiosyncratic and a cumulative process.

The results presented in Table 19 indicate the number of paragraph and concept map responses to question 3A. This question examined students' knowledge and comprehension of the concepts comprising the topic, the dry cell. This represented the first test question where specific concepts pertaining to the topic were provided for the students to use in their answers. The concepts were included to examine the effect this would have on the number of students using each answer format as well as the overall quality of the students' answers. Students had copied paragraph summaries as well as concept maps on this topic during their studies of this unit.

The majority of students chose to use the concept mapping strategy to answer question 3A. The average grade assigned to the concept map answers was slightly higher than the average grade of the paragraph answers. This suggests that, for this topic on the Dry Cell, these students felt more confident in using the concept mapping strategy and developed answers with more detail and clarity than those using the paragraph format. Approximately 75% of the high achieving students, on this test, used the concept mapping strategy to answer this question. This indicates a strong preference by this group of students for the concept mapping strategy when they are required to describe and explain, show knowledge and comprehension.

Table 19. Results to the Paragraph/Concept Map question #3 part A. (N = 94)

Question #3 - Part A. Explain how a dry cell produces electricity. (12 concepts were identified for use in paragraph or concept map).

Number of students using: Concept Maps = 47 Paragraphs = 42
Average grade: Concept Maps = 6.7 Paragraphs = 5.9

Number of students not attempting question = 5

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 11
Used paragraphs = 4

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 15
Used paragraphs = 20

Over one-half of the students identified as low-academic achievers, on this test, chose to use the paragraph format to answer question 3A. This proference for the paragraph format suggests that low academic achievers prefer to use a more familiar structure or approach to answer a question requiring simple recall and explanation.

Students, identified as low-academic achievers, have expressed experiencing difficulty when they attempt to memorize the concepts and the resulting map structure presented in class as a means of explaining a topic. Students who attempt to memorize concept maps to use at a latter date as answers on test question may find this a perplexing task.

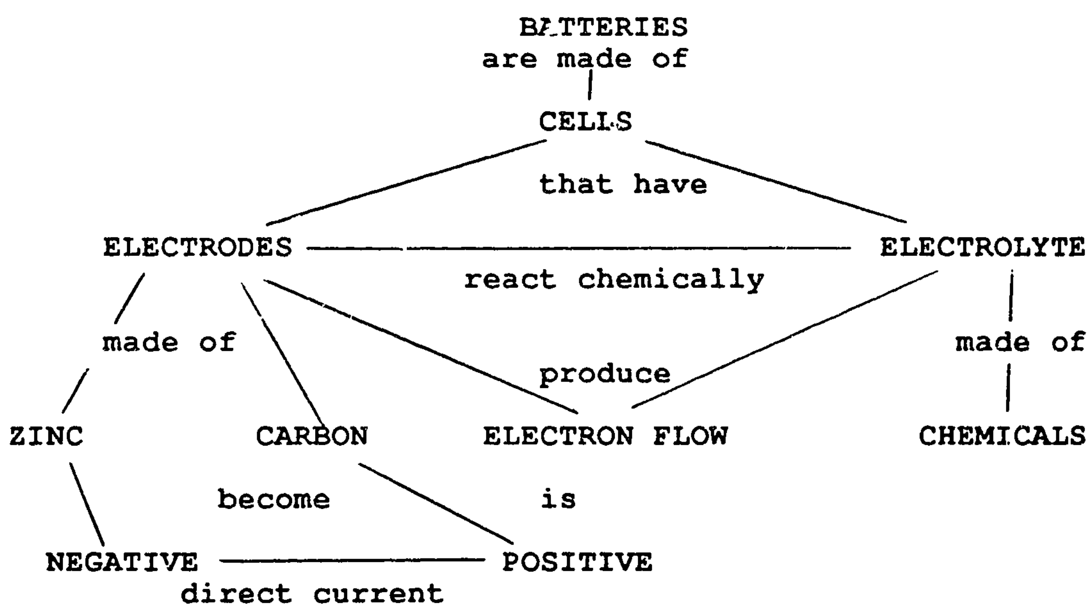
Only 5% of the students did not attempt to answer this question. This increase in students attempting this question, as compared to previous test questions of this type, may be attributed to the identification of specific concep students to use within their answers.

The student maps presented in Table 20 vividly differing levels of complexity and the varyi detail which can be expressed by students using mapping technique. The map constructed by s includes numerous correct propositions organized in an effective hierarchical fashion. The connection of adjacent concepts, forming cross links, indicates this student has a thorough understanding of this topic. The formation of cross links, in this map, allows the student to convey understanding of this topic in a succinct and direct manner which may not have been possible using a paragraph format.

The map constructed by student F25 suggests this student has a limited understanding of this topic. This linear concept map includes some of the most basic concepts, established as propositions, associated with this topic. The lack of branches in this map suggests this student did not possess a well organized and detailed knowledge base on this topic. This map was representative of concept maps constructed by other low-achieving students.

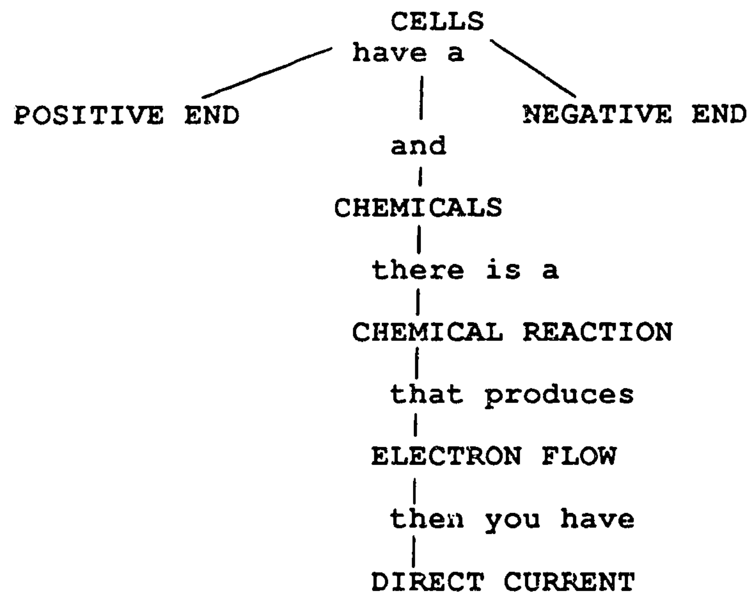
Table 20. Examples of student concept maps used to answer question #3 Part A.

Student B26 - Concept map constructed by high-achieving student. Map rated as Good (9/10).



Levels = 3 Propositions = 13 Cross links = 2

Student F25 - Concept map constructed by low-achieving student. Map rated as Attempted (5/10)



Levels = 2 Propositions = 6 Cross links = 0

The second part to question #3 again required the students to use their knowledge and comprehension to explain what a circuit is and what parts make up a circuit. As in the first part of this question a dozen relevant concepts were identified for students to use in their answer. The topic of series and parallel circuits had been presented in class as separate topics. Paragraph summaries and concept maps were employed to explain series and parallel circuits and this question represented the first instance when the students were to integrate their understanding of circuits into a single paragraph or concept map.

Table 21. Results to the Paragraph/Concept Map question #3 part B. (N = 94)

Question #3 - Part B. Explain what a circuit is and what parts make up a circuit. (12 concepts were identified for use in paragraph or concept map).

Number of students using: Concept Maps = 29 Paragraphs = 47
Average grade: Concept Maps = 6.0 Paragraphs = 5.0

Number of students not attempting question = 18

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 8
Used paragraphs = 5

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 12
Used paragraphs = 23

The results presented in **Table 21** show that a significant majority of students used the paragraph format to answer this question. The majority of high-achieving students used a concept map to express their knowledge of this topic. The average grade assigned to the concept map answers was about 10% higher than the average grade assigned to the paragraph answers. Perhaps of greatest significance was the considerably larger number of low- achieving students, those scoring 45% to 55% on the multiple choice questions, who employed the paragraph format as opposed to the concept map.

One suggestion for this preference of the paragraph format, by low-achieving students, is that these students had a limited understanding of the topic. With only a superficial understanding of this topic the low-achieving students were unable to identify relationships between the concepts displayed in the question and resorted to using the familiar paragraph format. As an extension it may be proposed that concept mapping may prove a difficult strategy for students to use if the students have only a cursory understanding of a given science topic.

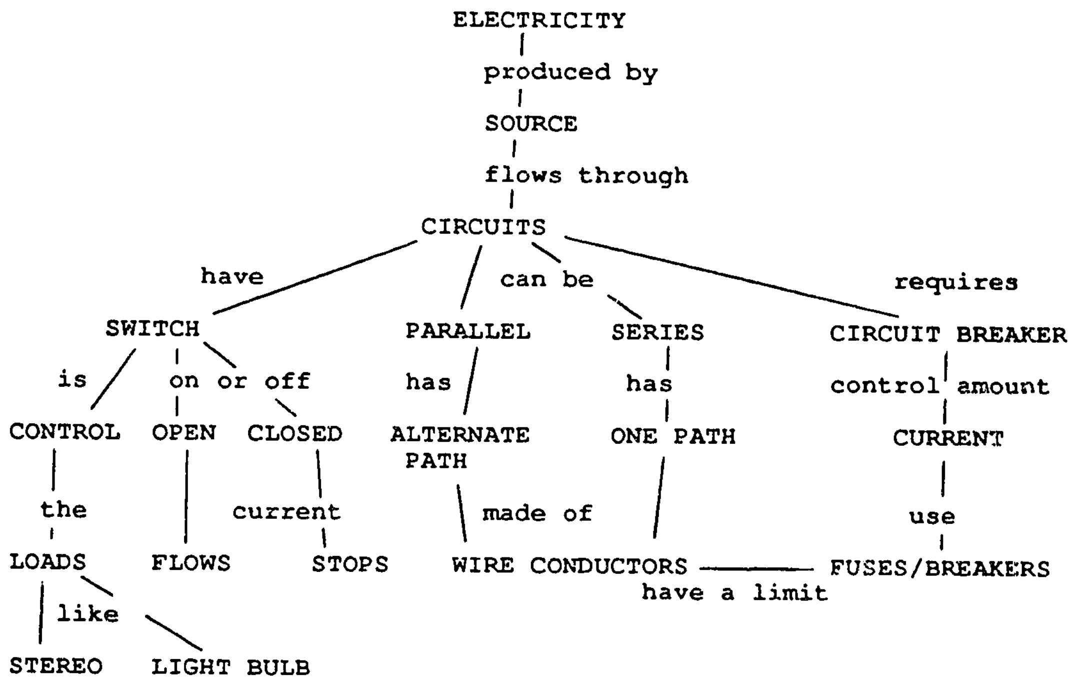
The concept maps and paragraph answers presented in **Table** 22 illustrate the variations which occur in paragraph answers and concept map answers. Concept maps tend to identify the more general concepts and join related, more specific concepts to these broader concepts in hierarchical manner. Related concepts which pertain to a common issue are linked to form a branch and concepts in adjacent branches may be linked to identify broader associations.

Table 22. Examples of student concept maps and a paragraph used to answer question #3 Part B.

Student B3 - Paragraph constructed by high-achieving student. Paragraph rated as Satisfactory (8/10).

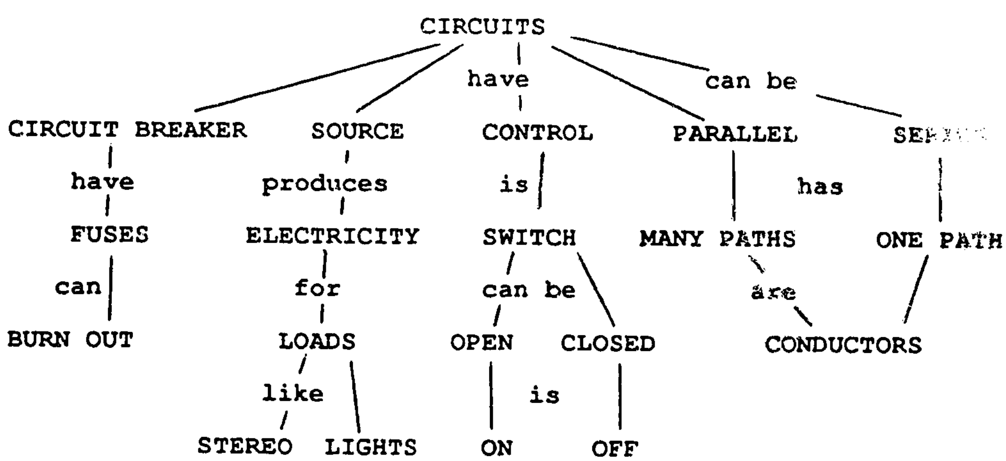
Janet would need to set up a parallel circuit between the two loads (stereo and light). Don't use a series circuit, the first load might use up all the energy or both need to be on to work. Get a good conductor like copper to join the two loads. Your source of energy could be a plug-in. To open or close your circuit you could use a switch. To control the amount of electricity to send to the bulb and stereo use a variety of fuses. Set up a circuit breaker to keep your system from blowing up.

Student F7 - Concept map constructed by high-achieving student. Map rated as Good (9/10).



Levels = 3 Propositions = 20 Cross links = 1

Student B15 - Concept map constructed by low-achieving student. Map rated as Satisfactory (7/10).



Levels = 2 Propositions = 20 Cross links = 0

Paragraphs tend not to identify the most general concepts first and relate more specific concepts back to the encompassing ideas. Individual sentences isolate the concepts and limit the opportunity to identify relationships between concepts already discussed. The paragraph structure may act to narrow the focus on specific detail rather than encourage the identification of broader affiliations. The maps constructed by students F7 and B15 illustrate considerable variability in terms of the propositions formed and the arrangement or organization of the propositions. Both maps show an abundance of accurate information presented in a manner which suggests considerable individuality. These maps also suggest opportunity for expanding the students answer and therefore personal understanding far beyond the opportunity present in the paragraph format.

Question 4 was included on the **Understanding Chemistry** unit exam and was the final question to examine the students preference for using concept mapping or paragraph writing. Part A examined the students knowledge and comprehension of the concepts related to the topic of matter. Nine concepts were identified for the students to incorporate in their answer. These topics had been discussed separately with students receiving summary notes on the topics of pure substances and mixtures as well as reviewing prepared concept maps.

The results presented in **Table 23** reveal a distinct and substantial preference for the use of the concept mapping strategy by both the high-achieving students and the low-achieving students. The average grade assigned to the concept map answers was also notably higher than the average grade for the paragraph answers. This striking preference for the use of the concept mapping strategy, by these students on this specific question, may be due to various factors. One possibility is that overtime students had developed greater confidence in their ability to construct concept maps. It may be suggested that concept mapping requires a variable period of time for the individual to develop the necessary aptitude and attitude to effectively use the mapping strategy.

The identification of the nine concepts may also have served to enhance the students ability to construct concept maps. These concepts had been identified in paragraph summaries and concept maps constructed in class and therefore served as aids which assisted the recall of additional concepts. The relatively high average grades of both the concept map answers and the paragraph answers suggest that these students had a solid understanding of this topic.

Table 23. Results to the Paragraph/Concept Map question #4 part A. (N = 96)

Question #4 - Part A. Explain what a Mixture and Pure Substance is and give examples of each. (Nine concepts were provided).

Number of students using:	Concept Maps = 55	Paragraphs = 28
Average grade:	Concept Maps = 6.8	Paragraphs = 5.7

Number of students not attempting question = 13

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 16
Used paragraphs = 2

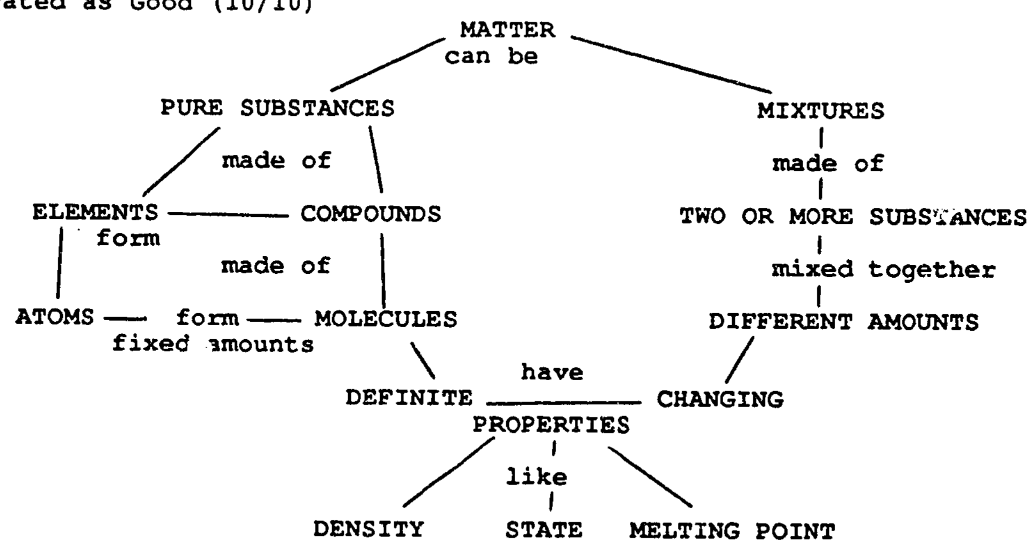
Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 28
Used paragraphs = 12

The student concept maps presented in **Table 24** demonstrate how students of differing abilities organize the same concepts into considerably different end products. Student F12 establishes a clear hierarchical arrangement of concepts and identifies relationships between concepts which are related. Cross links identify relationships between concepts in adjacent branches using simple and effective linking words. This map suggests this student's knowledge of this topic is accurate and well organized.

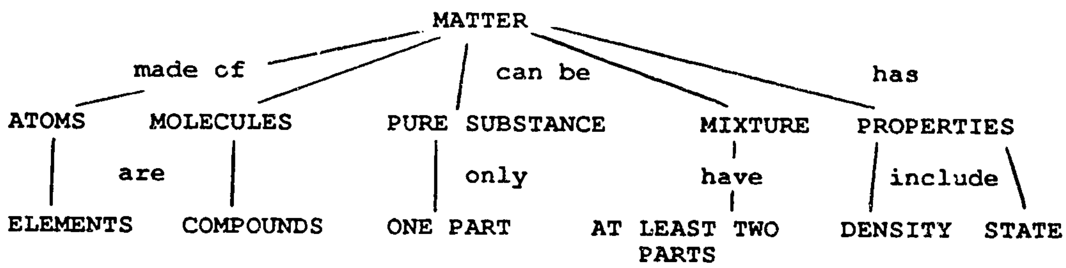
Table 24. Examples of student concept maps used to answer question #4 Part A.

Student F12 - Concept map drawn by high-achieving student. Concept map rated as Good (10/10)



Levels = 4 Propositions = 17 Cross links = 2

Student D23 - Concept map made by low-achieving student. Concept map rated as Satisfactory (7/10)



Levels = 2 Propositions = 10 Cross links = 0

The map constructed by student D23 incorporates most of the same concepts presented in the map by Student F12; however the concepts are not arranged in a clear hierarchical order. This map illustrates a common practice in which many concepts are link to one general concept. These types of maps may be viewed as typical of students who are not yet able to view the topic with a broader perspective. The limited number of propositions as well as the absence of cross links and relatively short branch structure may indicate an attempt to identify discrete facts. This student may find the concept mapping strategy an effective and practical strategy to learn the topic by incorporating it as a tool for rote learning.

The second part of question 4 required the students to explain physical and chemical changes. This question required students demonstrate their knowledge and comprehension of this topic. This question represents a topic on which the students received paragraph summary notes and constructed a concept map. This question provided the opportunity to examine the effect of earlier mapping practice of the students on the quality of answers and their answer format preference. This question did not include a list of concepts to be included in the answers.

The summary of data for Question 4B presented in Table 25 indicates the majority of students choose to use the paragraph format as opposed to concept mapping. Twice as many high achieving students, on this question, chose to use the concept mapping strategy rather than a paragraph. The average grade assigned to the concept maps was noticeably higher than the average for paragraph answers. Twice as many low-achieving students used the paragraph answer as did those using concept maps.

Table 25. Results to the Paragraph/Concept Map question #4 part B. (N = 96)

Question #4 - Part B. Explain what types of changes matter can undergo and describe these changes including examples. (No concepts were provided).

Number of students using: Concept Maps = 34   Paragraphs = 49
Average grade: Concept Maps = 6.5   Paragraphs = 5.7

Number of students not attempting question = 14

Students scoring 80% or better on multiple choice portion of test:

Used concept maps = 12
Used paragraphs = 6

Students scoring between 45% and 55% on multiple choice portion of test:

Used concept maps = 9
Used paragraphs = 18

The large number of high-achieving students using the concept mapping format suggests that this group of students were not dependent on concepts being identified in the question to assist them in constructing their concept map answer. Those students identified as low-achieving students were reluctant to use the mapping strategy without the list of related concepts.

The classroom mapping exercise may also have had an effect on this groups performance on this test question. High-achieving students may demonstrate a greater degree of transfer of learning from the classroom exercise to the test situation. It is also possible that the high-achieving students were able to remember, in greater detail, the specific concepts and associations than were the low-achieving students.

The concept map answers and paragraph answer displayed in Table 26 illustrate the range of answers these students produced for this question. The concept map drawn by Student D28 possesses the characteristic features of effective maps. Concepts are arranged hierarchically from general to specific, numerous propositions are correctly established, branches containing related concepts are clearly shown and cross links identifying cross branch associations defined. This student also completed a classroom mapping assignment, on a similar topic, which is displayed in Table 11. We can see many similarities in these two maps which indicates that concept maps do serve as a method for learning, prove useful in ascertaining what students know about a topic, and may be retained in memory for extended periods of time.

The paragraph formulated by student B18 identifies the main concepts presented during instruction. It provides and adequate explanation of the basic concepts, including relevant examples. As is common with paragraph answers, the concepts tend to be identified and described in isolation often without establishing clear associations to the more encompassing, general concepts.

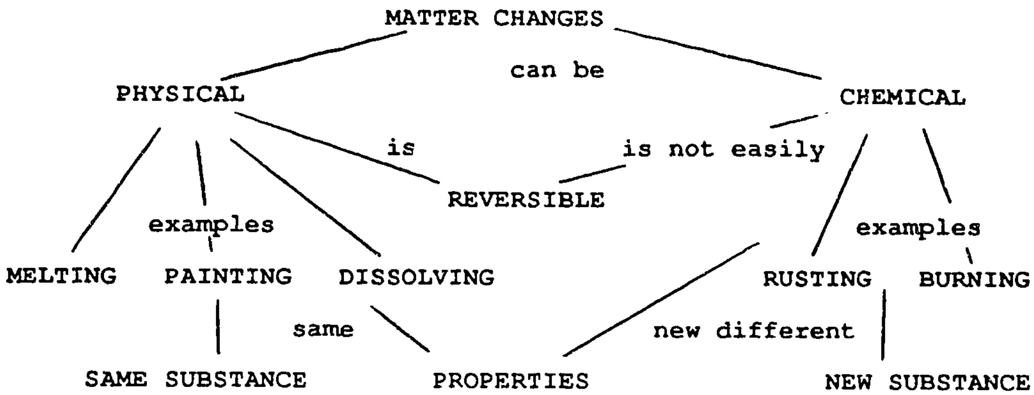
Without students making effort to organize their understanding of the topic prior to composing their explanation it is common to have a concept identified and explained in one sentence followed by a related concept delineated in a later sentence. Each sentence is isolated and distinct and rarely is their opportunity to establish those critical associations between concepts which are encased within separate and distinct sentences.

Table 26. Examples of student concept maps and a paragraph used to answer question #4 Part B.

Student B18 - Paragraph made by a low-achieving student. Paragraph rated as Satisfactory (7/10).

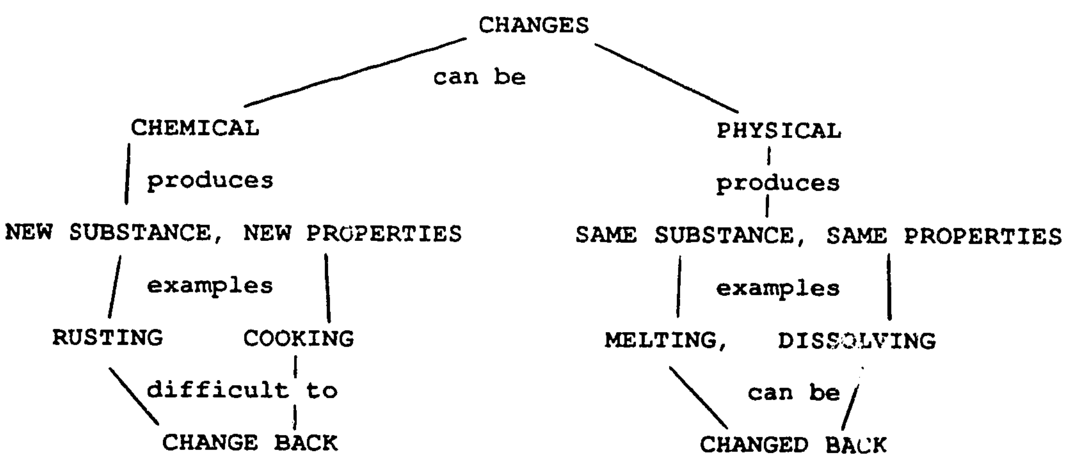
There are two types of changes, chemical changes and physical changes. Chemical changes is when the substance undergoes a change where the product is a new substance and different from the old substance. An example would be rusting of the car. In a physical change the substance changes state or form. An example would be when an ice cube melts into liquid. The water can be changed back to the ice by freezing it. Jack's car rusted and cannot be changed back because rust is a new substance because of the chemical change.

Student D28 - Concept map made by high-achieving student. Map rated as Good (9/10).



Levels = 3 Propositions = 13 Cross links = 2

Student F13 - Concept map made by high-achieving student. Map rated as Satisfactory (7/10).



Levels = 3 Propositions = 12 Cross links = 0

Concept Mapping Survey Results

After students completed the final test on the unit **Understanding Chemistry** the Concept Mapping Survey was administered. Students were informed that there were no right or wrong answers rather the survey was an attempt to ascertain their feelings about the effectiveness of the concept mapping strategy.

The results of the survey are presented in Appendix 11 and a selection of survey statements and student responses are presented in **Table 27**.

The results of the student survey on concept mapping provide insight into this particular group of students' feelings towards this strategy. The majority of these students indicated that they were able to make concept maps and that a person does not have to be smart to be able to make concept maps. A large majority of students expressed the feeling that concept maps are difficult to make. These students indicated that deciding on which concepts to use, as the starting concept and in constructing the map, was a demanding task. A large number of the decided students strongly supported the statement that they get confused when they tried to make a concept map.

A majority of student responses supported the statement that concept mapping encouraged them to think about the topic and that mapping is a good way to find out what you don't know about a topic. Most students agreed that it was easier to construct a concept map a second time. Over one-half of the decided students felt that concept mapping helped them learn science.

A significant number of students indicated that they did not like making concept maps and that they would not make maps if they were not required to. Approximately one-third of these students agreed that concept maps do not include enough information and that you have to think too much to make a concept map. One half of the decided students felt that concept maps take too much time to make and an even greater majority felt that concept maps did not help them learn science better. Less than one-half of the decided respondents indicated that making concept maps did not help them remember the mapped topic and they would not use a concept map to explain a topic to another student.

Table 27. Concept Mapping survey. Students responses are expressed as raw scores (N = 94).

SA = strongly agree; A = agree; U = undecided;
D = disagree; SD = strongly disagree.

	SA	A	U	D	SD
I am able to make concept maps.	15	39	4	20	16
Concept maps are difficult to make.	26	40	10	17	1
I find it hard to decide on which concepts to use in a concept map.	34	41	11	7	2
I don't like making concept maps.	21	27	17	19	10
Making concept maps help me to remember the topic.	8	24	19	30	13

	SA	A	U	D	SD
I would not make concept maps in class if I did not have to.	22	33	18	17	14
I like to be able to use concept maps as answers on tests.	11	16	22	30	15
Choosing which concept to start the map is usually hard to do.	23	35	12	17	7
I get confused when I try to make a concept map.	23	18	18	24	2
A concept map gives me more useful information than do notes.	10	26	15	24	19
You have to be smart to be able to make concept maps.	9	15	12	46	12
I prefer to use sentences and paragraphs to answer test questions.	22	27	15	21	9

When comparing concept mapping to note taking a greater number of the decided students indicated a preference for note taking and suggested that notes provided more useful information than do concept maps. A majority of students responded that they did not like to use concept maps as answers on tests and that they preferred using sentences and paragraphs to answer test questions. Less than one-half of the decided students felt that concept mapping helped them learn on their own and that concept maps should be used in other subjects.

Results to the Concept Mapping survey open-ended questions.

Two open-ended questions were included on the Concept Mapping survey to allow students to voice any other feelings they had pertaining to the use of the concept mapping strategy. **Table 28** includes examples of responses, which characterize the types or classes of responses, given by students when asked to identify those aspects which they liked about the concept mapping strategy.

Table 28. Student replies, representing response types, to the open-ended question; What do you like about making and using concept maps?

They (maps) are quick to make and take less time than notes.

It's easier to organize and learn the topic using concept maps.

Maps are easy to read.

You can be artistic.

Sometimes you can work with your friends on the map.

I like using them but not making them.

Everything is right there.

I understand the topic more (when maps are used).

They are easier to use than a jumble of notes.

It is a good way to research your topic, to see what you already know.

Making maps makes you read the information more carefully.

Making a map is kind of challenging like a puzzle.

It (maps) doesn't have extra words to confuse you.

The student responses in **Table 28** identify a wide range of beneficial qualities associated with the concept mapping strategy. Many of the statements focus on the value of the organizational structure associated with mapping. Students appreciate the succinct yet informative format of maps, the opportunity for personal styling, and the challenge inherent in their creation.

The second open-ended question on the Concept Mapping survey asked the students to identify those aspects about concept mapping which they did not like. **Table 29** includes selected responses which serve to portray the types of responses given by students.

Table 29. Student replies, representing response types, to the open-ended question; What don't you like about making and using concept maps?

Some topics are hard to do as maps.

I get confused about which word goes where.

I usually need to make 2 copies in order to get all the ideas in the right places.

You really have to think to make maps.

It's hard to think of the right linking words for the map.

They (maps) take too much time.

Maps are not as clear as notes.

I don't like having to make so many maps in class.

They (maps) don't tell enough of the details.

The types of responses presented in **Table 29** identify three major areas of difficulty these students experienced when using the mapping strategy.

A large number of responses centred on the difficulty in identifying relevant concepts, the selection of linking words, and the organization of the maps in general.

A second, commonly identified, cause of dislike was the need for concentration, thinking, and considerable time in order to complete a concept map.

The third reason, expressed by many students, was that concept maps could not be used with all topics and that concept maps may not include the required detail.

It may be suggested that with continued practice and effort all students could develop proficiency in the making of concept maps. This may require the students to develop a new way of looking at topics of study; incorporating a perspective which seeks out the broader relationships and associations between the concepts which constitute the topic. This new perspective would encourage students to move away from a practice where individual details and isolated facts are the focus of rote learning towards a more meaningful understanding of the interrelationships of subjects.

The need to think in order to create useful and effective maps is suggested, by some of these students, to be a negative feature of concept mapping. Those students who have negative feelings towards thinking identifies a more critical problem and one more difficult to overcome. If students feel that meaningful learning can come about by simple memorization and rote learning of facts then the concept mapping strategy will be viewed as a demanding task. Students perceptions of their role in the learning process as well as how learning comes about may prove the critical factor in determining the students views on the value of this strategy.

The third and perhaps most authentic critique of the concept mapping strategy identifies the difficulty in using the concept mapping strategy with all topics. This appraisal may be especially valid when the strategy is used to communicate creative solutions to a question requiring abstract, higher-order-thinking skills. In these instances the concept mapping strategy may seem restrictive or demanding, to some users, as they attempt to use an unfamiliar strategy with a complex thinking process.

Results of the student interviews.

The student interviews, which were conducted as part of the main study, were held after all examinations and the Concept Mapping survey had been completed. During class discussions, prior to the interviews, the list of questions to be used during the interviews were read to the students and they were asked to consider how they might answer them. Over the following three days nine students were interviewed; these students represented both high and low-achieving students of both genders. An effort was made to select students who had made an effort to learn the concept mapping strategy but were not necessarily in favour of the strategy. The transcripts of five interviews are provided in Appendix 12.

The common feeling, expressed by many of the students interviewed, was that concept mapping requires time to learn and that some topics are easier to map than others. Including lists of main concepts, to be used in the map, facilitates the mapping process. Dan, a low-achieving science students comments that, "I'm getting better at them now, at first they seemed way too difficult and I couldn't see why we had to do them." Nick, a high-achieving science student, describes conditions which increase the difficulty of mapping,"The hardest maps are when you don't have any information and you just have to use what you know then it takes a long time."

Students, who expressed confidence in their mapping ability, indicated that maps allowed them to express their knowledge in a more individualized way. Sonja, a high-achieving student, expresses what she likes about concept mapping, "Maps don't have to be done one way so you don't have to worry about it being exactly like the one you made in class." Additional advantages associated with using concept mapping, expressed during interviews, include; the ability to present answers in a concise fashion; the opportunity to easily add additional details to the map; and that mapping is an alternative to traditional sentences and paragraphs.

Nick, a high-achieving science student, draws our attention to a most practical advantage of mapping when he states, "If you have to write out what you are going to say, before you finish you forget some of the main ideas and you don't write them in your answer." This forgetting of details or jumbling of relevant and irrelevant information, which many experience during testing situations, may be alleviated by students becoming effective concept mappers. Many students, who were interviewed, voiced the feeling that constructing maps was made easier when done with another student or as a class assignment.

The majority of students interviewed indicated that, to varying degrees, they used concept maps as answers to test questions. Most of these students felt that it was a good idea to allow students to use concept maps if they wished.

Nick, a high-achieving science student describes how the process of making a concept map helps to answer questions, "Sometimes when I start the map I don't have all the main ideas figured out but then I remember them as I make the map." Those students who lacked confidence in their mapping ability expressed a preference, during the interview, for the use of paragraphs because of their familiarity and previous success.

Students indicated, during their interviews, that they had trouble starting concept maps, picking out the main concepts, deciding on effective linking words, choosing the proper arrangement of concepts, and visualizing what the map should look like. These obstacles to the mapping process represent limitations within the individuals using the strategy as opposed to restrictions inherent within the process. This strategy requires students to make a genuine effort to extend themselves beyond what is familiar and the practices with which they have become comfortable.

While some students are not intimidated by change, Nick a high-achieving student explains why some students have problems making concept maps, "I know students who don't really try and they say they can't do them [maps], they pretend it's too hard so they don't do them."

The findings from the main study indicate that a large majority of these students were willing to attempt to complete concept map assignments. Generally one-third of students, completing mapping assignments, constructed maps which were rated as satisfactory or good. A considerable number of students preferred to use concept maps, as opposed to paragraph answers, on certain types of test questions. A majority of high-achieving students, as determined by scores on the multiple choice questions of the test, consistently used concept maps, more frequently than paragraphs, as answers on test questions when the question included relevant concepts to use. Approximately one-half of the low-achieving students also chose to use concept maps, as opposed to paragraphs, as answers on test questions when the question included relevant concepts to use within the answer. A large majority of students preferred to use paragraph answers for questions which required higher-order-thinking strategies and when no relevant concepts were provided in the question.

Students' feelings and attitudes towards the use of concept maps, as determined by surveys and interviews, are diverse and complex. A majority of the decided students felt capable of constructing concept maps and indicated that maps help them learn and remember science topics. These students indicated that they experienced some difficulty in making concept maps and that they would not make concept maps in class if they were not required to. The majority of decided students indicated that they preferred to use sentence and paragraphs on test questions.

Student responses during interview sessions indicated that concept mapping requires individual effort to develop proficiency and that some students may not be willing to put forth the necessary effort. High-achieving students suggested a preference to use concept maps on assignments or test questions which involved recall and appreciated the opportunity, provided by the mapping strategy, to structure their answers in a personal fashion. Low-achieving students consistently indicated their preference to construct concept maps as whole class activities or with student partners. These students acknowledged experiencing difficulty identifying and organizing concepts into an effective map structure. Most students agreed they should be provided the opportunity to use concept maps or paragraphs as answers on test questions.

Chapter 5

Conclusions and Recommendations

The pilot study and the main study examined the use of concept mapping by grade nine students in science class. The objectives of the pilot study were to determine whether grade nine students could construct concept maps and whether the use of concept mapping enhances meaningful learning as indicated by academic achievement. The students' attitudes about concept mapping were determined and information was obtained on the students' perceptions of learning school science.

Pilot Study Methodology

The pilot study employed a mixture of quantitative and qualitative techniques to gain insight into the value of the concept mapping strategy. The transferability of the findings of this pilot study may be affected by the various factors including: the limited number of students participating in the study; the principle teacher also serving as the primary researcher; and the effectiveness of the evaluation tools used to determine the degree of academic achievement.

The variety of strategies employed allowed for a considerable range of information to be collected. The resulting diverse collections of data provided the opportunity to authentically assess the impact of the concept mapping strategy on student learning of science.

Pilot Study Findings on Concept Mapping and Academic Achievement

A major finding of the pilot study supports claims made by researchers (Barenholz and Tamir 1992; Bodolus 1986; Lehman, Carter and Kahle 1985) that most students at the Grade 9 level were able to construct concept maps on their own with little or no guidance from the teacher. Though entire classes did not show significant gains in achievement in this study, the strategy did not appear to impede academic achievement.

Critical to the effectiveness of concept mapping and the promotion of meaningful learning is student commitment to the learning and use of this strategy. The opportunity to act as both researcher and teacher permitted me to make valuable observations pertaining to the degree to which student commitment to this strategy occurred. From these observations, grounded in the study and supported by tacit knowledge, many students who showed genuine effort to employ concept mapping, enhanced their learning significantly.

Survey and interview findings, from this pilot study, indicate that students' attitudes toward concept mapping are, as suggested by Barenholz and Tamir (1992), somewhat complex. Ma [illegible] ts find concept mapping a difficult task, which can be f [illegible] g, but also helpful in their learning science in a mor [illegible] ividual or personal way. The responses of low-achieving students during interviews indicated a lack of confidence in their ability to construct concept maps. These findings agree with those of Briscoe and LaMaster (1991) and suggest that success in constructing concept maps is affected by the students' confidence in themselves as learners.

Main Study Methodology

The main study attempted to determine whether concept mapping was an effective, valued strategy for displaying individual knowledge. This study was guided by proposals, put forth in the pilot study, that students would take advantage of and benefit from the opportunity to use concept maps as answers to evaluation questions. To examine whether students would take advantage of the opportunity to use concept maps as a strategy for displaying their understanding, a variety of practices were employed.

The strategies used to promote student learning of concept mapping were both effective and practical. Students' feelings about the methods used to teach mapping, based on in-class discussion and personal interviews, were positive. Through these activities, used to instruct the students in concept mapping, the notion of learning as being idiosyncratic and resulting from the association of new concepts to those already established in the learner's mental framework was established.

The use of teacher prepared summaries, as support materials for the construction of concept maps on a given topic, was deemed functional and practical by students and teacher.

The evaluation of student concept maps, using the ratings of Good, Satisfactory, and Attempted was a constructive practice. If student commitment to learning and using concept mapping determines the overall value of the heuristic, then all attempts must be made to encourage student application of the strategy. This form of evaluation avoided downgrading student work by acknowledging students' effort as worthy and in most instances an improvable attempt. This practice reinforced the notion that the value of concept mapping is not only in terms of the product, the finished map, but also the process. The actual grading of student concept maps, which constituted practice assignments or assessment answers, did not serve as a critical component in this study. The teacher-researcher, acting as the principle evaluator of student work, served to maintain consistency in areas of assessment.

The paragraph/concept map questions, employed to provide students the opportunity to use their preferred strategy, were considered valid by the principal teacher-researcher, as well as by professional colleagues. Roth and Roychoudry (1993) describe the concept map as a valuable evaluation tool to examine the quality of student understanding. Each of the questions served to examine the impact of diverse variables on student preference for the paragraph or concept map. The variation in question format examined student preference in using paragraphs or concept maps under a number of different conditions. The affects of providing concept clues, of using question stems which had been presented directly in class previously, of requiring higher-order-thinking processes within the answers, and of presenting novel questions without any form of support were examined within paragraph/concept map question framework. The multitude of variables which impacted on the students, involved in this study, were diverse and could be managed only to a limited degree. The opportunity to use concept maps, as answers to test questions, was considered as valuable as it provides the student the opening to establish new links between concepts, new connections between ideas which they had not thought of before (Roth and Roychoudry 1992).

Main Study Findings on Concept Mapping and the Presentation of Individual Understanding

The findings resulting from this study suggest that students do appreciate and will utilize the concept mapping strategy to convey their understanding of a given topic, when required to in an assessment of test situation. While there were no consistent patterns established by the students participating in this study some inferences can be made.

The majority of high-achieving students, as determined by the multiple choice component of each test, used concept maps to answer the test questions, on four of the seven pertinent test questions. This implies that the majority of high-achieving students, in this study, preferred using concept maps to display their understanding of a topic over the use of paragraphs.

In only two instances, question 1 and 4A, did low-achieving students, as determined by their grade on the multiple choice section of the test, use concept maps more frequently than paragraph answers.

A large majority of low and high-achieving students, as determined in this study, chose to use concept mapping in situations were relevant concepts were provided as part of the question and students had previously constructed concept maps related to the question. The results to question 4A indicate that concept mapping was overwhelming preferred by all students. This may indicate that concept mapping is an effective strategy to assist students to remember or recall and display their learning, when used during instruction. Roth and Roychoudry (1992) state that their research indicates that concept mapping is an effective strategy for the structuring of knowledge which remains meaningful for longer periods of time.

The preference by high-achieving students, for concept mapping rather than using paragraph answers, suggests that these students are more capable of using this strategy and are able to use it in diverse situations. The student interviews, resulting from this study, tend to support the assumption that high-achieving students find it easier to use concept mapping than do low-achieving students.

The opportunity offered by concept mapping, to present information in a great variety of suitable formats is also clearly supported by the findings of this study. The relatively small sample of concept maps displayed above, constructed by participating students, explicitly provides evidence that this strategy allows for considerable uniqueness in terms of answer format. The value of not having to present one's knowledge in a rigid, predetermined way is valued by many of the students who participated in this study. This preference for a more individual approach to displaying meaning also requires a flexibility in the approach to assessment.

The suggestion that students feel stress due to test or evaluation situations is clearly supported by survey results and student interviews conducted during this study. If the use of concept mapping does allow for more individual approaches to be used in assessment concept then mapping may be considered an effective and practical mechanism to reduce student stress.

Students' responses to the Concept Mapping survey questions, as well as statements made during interviews, indicate that students feel a need to be actively involved in their learning and are capable of learning independently. Concept mapping, by its very nature, requires that students identify their personal understanding of a topic and attempt to reconcile or build associations with new concepts. This implies concept mapping requires the individual to reassess their understanding and belief in the creation of knowledge.

The traditional approach of presenting learning as a passive and extraneous process does not fit with the concept mapping heuristic. This requirement to rethink ones personal understanding of epistemological processes may promote the paradigm shift which reposition the individual at centre stage in the life-long process of learning. The practice of concept mapping draws attention to learning as a dialectical process and knowledge as dynamic and not a rigid product.

Recommendations and Personal Reflections

This study has provided additional information on the usefulness of concept mapping as a heuristic which facilitates classroom teaching and learning. The findings of the pilot study and the main study contribute to the ever increasing body of research data examining the role of concept mapping in promoting meaningful learning. The voluntary use of concept mapping, by numerous students participating in this study, suggests that this strategy may serve as a valuable tool for the structuring and expression of personal knowledge. Concept mapping enhances the opportunity, afforded to each individual, to express their knowledge in unique and diverse forms. The teaching and use of this strategy supports the constructivist view of learning as an active process in which prior knowledge and personal experience are essential components of the process.

To extend our understanding of the role of concept mapping in enhancing learning the identification of factors which promote the use of this strategy would be of value. The examination of methods which assist students in selecting linking words and arranging concepts to form useful maps would prove useful. To date the relationship between students' academic ability and their ability or preference to construct concept maps is unclear and warrants further study. Longitudinal studies to examine the type and extent of use of the concept mapping strategy, by students familiar with the strategy, would provide worthwhile data. The role individual learning styles play in the learning and use of concept mapping is of great importance and requires examination.

The premise that students feel restricted and alienated by the common practices employed in today's schools is supported by student commentary presented within this study as well as in the research literature. We see a broad-based movement, of practising teachers, researchers and educational policy makers, which claims there is a need to restructure all facets of our present day education system. This movement draws our attention to the reality of today's schools as being grounded in old ways and perceptions of student learning and methods of assessment.

Novak brings perspective to the potential crisis which education may currently be promoting when he states, "By grades four or five, most students have learned to accept rote learning and prefer it over other learning methods", (1991 p45). Hope is extended to us within teaching and learning strategies which facilitate meaningful learning. The potential for our students to experience success is directly entrenched in the choices we, as educators, make pertaining to our support of student learning. If we do not provide our students with strategies and practices which promote them to be active and effective thinkers then we will experience crisis conditions in education. If learning is presented as a process which is rigid, passive, and unaffected by what each person brings to the learning process then rote learning will predominate. If learning is presented as on-going, cumulative and personal then meaningful learning can flourish in our classrooms.

Though no definite statements can yet be made about the overall effectiveness of concept mapping in enhancing meaningful learning of science by students, it looks promising. This study has provided a glimpse into the incredibly diverse opportunities and potential residing within a strategy that supports learning as a unique and evolving process. Concept mapping holds out the possibility of a strategy that can empower all students to experience meaningful self-directed learning.

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APPENDICES 1 - 13

Appendix 1 - Concept Map marking scheme as used in the pilot study.

Main Mapping Elements	Mark Value
Proposition	1/Correct Proposition
Hierarchical Level	1/Level
Cross Link	1/Cross Link

Appendix 2 - Topic summaries for the unit Chemical Properties and Changes.

Summaries were provided to Treatment and Control Classes. Control classes copied summaries as notes. Treatment classes received copies of the summaries and were required to construct concept maps which incorporated the key concepts contained in the summaries and any others they wished into the map.

Topic One: Chemicals

We use many different chemicals every day. A chemical is any substance used or produced in a chemical process. Some chemicals are naturally occurring and others are man-made. All chemicals are forms of matter and can be classified as a mechanical mixture, solution, or pure substance. Pure substances can be either elements or compounds. Elements are chemicals made from only one type of atom. Compounds are chemicals made from two or more elements chemically combined. The smallest particle of a substance which has all the properties of the substance is the atom. The smallest particle of a compound is a molecule. Elements and compounds can be identified by their properties such as state, colour, boiling point, melting point, density, and behaviour.

Topic Two: Pure Substances/Atomic Theory

The Atomic Theory states that all matter is made of tiny particles called atoms. There are approximately 90 different types of naturally occurring atoms called elements. Man has produced an additional 13 or so elements using specialized equipment. Atoms are made from subatomic particles called protons, neutrons and electrons. The proton is a positively charged particle found in the nucleus, the neutron is a neutral particle found in the nucleus, and the electron is a negative particle which orbits the nucleus in regions called "clouds". Each type of atom or element has different numbers of protons, neutrons and electrons. The various arrangements of the electrons in their "clouds" or orbits cause the different properties of elements and compounds. In every atom in it's natural state the number of positive protons equals the number of negative electrons so the atom is neutral.

Topic Three: Changes

Matter can undergo a variety of changes. The freezing of water, the melting of ice, the dissolving of sugar in water are examples of PHYSICAL CHANGES. In these types of changes no new substance is produced. In CHEMICAL CHANGES one or more new substances are formed. These new substances have properties which are different from the starting materials.

There are several clues which indicate that a chemical change has occurred: the substance changes colour; heat or light is given off; bubbles of gas are formed; a solid material (precipitate) forms in a liquid; the change is difficult to reverse.

Topic Four: Chemical Reactions

Most substances can be identified on the basis of their properties. Substances which have similar appearances can be distinguished by their behaviour. Chemical tests are distinctive chemical reactions that allow for the identification of substances.

<u>CHEMICAL TESTS</u>

Oxygen is a clear colourless gas which promotes combustion. If a glowing splint is introduced into a container of oxygen it will burst into flames. This property of oxygen can be used to identify this gas.

Hydrogen is a clear colourless gas which burns explosively. If a flame is introduced into a container containing hydrogen a loud "pop" (mini explosion) occurs. This property of hydrogen can be used to identify this gas.

Carbon dioxide is a clear colourless gas which does not burn. Carbon dioxide will extinguish a flame and cause limewater (calcium hydroxide solution) to turn a milky colour (white solid precipitate forms). These properties of carbon dioxide can be used to identify this gas.

Water is a clear colourless liquid which can be easily identified by using cobalt chloride paper. When dry the cobalt chloride paper is blue and it turns pink when it contacts water.

Topic Five: Acids and Bases

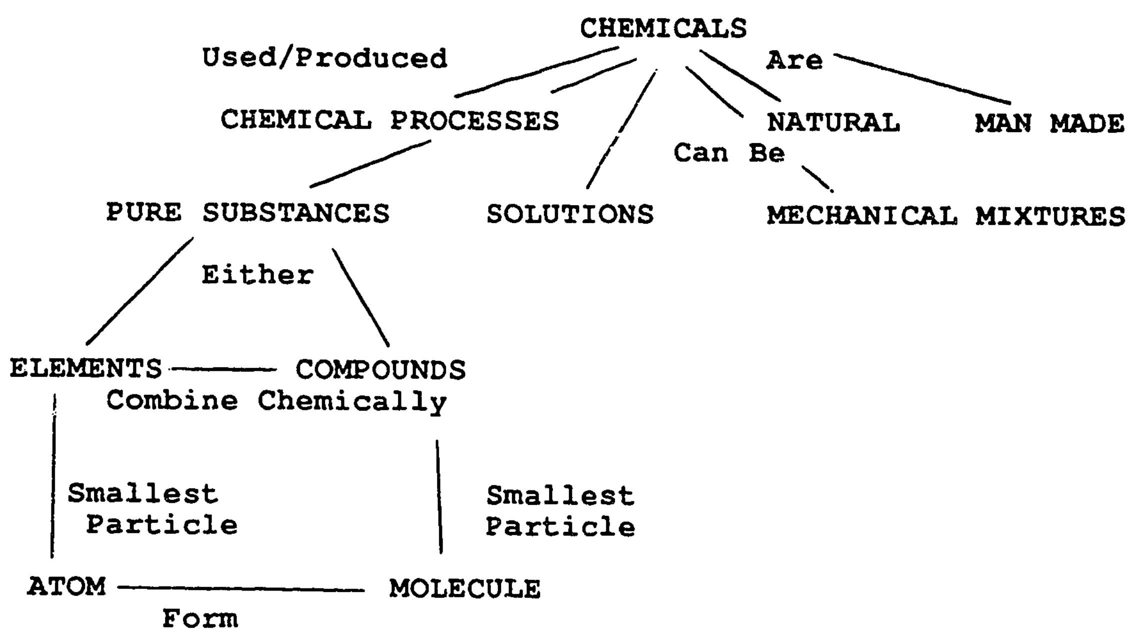
Acids and Bases are groups of compounds that have several properties in common. Acids taste sour, are soluble in water, and undergo similar chemical reactions. Bases taste bitter, are soluble in water, feel slippery, and react with acids. Substances that are neither acidic or basic are said to be neutral. Common acidic substances include lemon juice, vinegar, tomatoes and rain water. Common basic substances include baking powder, ammonia, and many cleaners. An Indicator substance is used to determine whether a substance is an acid or base. Litmus is a common indicator produced from lichens and is a different colour in acids than in bases.

Topic Six: Controlling Chemical Reactions

The speed at which a chemical reaction occurs is called the REACTION RATE. A variety of factors affect the reaction rate. TEMPERATURE affects the rate of all reactions. Increasing the temperature often speeds up the reaction. Increasing the SURFACE AREA of the solids involved in a reaction will generally speed up the reaction. Increasing the CONCENTRATION of a solution involved in a reaction will generally increase the reaction rate. Dilute solutions will generally cause reactions to occur more slowly than concentrated solutions.

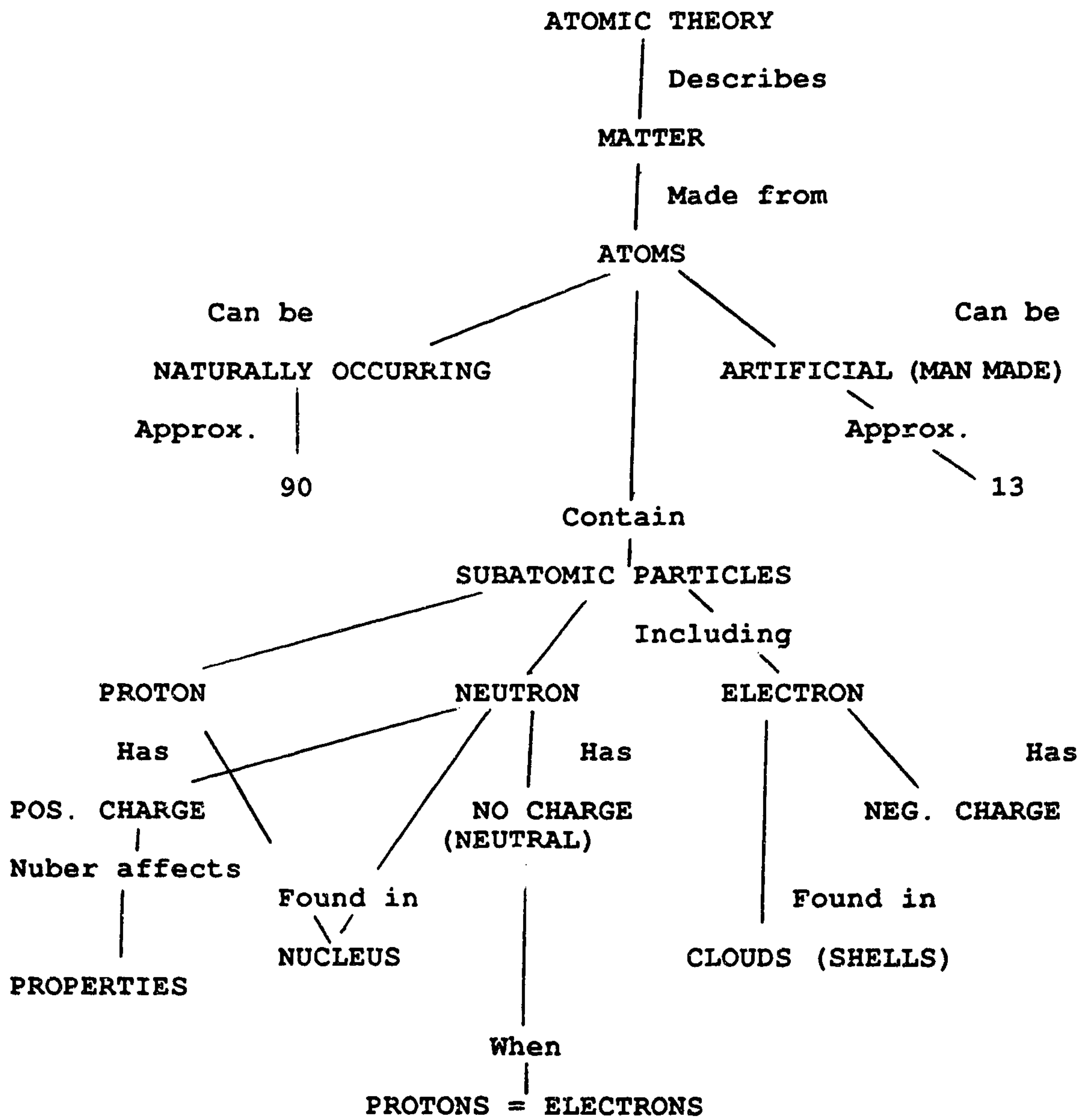
Appendix 3 - Teacher prepared concept maps used in evaluating student prepared concept maps constructed as assignments, using the Topic paragraph summaries for the unit Understanding Chemistry

Summary Map #1 - Topic: Chemicals



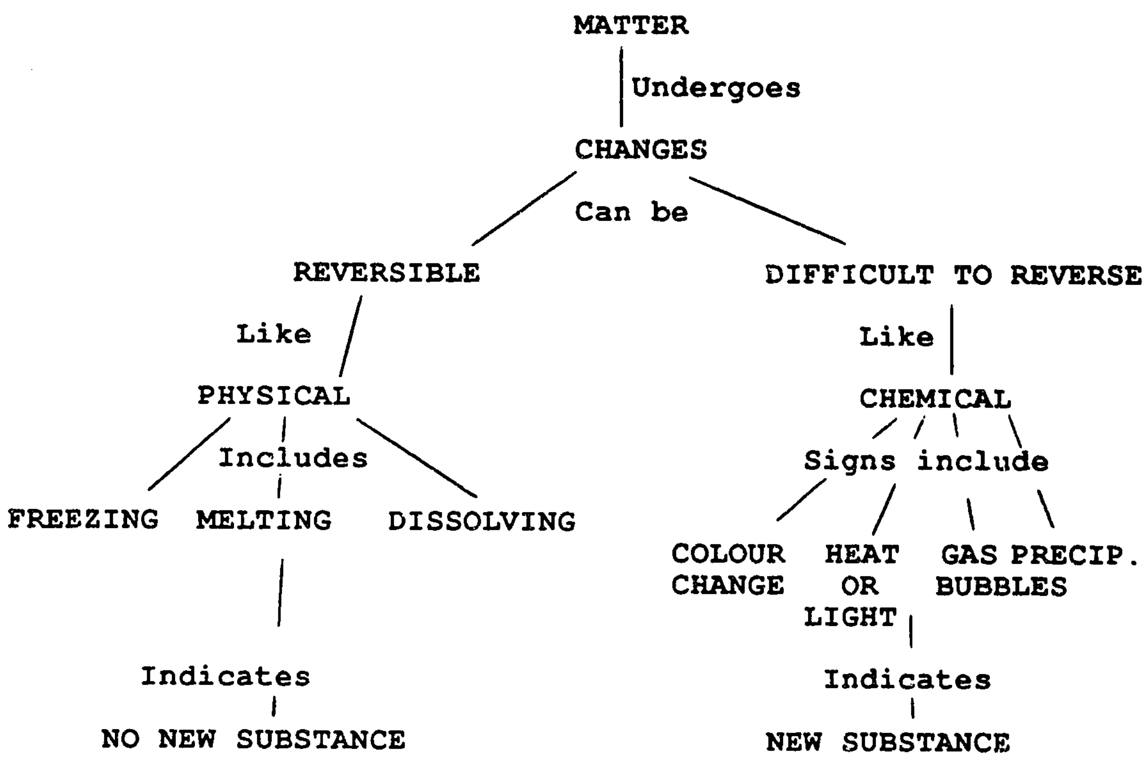
Propositions = 12 Levels = 3 Cross Links = 0

Summary Map #2 - Topic: Atomic Theory



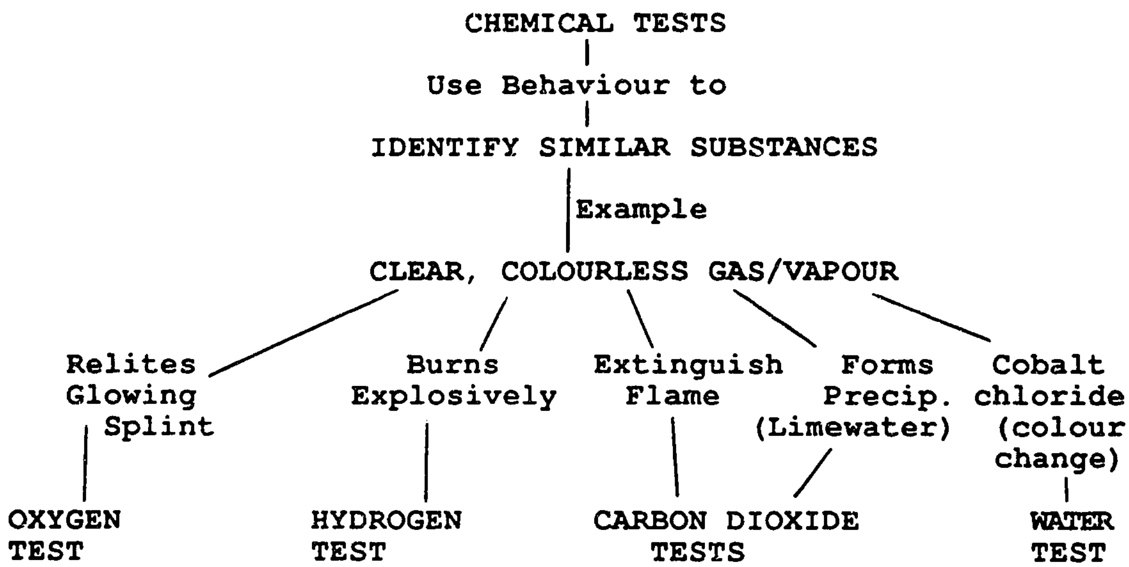
Propositions = 15 Levels = 3 Cross Links = 0

Summary Map #3 - Topic: Changes



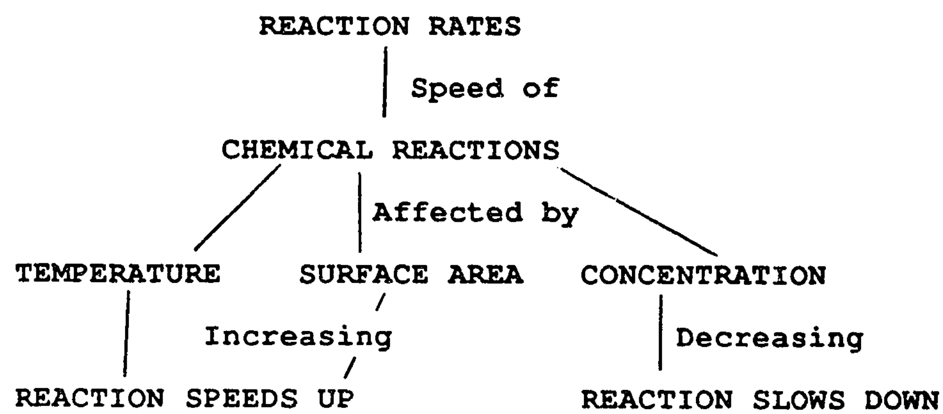
Propositions = 14 Levels = 3 Cross Links = 0

Summary Map #4 - Topic: Chemical Tests



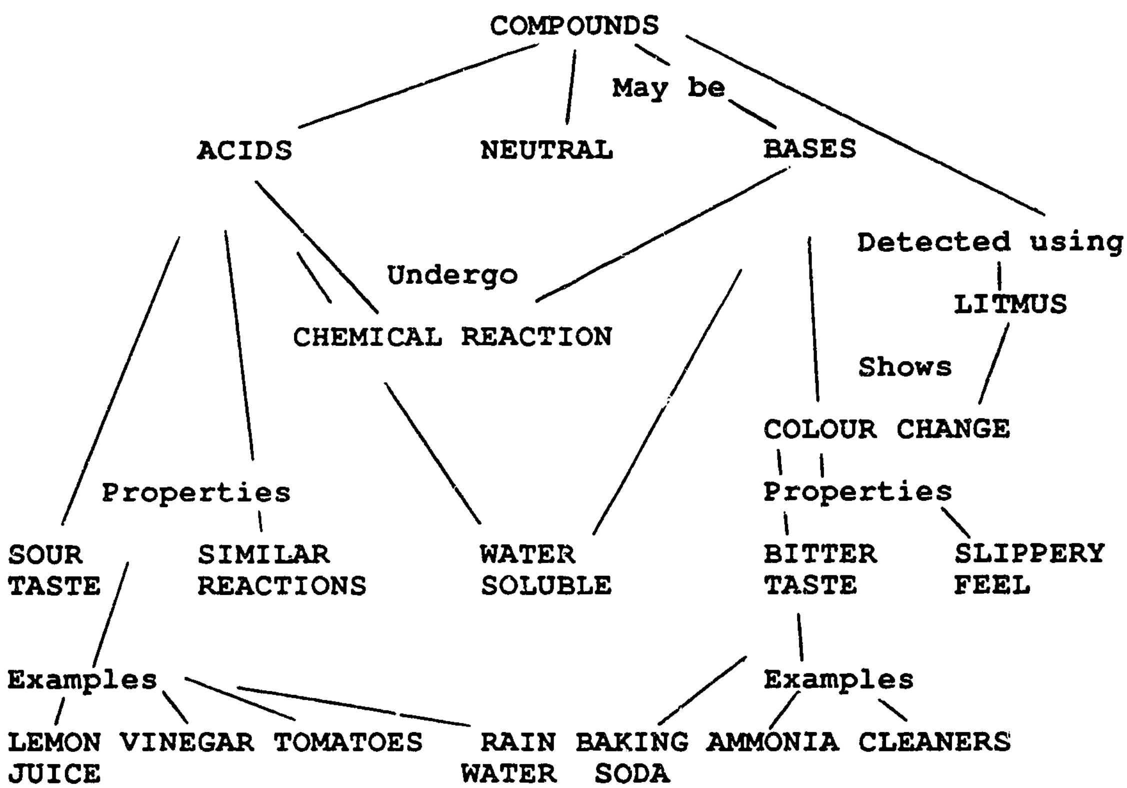
Propositions = 7 Levels = 2 Cross Links = 0

Summary Map #5 - Topic: Reaction Rates



Propositions = 10 Levels = 2 Cross Links = 0

Summary Map #6 - Topic: Acids and Bases



Propositions = 20 Levels = 3 Cross links = 1

Appendix 4 - Student/Teacher interviews conducted during the pilot study.

The following transcriptions were made from student interviews conducted between the student and teacher. The students selected for the interviews had completed at least 3 of the 6 assigned concept maps. An effort was made to interview students, of both genders, identified as high-achievers and low-achievers in science. All students were encouraged to express their feelings openly and it was emphasized that their responses would be used only as information for the study and not affect them in any other way.

Rhonda (Student 102, high-achieving science student)

Teacher: Thank you for accepting to be interviewed, I'd like to ask you a few questions about concept mapping. Are you able to make concept maps?

Rhonda: I found concept mapping hard to do at first because I wasn't sure what was expected, what you (teacher) wanted. I wasn't used to putting the ideas down like that but after awhile I got the hang of it.

Teacher: Do you think making concept maps helps you to learn science?

Rhonda: Yes I think so because it helps you get the main ideas figured out on paper. You can see the things you need to know and how they can fit together. When you're not sure of something you can't see how it fits and you know that you should check it.

Teacher: What do you find to be the hardest part of making a concept map?

Rhonda: Usually it's at the beginning to get the map started and to pick the words to start off. You can't see where you're going, what the maps going to look like so you're not sure how to put the words together. When you have the key words given to you, like on some assignments we do, it's easier to see how to join the words.

Teacher: What do you think are some good points or benefits of making concept maps? Do you like some things about concept mapping?

Rhonda: I like the way maps let you use your own way of putting down the ideas. I think it's better when you don't have only one way of giving an answer to a question, like with maps you can say what you know about the topic easier.

Teacher: Do you think concept mapping is a good thing to teach students how to do? Is concept mapping a good thing to teach in school?

Rhonda: Yes I do because some people find it easy, especially when the main words are given to you. I think they're better than always doing the same thing like taking notes.

Dean (Student 209, high-achieving science student)

Teacher: Thank you for accepting to be interviewed, I'd like to ask you a few questions about concept mapping. Are you able to make concept maps?

Dean: Yes I can make maps, on most topics anyway, sometimes they are easier to make and other times they are harder because there are more words to fit in.

Teacher: Do you think making concept maps helps you to learn science?

Dean: I guess so because your using the main ideas and joining them so they make sense so that way your learning about how they fit together.

Teacher: What do you find to be the hardest part of making a concept map?

Dean: For me the hardest part is to make sure I get all the main words in the right places otherwise it's hard to go back and fit them in. At the beginning I look at all the main words first and get an idea of how they can fit and then start writing them down and joining them.

Teacher: What do you think are some good points or benefits of making concept maps? Do you like some things about concept mapping?

Dean: Once you can make maps and you know the main points the information seems to fit together and make sense. Maps let you put down your ideas more easily than if you have to write it all out. I know the stuff and I have the ideas in my head but mapping helps me organize it.

Teacher: Do you think concept mapping is a good thing to teach students how to do? Is concept mapping a good thing to teach in school?

Dean: I think concept mapping is good for some things like reviewing or maybe studying for a test. Some people like maps and probably others don't. Maps can be easy when you know the topic but if you don't understand the topic then maps are hard to do.

Becky (Student 122, high-achieving science student)

Teacher: Thank you for accepting to be interviewed, I'd like to ask you a few questions about concept mapping. Are you able to make concept maps?

Becky: I can make maps in class when we do them together but when I have to do them on my own they are harder to do and take a long time.

Teacher: Do you think making concept maps helps you to learn science?

Becky: I'm not really sure because sometimes they don't seem to work out and I have to do them again. When we do them in class they make sense to me and I think they help me learn then.

Teacher: What do you find to be the hardest part of making a concept map?

Becky: Maps are hard when you have lots of main words to use and your not sure where to start. When you have too many ideas to join then it's confusing and it's easy to make a mistake.

Teacher: What do you think are some good points or benefits of making concept maps? Do you like some things about concept mapping?

Becky: I like the maps when everything fits together, when the main ideas fit at the top and the other words join to make the map. Maps look neat when everything works and they can give lots of information.

Teacher: Do you think concept mapping is a good thing to teach students how to do? Is concept mapping a good thing to teach in school?

Becky: Some people are good at making maps so for them it's good to teach them how but if you have problems with maps you shouldn't have to do them if you don't want to. Maps are good for some things and maybe not as good for others.

Brian (Student 114, low-achieving science student)

Teacher: Thank you for accepting to be interviewed, I'd like to ask you a few questions about concept mapping. Are you able to make concept maps?

Brian: If I have to I can make maps but I don't like mapping. Maps take too much time and when you don't put the words in the right place it's wrong and you have to do it again.

Teacher: Do you think making concept maps helps you to learn science?

Brian: Maybe if you use them long enough and know how to do them. I think I learn by listening in class and doing questions and other stuff.

Teacher: What do you find to be the hardest part of making a concept map?

Brian: When you have to make a map you have to figure out what the words are and put them together. Sometimes I can't see how to put the words together, I get confused and I feel frustrated when I can't do the map the right way.

Teacher: What do you think are some good points or benefits of making concept maps? Do you like some things about concept mapping?

Brian: I like maps when we do them in class or with a partner, then they're fun and they work out better. If you can do them when you want to and with other people then I think they'd be better.

Teacher: Do you think concept mapping is a good thing to teach students how to do? Is concept mapping a good thing to teach in school?

Brian: It's good for those people who can do them and like doing them but you shouldn't have to do them if you don't want to. Maps are harder to do than notes and notes give you more of the information you need.

Nola (Student 218, low-achieving science student)

Teacher: Thank you for accepting to be interviewed, I'd like to ask you a few questions about concept mapping. Are you able to make concept maps?

Nola: At the beginning I had a lot of problems with maps but now they're a little easier to make. Sometimes I need a little help but usually I can do them now.

Teacher: Do you think making concept maps helps you to learn science?

Nola: I'm not sure exactly because I have trouble with science but when we do them in class they help me to understand but when I do them on my own it's not that clear to me.

Teacher: What do you find to be the hardest part of making a concept map?

Nola: Mostly trying to put the words down and then join them up to make sense. When we get the list of the main words to use then that helps a lot. I get stuck sometimes and I'm not sure where to go next, I sort of guess 'cause I'm not sure which way the map should go.

Teacher: What do you think are some good points or benefits of making concept maps? Do you like some things about concept mapping?

Nola: Maps are different because they don't usually take a lot of writing so you can put down the information quicker. If I do them with someone else then it helps me to understand more about the stuff were taking.

Teacher: Do you think concept mapping is a good thing to teach students how to do? Is concept mapping a good thing to teach in school?

Nola: I do think it's good to teach because some people like to do maps instead of notes and sometimes on tests they're easier to use than to write out lots of information. If someone likes to use them then they should be able to because they do show the information when they're done right.

Appendix 5 - Guidelines for constructing concept maps and paragraph summaries.

Students were introduced to definitions of terms used in concept mapping: concepts, propositions, hierarchy, relationships, cross-links, and general-to-specific examples. They were presented with the following guidelines for making concept maps.

Guidelines for concept mapping

1. Arrange the concepts in a hierarchical manner, beginning with the most general, abstract concept, and proceeding to the most specific, concrete one.

2. Place the most general, abstract concept(s) at the top of the map.

3. Group more specific concepts under the related more general concepts. Concepts of approximately the same generality should be placed on the same hierarchical level.

4. Link related concepts by means of connecting lines, these lines may be vertically or horizontally (cross-link).

5. Label the lines to form propositions, using words or phrases to show relationship between the two concepts.

Students were shown how summary paragraphs can be used to describe a topic or theme by identifying the related concepts and explaining the relationships between the concepts. Examples of summary paragraphs were used to illustrate the technique and the guidelines explained.

Guidelines for constructing paragraph summaries.

1. Identify the main theme or general concepts to be covered in the paragraph using a topic sentence.

2. Select appropriate supporting ideas or related concepts which explain or describe the main theme.

3. Group these supporting ideas or concepts and explain how they relate to the main theme. Use descriptive sentences to clearly explain the existing relationships.

4. Where possible include specific examples which illustrate the general concepts and the main theme.

Appendix 6 - Guidelines for rating concept maps as G (good), S (satisfactory), or A (attempted).

Propositional Relationships:

One point for each correct relationship between two concepts provided.

Hierarchy/Levels:

One point for at least one correct relationship per level.

Cross Links:

Cross links show a relationship between concepts on one branch of the hierarchy with concept on another branch. A rating of one point is given for each cross link showing the integration among concepts.

Maps rated as Good would have earned a score of 9 or 10 out of a maximum of 10. In order to receive this rating the maps would be required to all of the main concepts identified in the concept list or paragraph summary as correct propositions. The concepts should be arranged into at least three distinct levels, two or more branches and at least one cross link should be established in the concept map.

Maps rated as Satisfactory would have earned a score of 7 or 8 out of a maximum of 10. In order to receive this rating the maps would be required to use the majority of the main concepts identified in the concept list or paragraph summary as correct propositions. The concepts should be arranged into at least three distinct levels, and two or more branches.

Maps rated as Attempted would have earned a score of 5 or 6 out of a maximum of 10. In order to receive this rating the maps would be required to use the majority of the main concepts identified in the concept list or paragraph summary as correct propositions. The concepts should be arranged into at least two distinct levels, and two or more branches.

Appendix 7 - Student Attitudes about Science and Learning Science Survey. The results in each category are expressed as a percentage of the total (N = 96).

KEY: SA = strongly agree; A = agree; U = undecided; D = disagree; SD = strongly disagree

	Statement	SA	A	U	D	SD
1.	You have to be smart to understand the work in science class.	9	28	14	36	13
2.	Science is an enjoyable school subject.	4	16	38	27	15
3.	All students can learn science if the subject is taught properly	32	46	9	9	4
4.	I feel comfortable in science class.	8	37	27	17	11
5.	Science is a difficult subject to learn.	23	37	20	14	6
6.	I learn the most about science by listening to my teacher's explanations.	6	31	24	26	13
7.	A person has to have a good memory in order to do well in science.	12	37	17	27	7
8.	There are too many definitions to remember in science class.	19	41	17	20	3
9.	The information presented in science class is easy to understand.	4	22	25	40	9
10.	Reading over my class notes helps me to understand the material in science class.	6	44	23	20	7
11.	Science is boring.	34	21	24	17	4
12.	When I study for a science test I usually do quite well.	6	15	27	36	16
13.	I often get confused when I try and study for a science test.	15	43	20	16	6

Item	Statement	SA	A	U	D	SD
14.	I feel a lot of stress and pressure when I study for a science test.	15	43	21	20	1
15.	Reading my textbook helps me to understand the material covered in science class.	11	55	21	12	1
16.	I often use the information I learn in science class in my everyday activities.	1	12	35	35	17
17.	I don't know how I learn things in science class.	7	16	39	31	7
18.	I learn the most in science class when I do experiments or other hands-on activities.	30	42	10	12	6
19.	Science tests are hard because the questions usually have only one right answer.	24	24	21	22	9
20.	Copying notes about science topics helps me understand the topics.	7	24	26	28	15
21.	Diagrams and pictures help me to understand science topics.	12	58	19	9	2
22.	I find it difficult to know what information is important in science class.	19	44	22	13	2
23.	It helps me to learn science when another student explains the topic.	7	31	34	16	12
24.	Science readings are difficult to understand.	10	27	43	16	4
25.	The topics covered in science help me to understand the world around me.	15	43	25	12	5
26.	My science teacher should tell me the important science facts in class.	21	36	33	7	3
27.	I am able to learn science on my own.	6	19	29	33	13
28.	I often try to use my own words when answering questions on science tests.	17	47	23	11	2

Appendix 8 - Individual Pre- and Posttest raw scores, for Treatment Group (classes 1 and 2) and Control Group (classes 3 and 4). Maximum score = 33.

Treatment Class 1

Student Number	Pretest	Posttest	Change (%)
101	16	18	5.7
102	22	26	11.4
103	18	26	22.9
104	6	10	11.4
105	5	7	5.7
106	13	27	40
107	15	15	0
108	7	9	5.7
109	18	19	2.9
110	9	16	20
111	6	15	25.7
112	9	10	2.9
113	13	26	37.1
114	9	11	5.7
115	7	9	5.7
118	5	10	14.3
119	6	12	17.1
120	7	16	25.7
121	6	8	5.7
122	17	25	22.9
Standard Deviation	5.02	6.44	0.11
Mean	10.82	15.73	14.03
Mean Change	4.91		
Median	9	15	

Treatment Class 2

Student Number	Pretest	Posttest	Change (%)
201	7	16	25.7
202	19	20	2.9
203	10	20	28.6
204	13	13	0
205	8	20	34.9
206	8	10	5.7
207	4	14	28.6
208	15	21	17.1
209	16	26	28.6
210	12	11	-2.9
211	9	9	0
212	9	8	-2.9
213	19	24	14.3
214	8	12	11.4
215	11	9	-5.7
216	7	11	11.4
217	18	21	8.6
218	8	11	8.7
219	10	11	2.9
220	10	8	-5.7
221	14	13	-2.9
222	15	20	14.3
Standard Deviation	4.12	5.44	0.12
Mean	11.4	14.9	10.1
Mean Change	3.55		
Median	10	13	

Control Class 1

Student Number	Pretest	Posttest	Change (%)
301	8	6	-6.1
302	6	13	21.2
303	4	15	33.3
304	10	10	0
305	16	23	21.2
306	4	6	6.1
307	9	11	6.1
308	13	15	6.1
309	4	21	51.5
310	10	16	18.2
311	9	16	21.2
312	13	16	9.1
313	9	10	3.0
314	6	3	-9.1
315	13	19	18.2
316	8	12	12.1
317	5	13	24.2
318	10	12	6.1
319	10	21	33.3
320	14	18	12.1
321	7	9	6.1
322	6	8	6.1
323	6	11	15.2
324	8	9	3.0
Standard Deviation	3.27	5.03	0.13
Mean	8.7	13.0	13.26
Mean Change	4.4		
Median	8.5	12.5	

Control Class 2

Student Number	Pretest	Posttest	Change (%)
401	8	10	5.7
402	21	26	14.3
403	9	12	8.6
404	14	18	11.4
405	16	15	-2.9
406	14	22	22.9
407	10	19	25.7
408	17	15	-5.7
409	12	10	-5.7
410	19	24	14.3
411	13	22	25.7
412	5	4	-2.9
413	5	18	37.1
414	10	10	0
415	13	14	2.9
416	6	15	25.7
417	11	17	17.1
418	14	20	17.1
419	13	16	8.6
420	9	18	25.7
421	14	12	-5.7
422	9	10	2.9
423	4	7	8.6
424	11	10	-2.9
425	14	14	5.7
Standard Deviation	4.2	5.3	0.12
Mean	11.6	15.2	10.17
Mean Change	3.6		
Median	12	15	

Appendix 9 - Paragraph summaries used, in conjunction with other information, in concept mapping assignments.

Paragraph summary on the topic Temperature.

All molecules have kinetic energy caused by their motion. The average speed of the molecules in a piece of matter determines its temperature. The faster the average speed of the molecules in a piece of matter, the higher the temperature. The slower the average speed of the molecules in a piece of matter, the lower the temperature. Hot water molecules have a faster average speed than cold water molecules.

Paragraph summary on the topic Current Electricity.

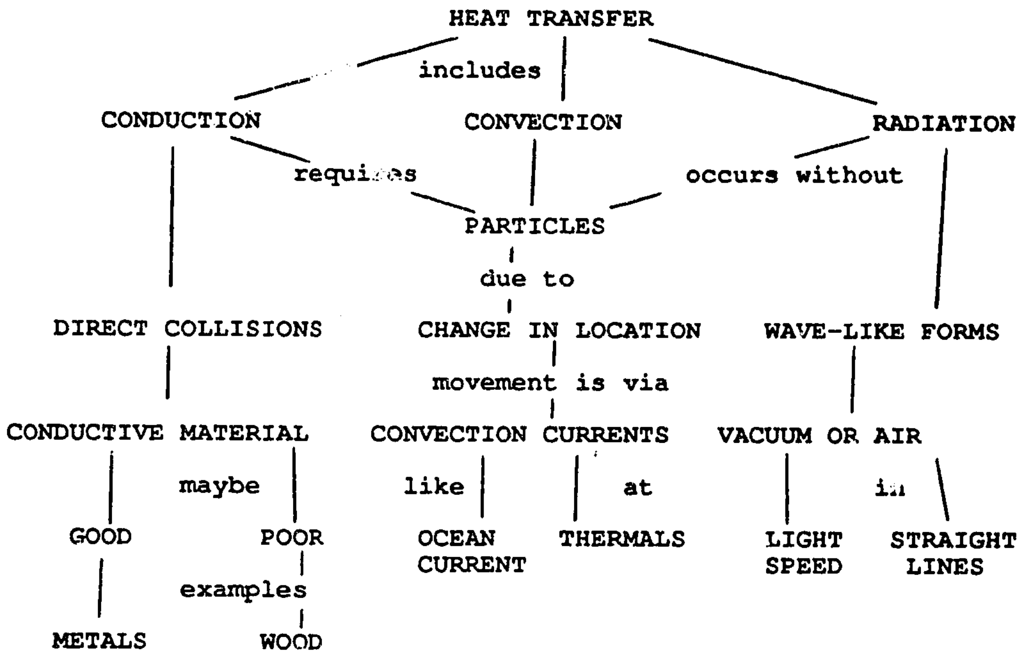
Everything is made from tiny particles called atoms. The centre of an atom is called the nucleus which is surrounded by electrons. In good electrical conductors, like metals, the outer electrons are free to move. When a conductor is connected to a power supply, these electrons are driven in one direction. The movement of electrons around a circuit is called an electric current. Power supplied by a battery pushes the electrons in one direction only. This is direct current. Electricity generation in a power station flows first one way then the other through the conductor. This is called alternating current.

Paragraph summary on the topic Matter - Types of Changes

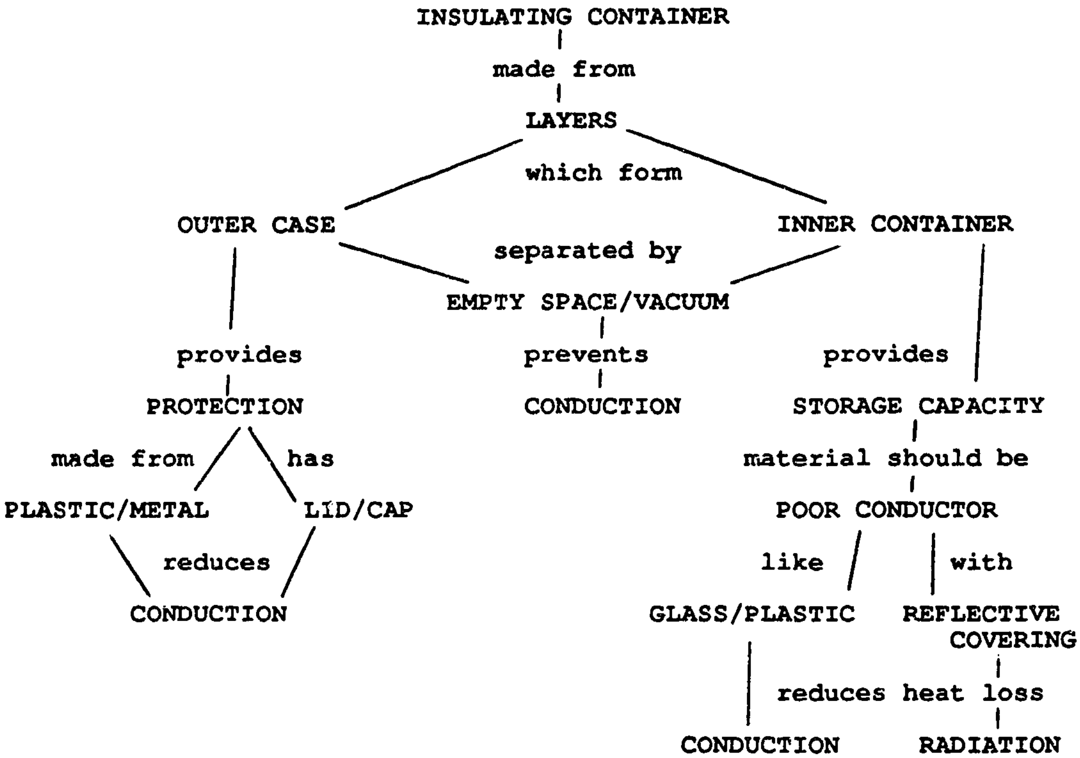
Matter can undergo a variety of changes. The freezing of water, the melting of ice, the dissolving of sugar in water are examples of Physical Changes. In these types of changes no new substance is produced. In Chemical Changes one or more new substances are formed. These new substances have properties which are different from the starting materials. There are several clues which indicate that a chemical change has occurred: the substance changes colour; heat or light is given off; bubbles of gas are formed; a solid material (precipitate) forms in a liquid; the change is difficult to reverse.

Appendix 10 - Teacher prepared concept maps used in evaluating students' maps completed in response to Paragraph/Concept Map questions.

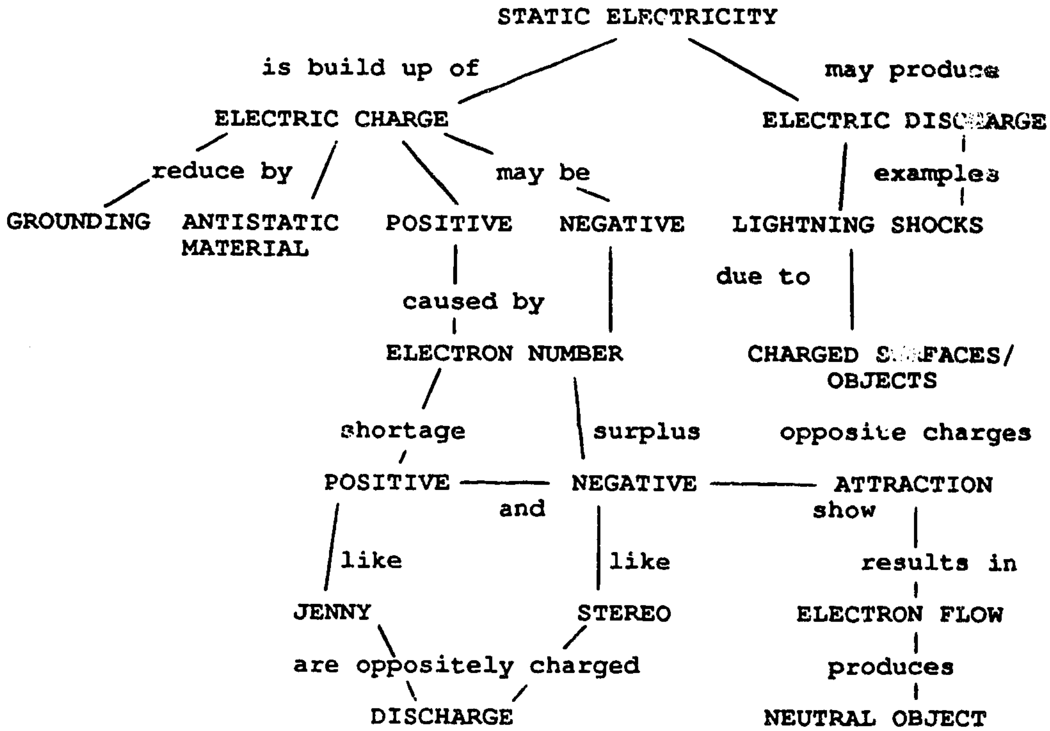
Question 1 - Methods of Heat Transfer



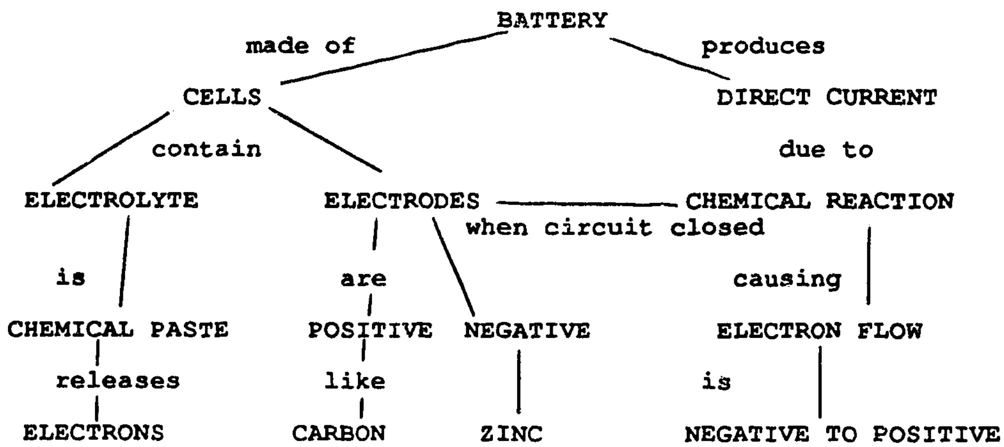
QUESTION 2a - Insulating Container



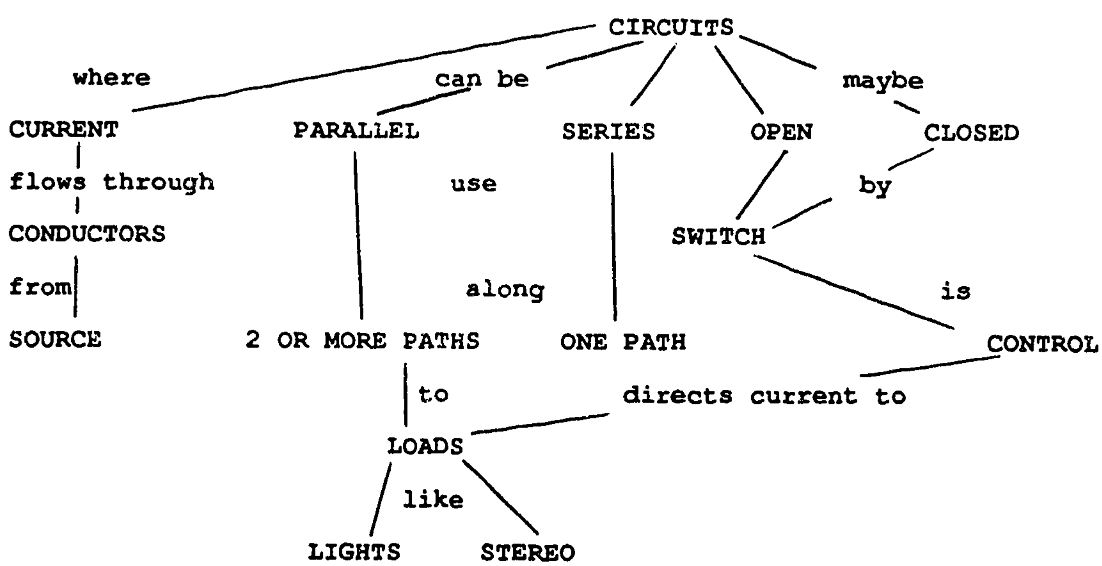
Question 2b - Static Electricity



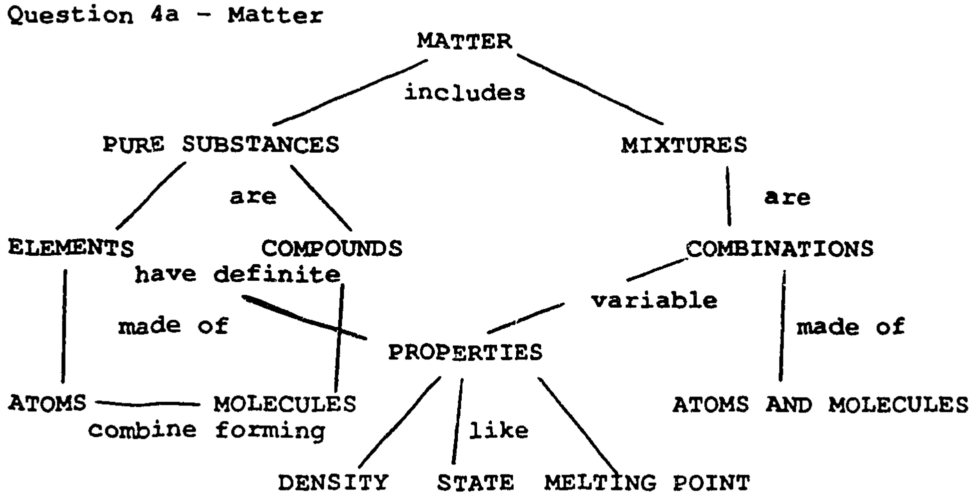
Question 3a - Battery and dry cells.



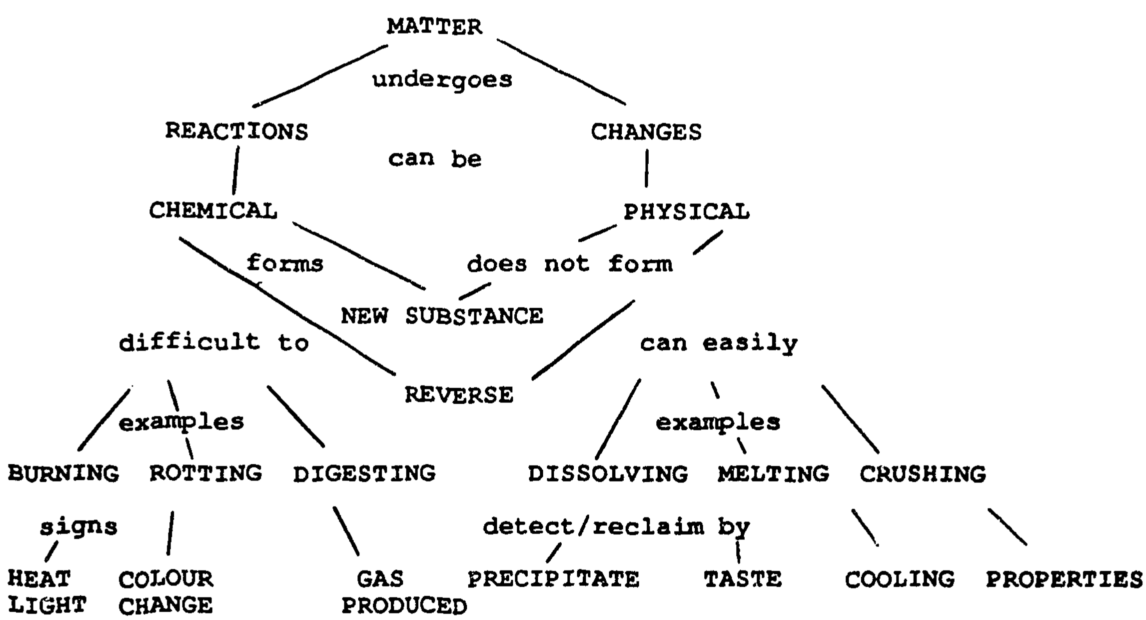
Question 3b - Circuits



Question 4a - Matter



Question 4b - Changes in matter



Appendix 11 - Summary of the Responses to Concept Mapping Survey, administered as part of the Main Study. (Raw Scores indicated for each category.)

SA = strongly agree   A = agree   U = undecided
D = disagree   SD = strongly disagree

	Statement	SA	A	U	D	SD
1.	I am able to make a concept map.	15	39	10	20	16
2.	Concept maps are difficult to make.	26	40	16	17	1
3.	Making concept maps helps me to understand the topic I am learning.	13	28	24	19	18
4.	Concept maps let me organize the information in my own way.	9	34	16	22	19
5.	I prefer making concept maps on a topic rather than taking notes.	17	18	18	20	26
6.	I find it hard to decide on which concepts to use in a concept map.	34	41	17	7	2
7.	I don't like making concept maps.	39	21	23	13	4
8.	Making concept maps help me to remember the topic.	6	24	25	32	15
9.	I would not make concept maps in class if I didn't have to.	42	33	14	7	14
10.	Making concept maps makes me think about the topic.	10	30	22	24	14
11.	Concept maps let me use my own words to explain the science topic.	4	38	20	22	15
12.	Selecting linking words to connect concepts is hard.	16	26	24	27	8
13.	I like to be able to use concept maps as answers on tests.	4	11	25	31	28

		SA	A	U	D	SD
14.	Choosing which concept to start map is usually hard to do.	23	35	18	17	7
15.	I get confused when I try to make a concept map.	23	18	24	24	2
16.	If I redo a concept map I find it is easier the second time.	6	46	28	13	6
17.	A concept map gives me more useful information than do notes.	4	26	23	32	15
18.	Concept maps help me to learn science topics.	5	37	18	23	16
19.	You have to think to much to make a concept map.	16	24	27	33	0
20.	You have to be smart to be able to make concept maps.	9	9	20	48	14
21.	Concept maps should be used in other school subjects.	5	17	22	24	12
22.	Concept maps do not include enough details about a topic.	11	25	32	24	8
23.	Concept maps take to much time to make.	17	23	20	34	5
24.	Making concept maps help me to learn on my own.	5	29	24	30	12
25.	Making concept maps is a good way to find out what you don't know about a topic.	5	40	23	22	10
26.	I would use a concept map to explain a topic to another student.	7	25	21	28	19
27.	I prefer to use sentences and paragraphs to answer test questions.	25	31	15	19	8
28.	I feel that making concept maps helps me to learn science topics better.	4	28	26	26	16

Appendix 12 - Transcripted Interviews.

The interviews were held following the final unit test and after students had completed the Concept Mapping survey. Students were encouraged to express their feelings in an open manner. The transcriptions represent a summation of the students' responses to the questions which were recorded on audio tape or recorded by the interviewer.

Student #F9 (Sonja) - High achieving student in science

Question 1 - Are you able to make or construct concept maps?

At first I found making a map a little difficult because it was something new but after we made a few in class I caught on to the idea and now I can make maps.

Question 2 - What do you find hard about making concept maps? Are there some parts of making a map that are difficult?

If the main ideas are given in the question then its much easier to make a map than when you have to read the information an pick out the important ones to use. Once you have the main ones (concepts) you can usually figure out how to put them into the map from top to bottom and join them. Sometimes you have to make changes when you see a better way to join the ideas so they fit better.

Question 3 - Are there things you like about making concept maps?

I like making maps because you can make the map in your own. Maps don't have to done one way so you don't have to worry about it being exactly like one that you made in class. When you know the topic you can usually make a map pretty easily and you can make changes when you want.

Question 4 - Do you think making concept maps helps you to learn science?

I think they do help me to learn science because you have to think about the main ideas and join them to make sense. Maps make you think more about the topic, you're not just copying like with notes and its more work so you probably learn more.

Question 5 - It seems some students have problems making concept maps, could you suggest some reasons why that might be?

Maps might be hard for some students because you have to do the work yourself and not copy the information. Some students don't like to have to do the extra work and maybe they can't figure out how the ideas fit together. If you don't understand what you're suppose to be making into the map then it's hard to do.

Question 6 - Do you like being able to use concept maps as answers to test questions?

I think you should because it's different than writing paragraphs and it's good for some people. It was good to be able to use it on tests sometimes cause I found it faster and easier than using a paragraph. When you use paragraphs it's hard to add a new idea when you're at the end of the paragraph but it's easy with maps.

Student D28 (Nick) - High achieving student in science.

Question 1 - Are you able to make or construct concept maps?

I am able to make concept maps most of the time. Sometimes they are harder to make like when you don't have the main ideas given to you then it's harder and takes more time.

Question 2 - What do you find hard about making concept maps? Are there some parts of making a map that are difficult?

Well when you have to make the map from scratch without the ideas given on paper, then it takes more work from the start. The hardest maps are when you don't have any information and you just have to use what you know then it takes a long time. When you have the main ideas given in the question then it's easier to join them and make the map. Sometimes picking the linking words is hard but if you put the main ideas down first you can come back and pick the words which work so the map works and is right.

Question 3 - Are there things you like about making concept maps?

Using maps you can get down to the main ideas and not have to add a lot of extra information. I like being able to put the information down the way I see it and then you can add things as you need to. If you know something you can make a map pretty fast. If you have to write out what you are going to say sometimes you forget some of the main ideas and you don't write them in your answer.

Question 4 - Do you think making concept maps helps you to learn science?

I guess they do, with maps you have to figure out how the ideas fit together, you don't use them like notes and read them over. With maps you get to the main ideas and if you learn new stuff you can add them to a map, you can change the maps to add new ideas. You can see how the different ideas fit together and that helps you to learn.

Question 5 - It seems some students have problems making concept maps, could you suggest why that might be?

Some students don't understand the topic very well and they can't see how to connect the ideas to make a map. I know students who don't really try and they say they can't do them, they pretend it's too hard so they don't do them. I think if they try most people can make maps.

Question 6 - Do you like being able to use concept maps as answers to test questions?

I used maps for lots of test questions because they're faster and easier than writing out paragraphs. If you know the topic then maps are good because you use the main ideas and then you can add on as you go. Sometimes when I start the map I don't have all the main ideas figured out but then I remember them as I make the map so I can add them and not have to start over.

Student B26 (Matt) - High achieving student in science.

Question 1 - Are you able to make or construct concept maps?

I can make concept maps but sometimes they don't come out the way they should. They're hard to make sometimes because I'm not sure what the main points are and how they should fit together. When you know the main ideas or they're given to you then their easier to make.

Question 2 - What do you find hard about making concept maps? Are there some parts of making a map that are difficult?

I find it hard to pick out the main points to use and the words to join them together. You have to spend a lot of time trying to figure out how the words fit together. You have to get an idea of how its going to work form the start otherwise you get halfway and you get stuck or you don't use one of the main ideas.

Question 3 - Are there things you like about making concept maps?

I like maps when they're smaller and easier to make, when you use maybe only 8 main ideas but when you have to use lots of main ideas they're harder to make. I like using maps to put down the main ideas.

Question 4 - Do you think making concept maps helps you to learn science?

I'm not sure sometimes I found maps were confusing and they weren't that easy to connect all the main ideas to make a good map. Maps didn't really give all the information to explain the topic. I liked to have more details like in the textbook when you can read the paragraph and it gives all the information you need.

Question 5 - It seems some students have problems making concept maps, could you suggest some reasons why that might be?

Maps are hard because you have to pick out the main ideas and then how they fit together. It's hard to sort them out so that the main points are at the top and then the other points are down the map and then join them. I think the maps are more work to make a good one.

Question 6 - Do you like being able to use concept maps as answers to test questions?

I didn't use maps very often for answering tests but I think it's good to let someone use them if they want to. I like to use paragraphs to answer cause it's easier and quicker for me and I'm used to writing down my answers. With maps I wasn't sure how good my map was and with paragraphs I usually get a good mark.

Student B5 (Crystal) - Low achieving student in science.

Question 1 - Are you able to make or construct concept maps?

I can make concept maps but I find them hard to do. When the main ideas are given to us then it's a lot easier. When I have to figure everything out on my own they're really hard and I don't do very well.

Question 2 - What do you find hard about making concept maps? Are there some parts of making a map that are difficult?

Maps are hard to make when I have to pick out the important words from the paragraph and then connect them to make the map. It's hard to know which are the most important ideas and then fit them in the right way. You're not sure what the map is supposed to look like because there's no one way to do it so it's easy to mix up the words.

Question 3 - Are there things you like about making concept maps?

Sometimes maps seem easy like when we do one in class together or when we copy them like notes then they make sense and help me understand the topic. When I know the main ideas then I can sometimes do the map and I like how it seems simple and easy.

Question 4 - Do you think making concept maps helps you to learn science?

I think they help especially when we do them together in class but when I do them alone then it's harder and I'm not sure whether my map is correct. When I use the textbook and map the map from what's in the text then I can check to see if my map is right but then it's a lot of extra work.

Question 5 - It seems some students have problems making concept maps, could you suggest some reasons why that might be?

I try to do the maps but it's hard to do when you're not sure whether the words are connected right or wrong and if you leave out some of the words you don't know where to add them. If you can do the map with another person then it's much easier and you can help each other.

Question 6 - Do you like being able to use concept maps as answers to test questions?

Sometimes I use the maps to answer test questions when I'm sure that I know the main ideas or if we have made a map in class that was on the same idea and if I can remember how it sort of worked out. If I'm not too sure about the answer then I use a paragraph. I'm better at writing a paragraph answer then making maps.

Student D7 (Dan) - Low achieving student in science.

Question 1 - Are you able to make or construct concept maps?

I'm getting better at them now, at first they seemed way to difficult and I couldn't see why we had to do them. They were easy when we did them in class but took to much time to do a good one by yourself.

Question 2 - What do you find hard about making concept maps? Are there some parts of making a map that are difficult?

They took a long time to do because you had to read the paragraph first and then pick out the main words and then put them down and join them. It was easier just to read the paragraph or to copy notes about the stuff.

Question 3 - Are there things you like about making concept maps?

Sometimes the maps were ok because they were simple and fit together easily and things matched up without having to do them over. I didn't like having to do them over and make sure all the words fit in cause it was basically the same except with a few more words.

Question 4 - Do you think making concept maps helps you to learn science?

Maps might help you learn more but their more work to make them right. To fit the ideas together and connect them to be right is harder and lots of times you have to redo them so it takes longer.

Question 5 - It seems some students have problems making concept maps, could you suggest some reasons why that might be?

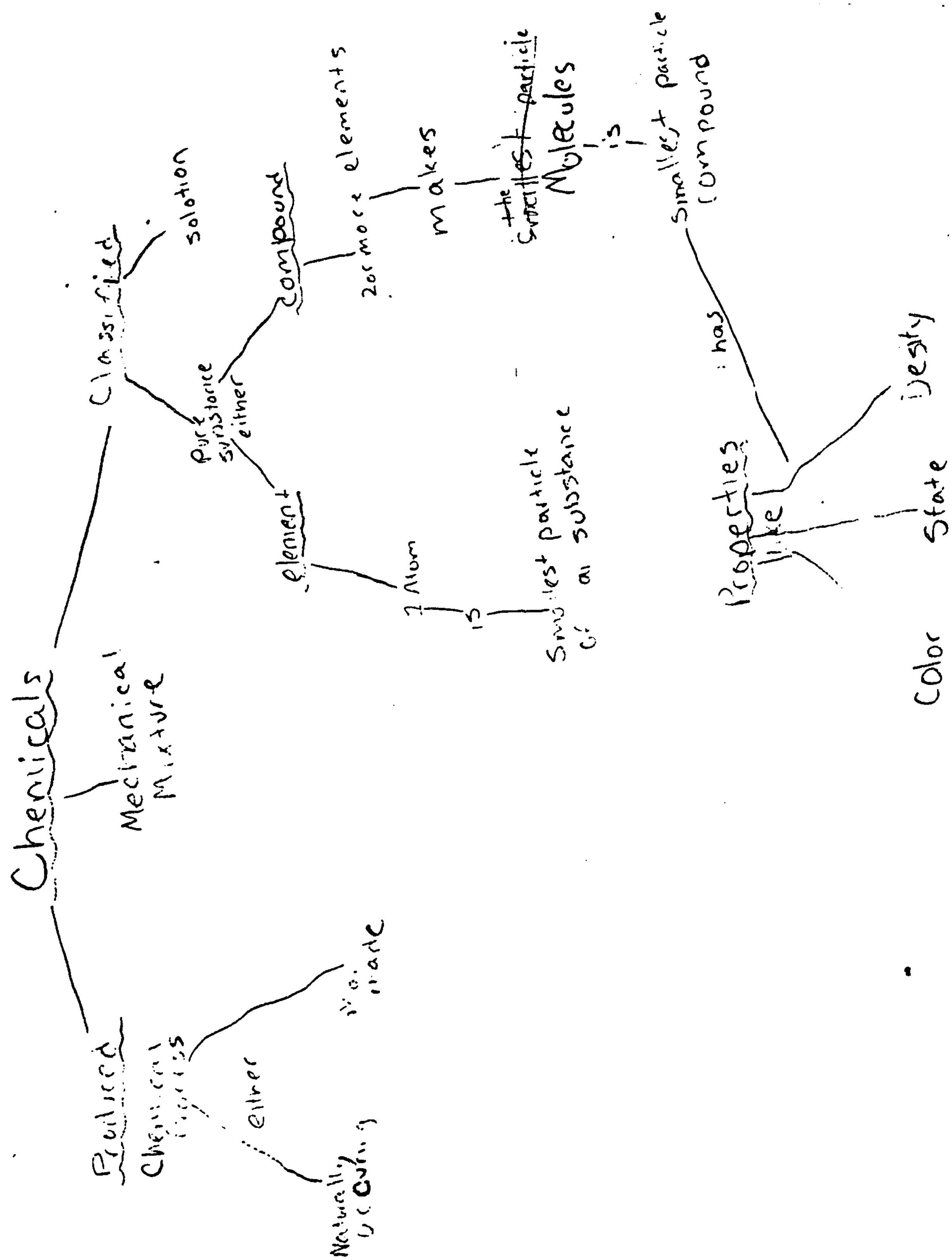
The problems might be with how the words have to connect and figuring out where they fit on the map. Connecting the ideas is hard because the word has to tell how they fit together and that's hard to find a word that fits. I don't like having to do the maps over again and I know that it's suppose to be better the second time but sometimes you don't know how to change it.

Question 6 - Do you like being able to use concept maps as answers to test questions?

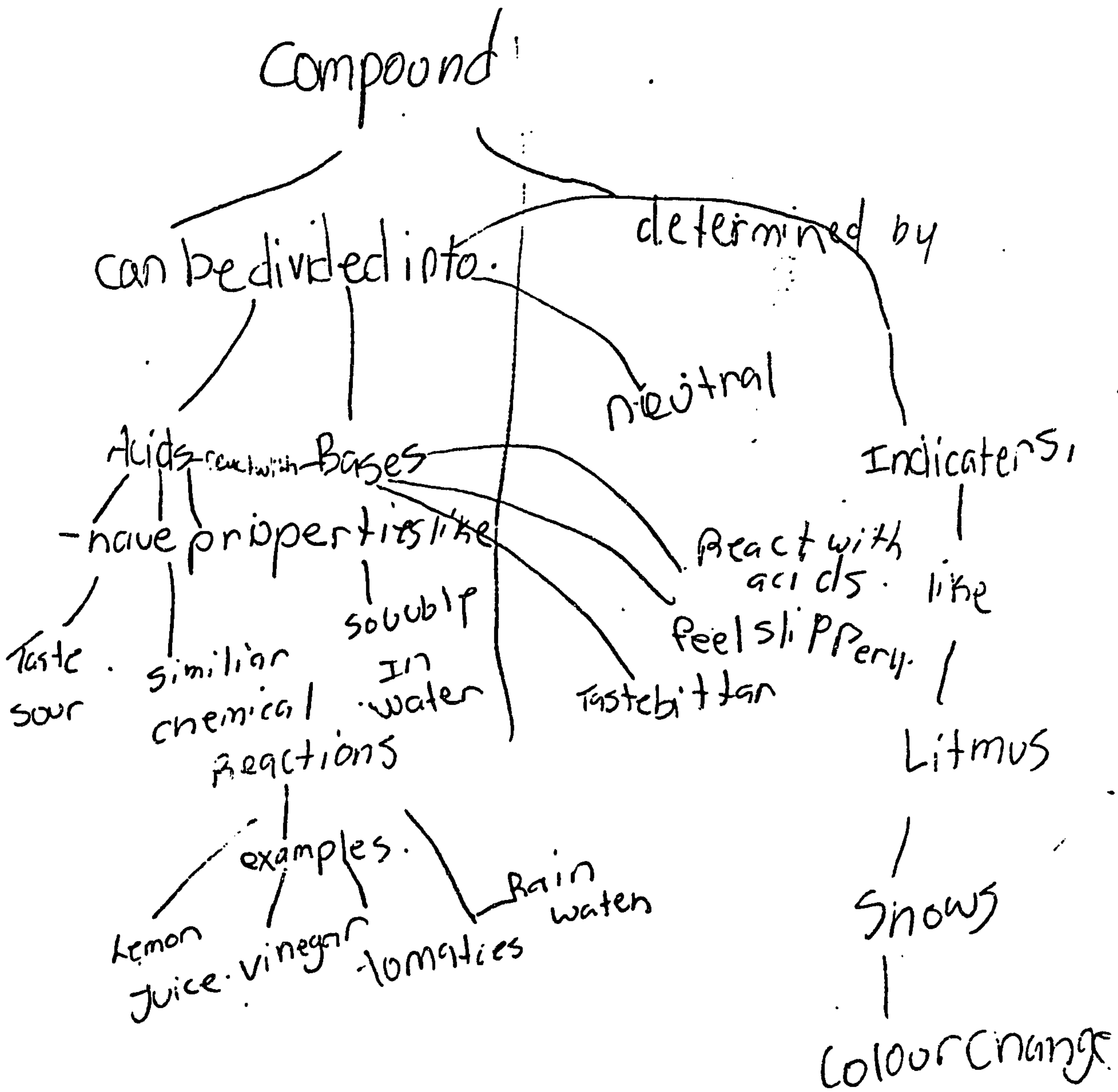
Maps are ok sometimes because you can just answer the question with the main words and join them. If you know the stuff then maps are good because they're shorter than paragraph answers and have the main ideas. Sometimes it's hard to use the map when your not sure what to put in the map cause you're not sure about the
answer.

Appendix 13 - Student concept maps completed as mapping assignments or as answers to concept map/paragraph test questions.

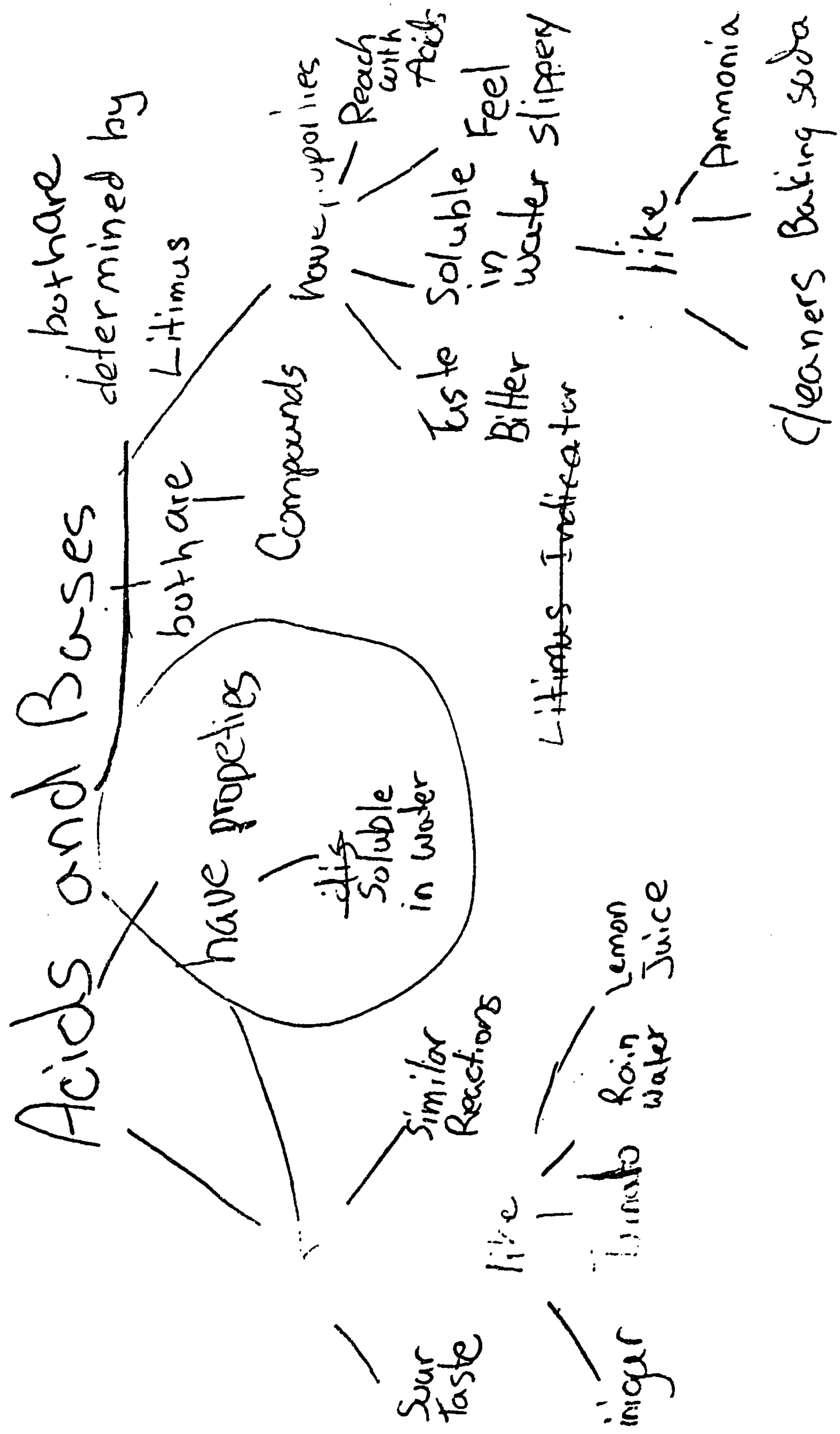
Student 103 - map displayed in Table 3



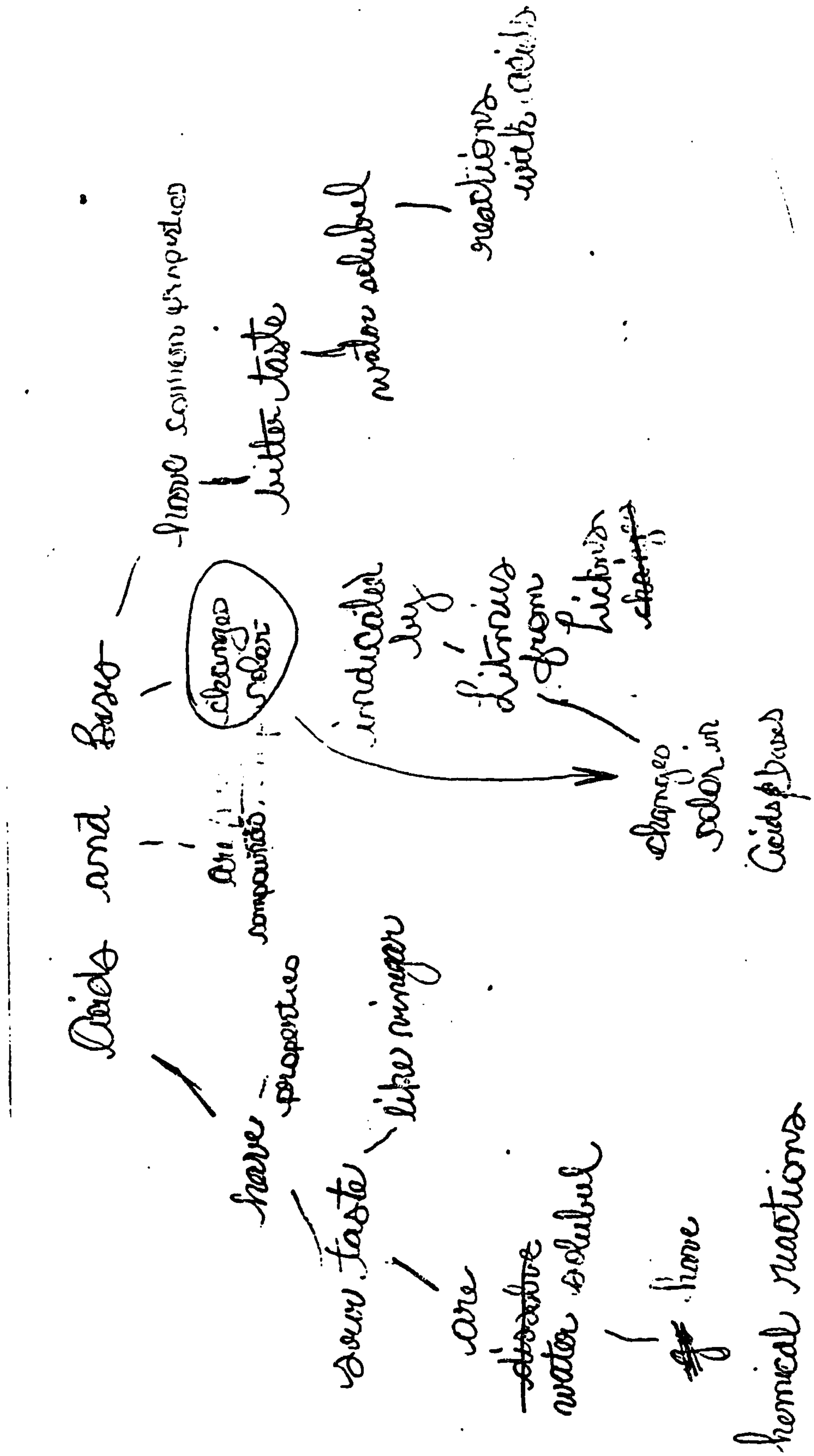
Student 122 - map displayed in Table 4



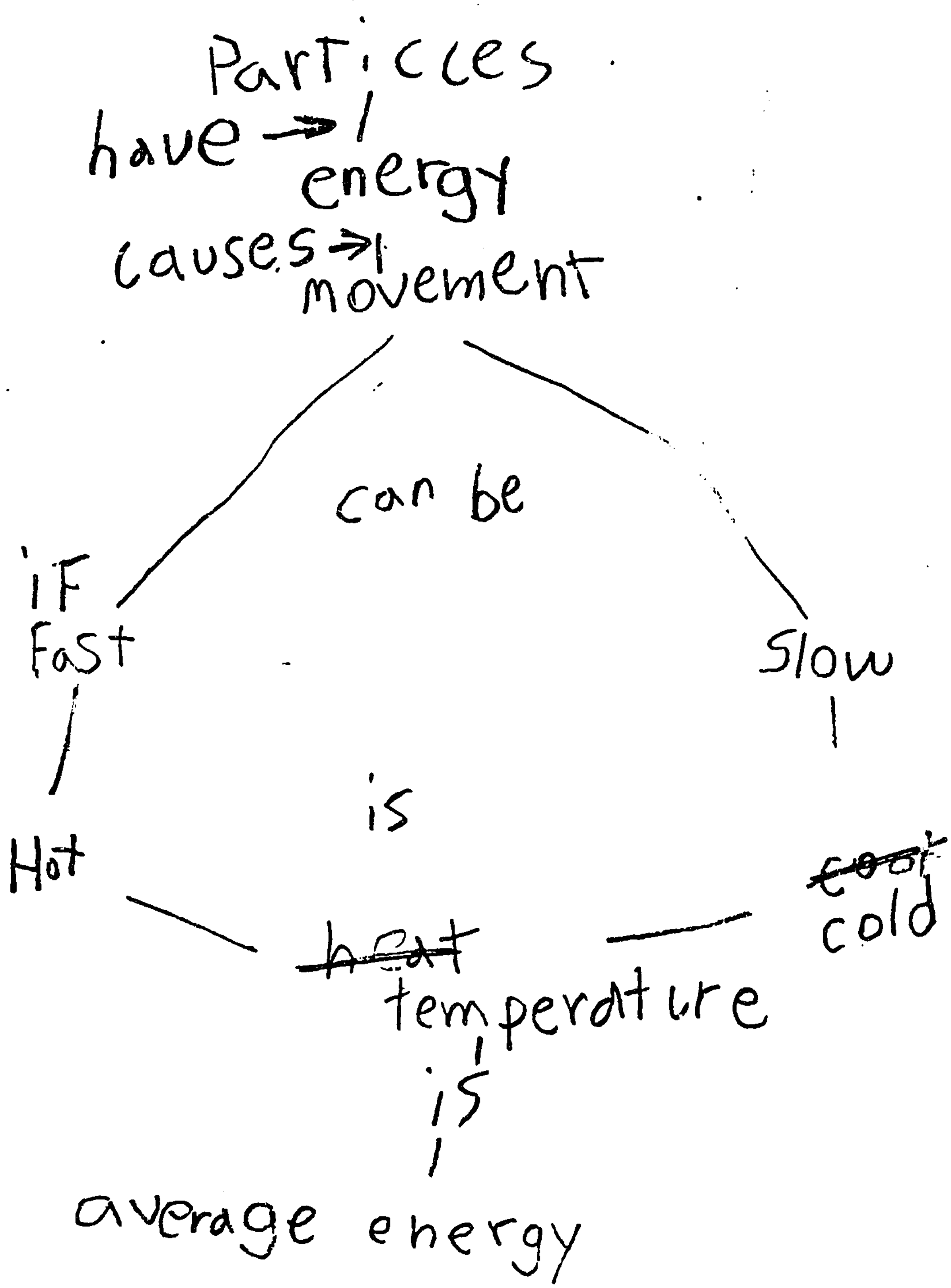
Student 222 - Map displayed in Table 4



Student 107 - Map displayed in Table 4



Student D11 - Map displayed in Table 8



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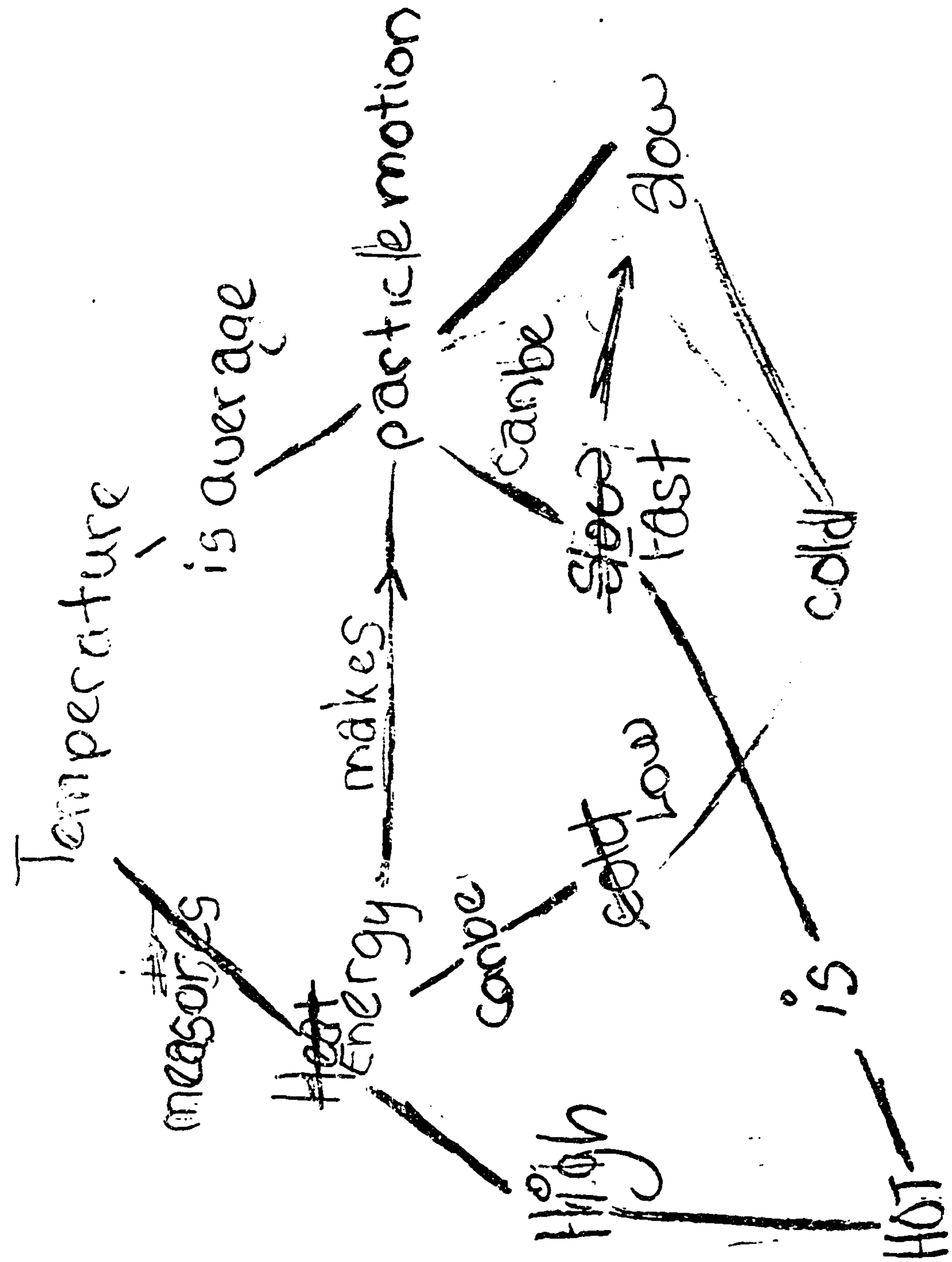
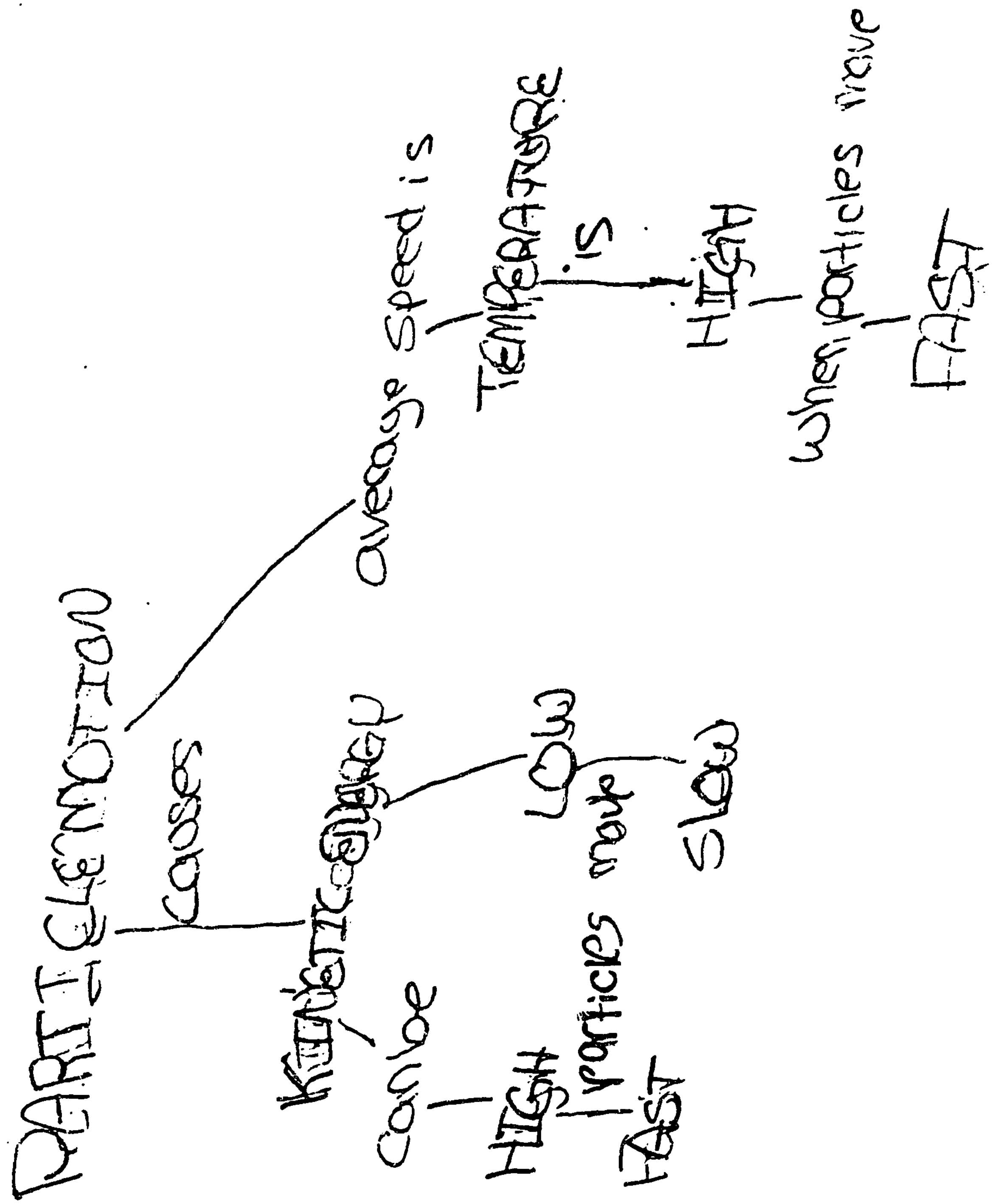


Student B28 -- Map displayed in Table 8



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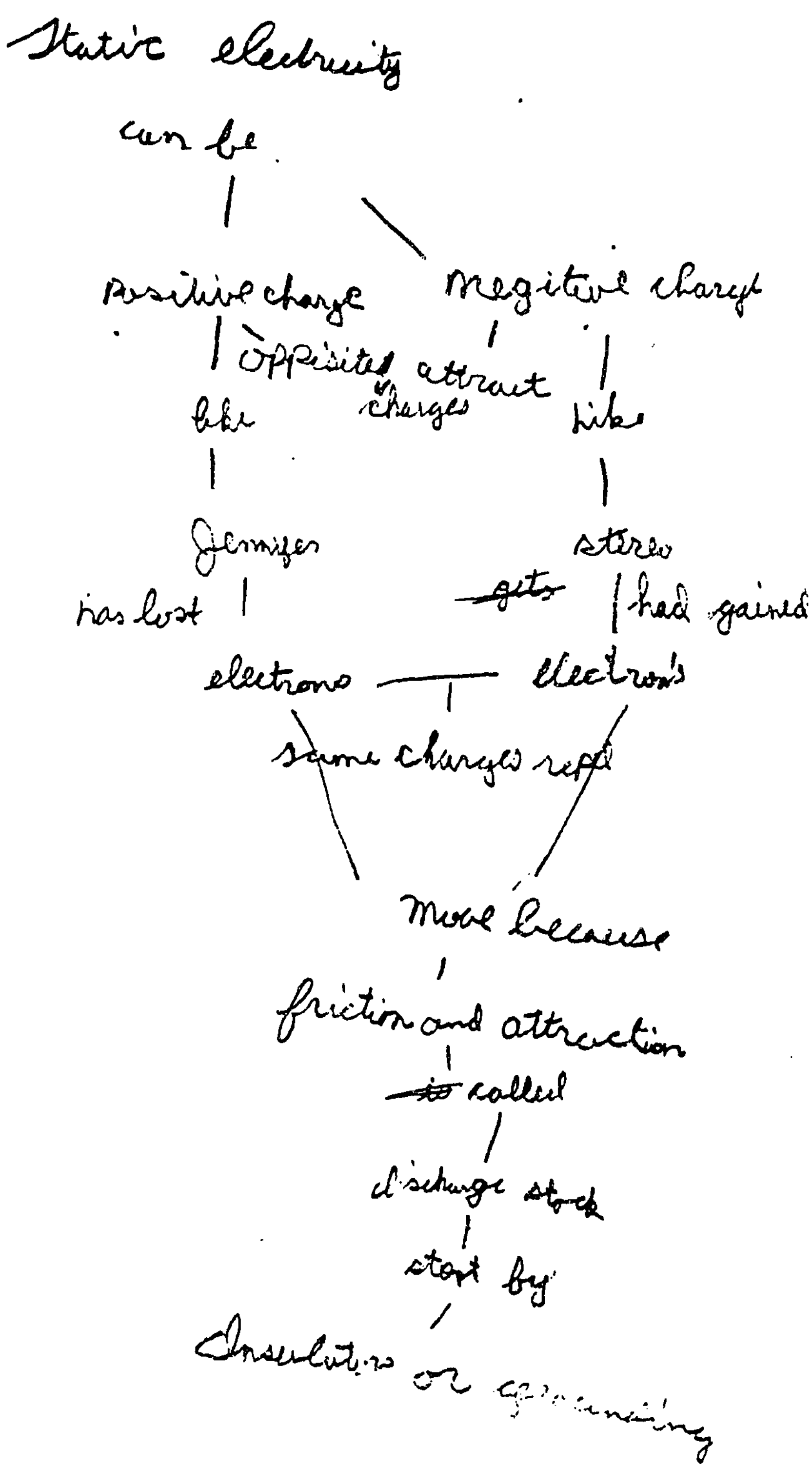

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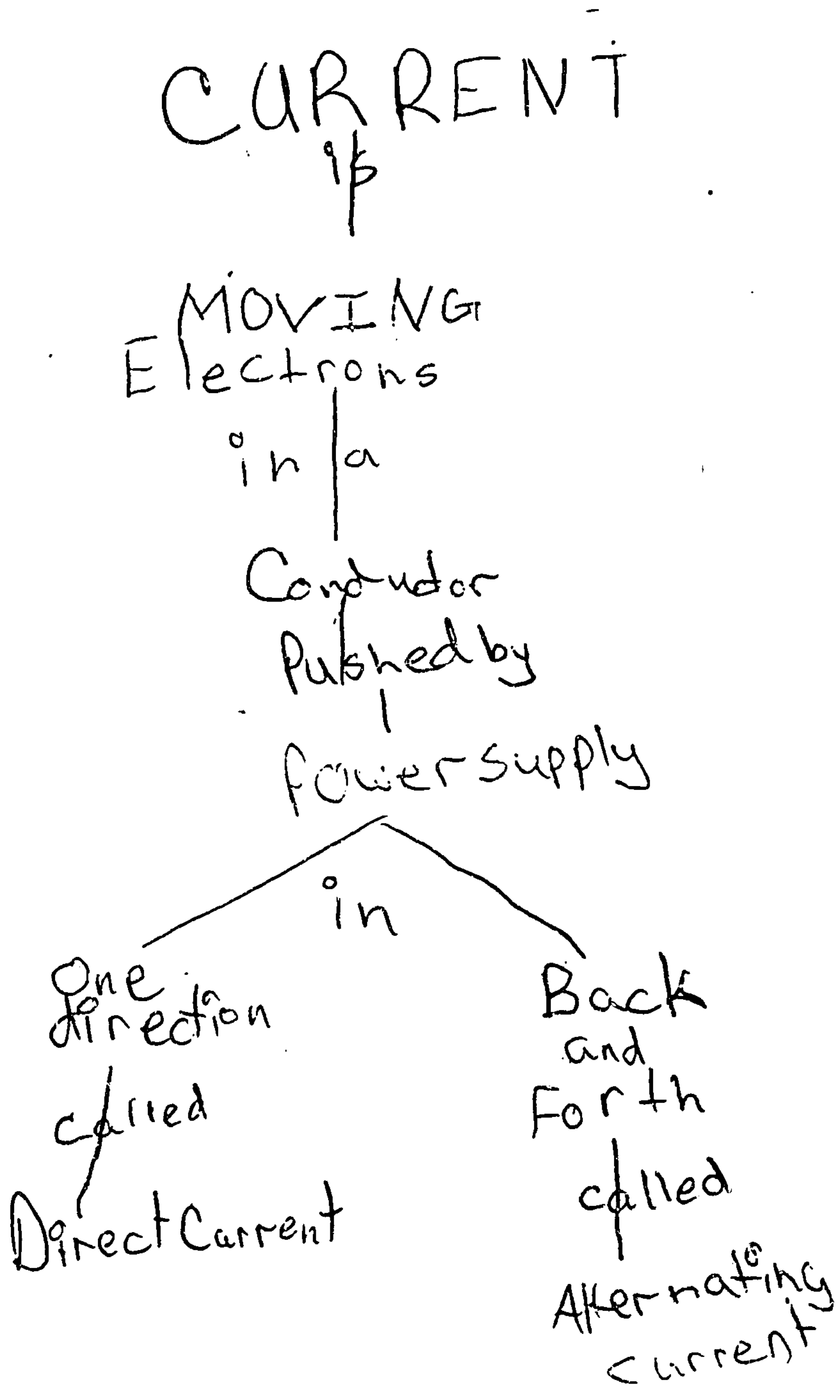

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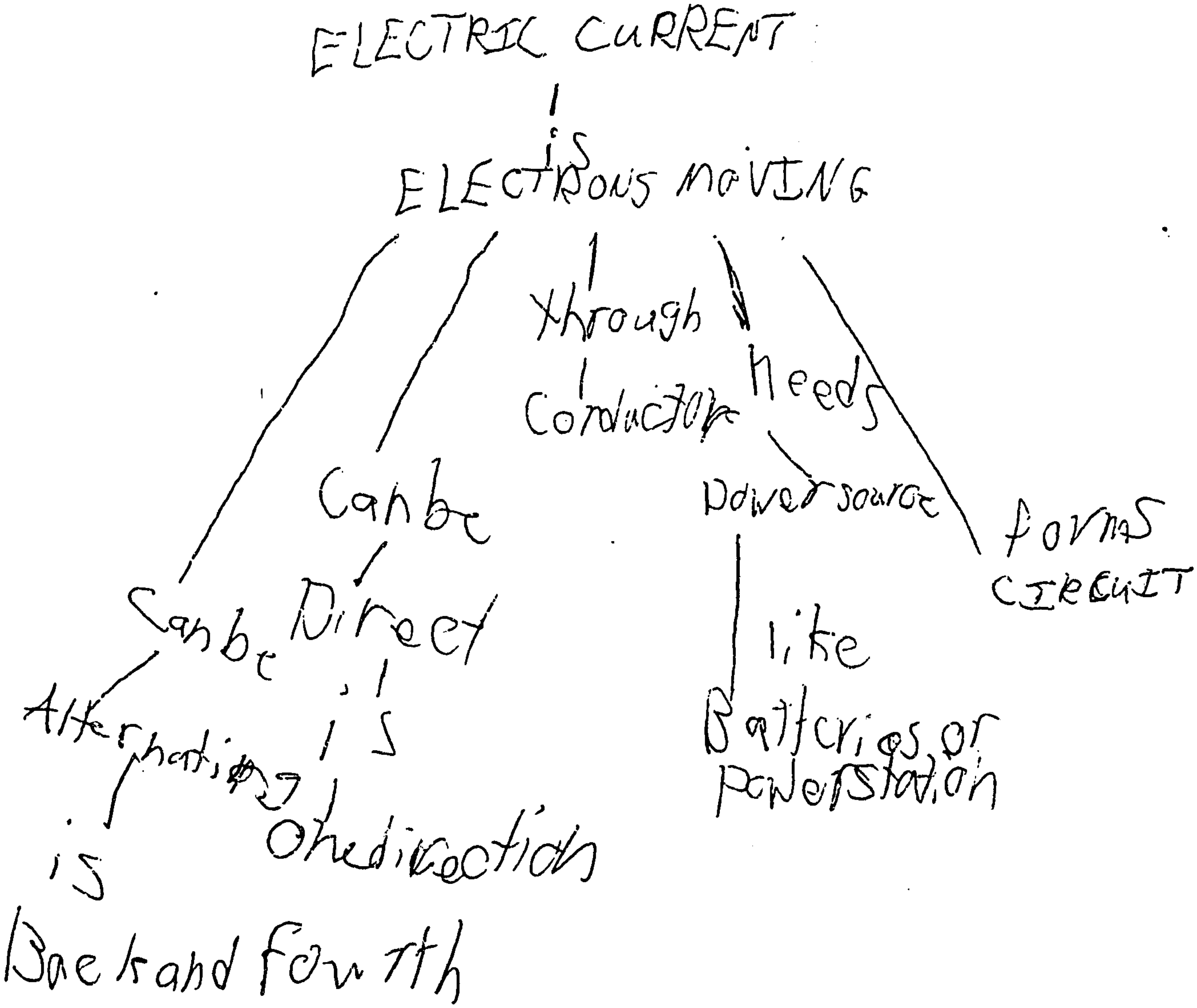

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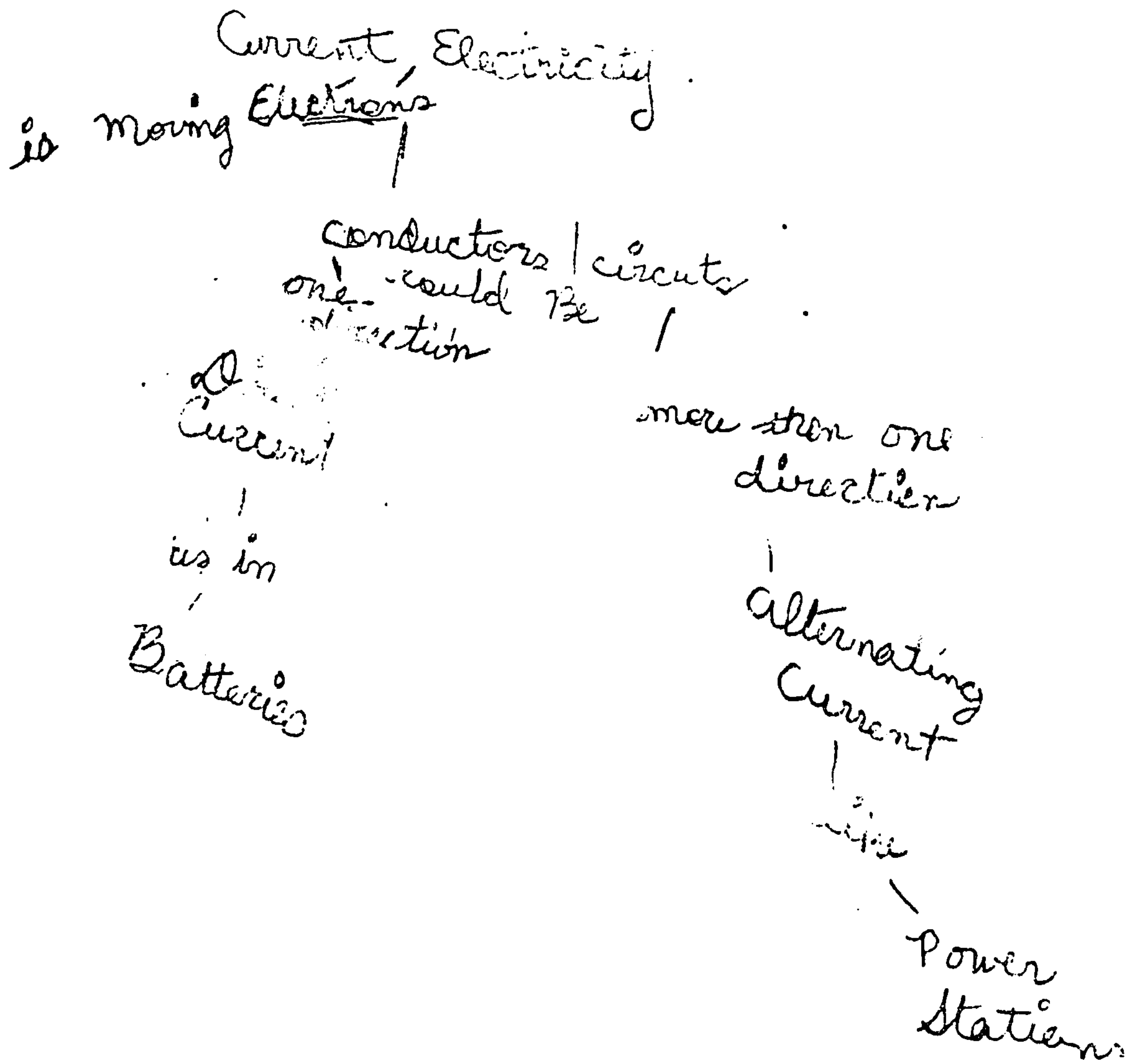

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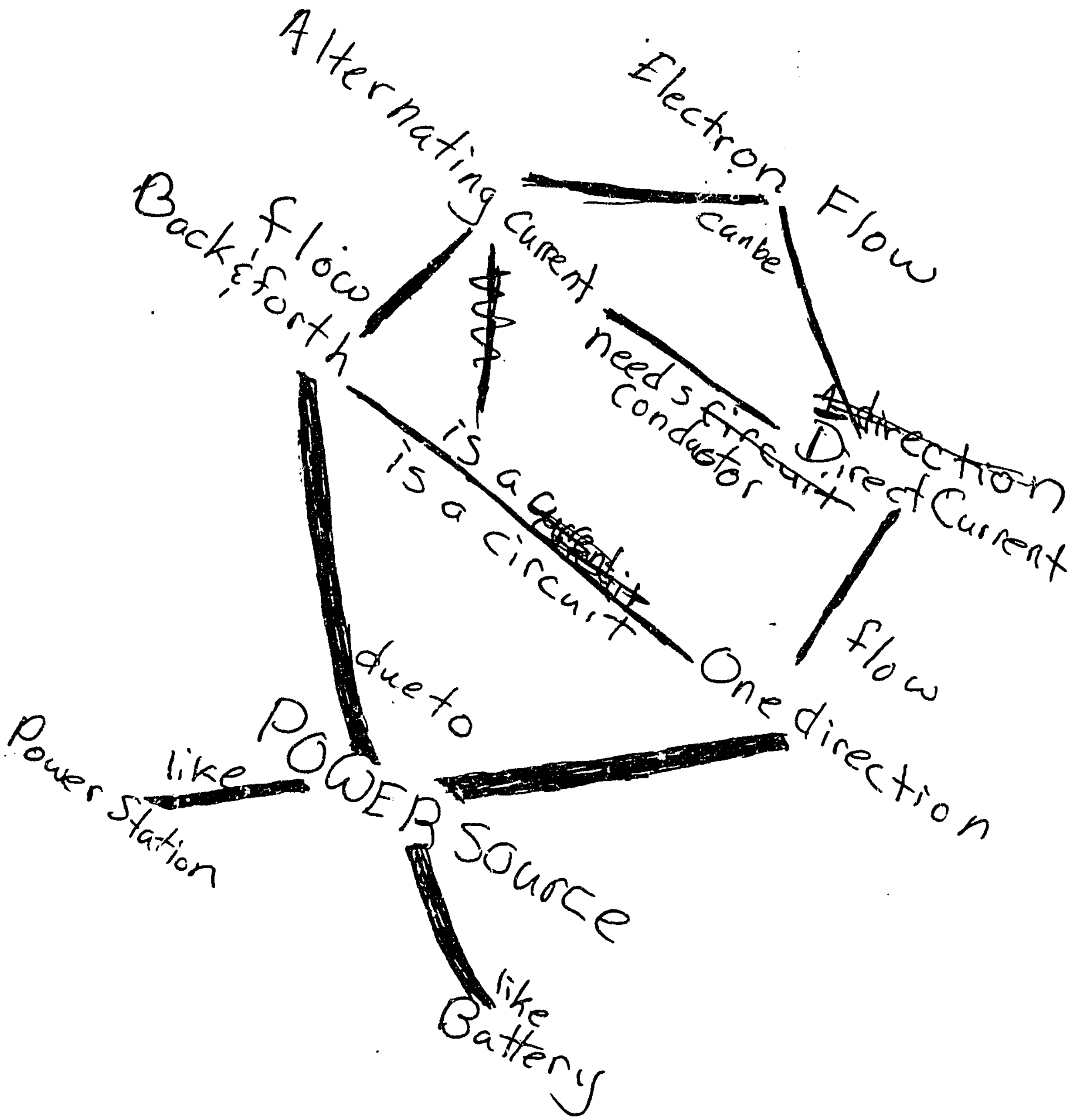
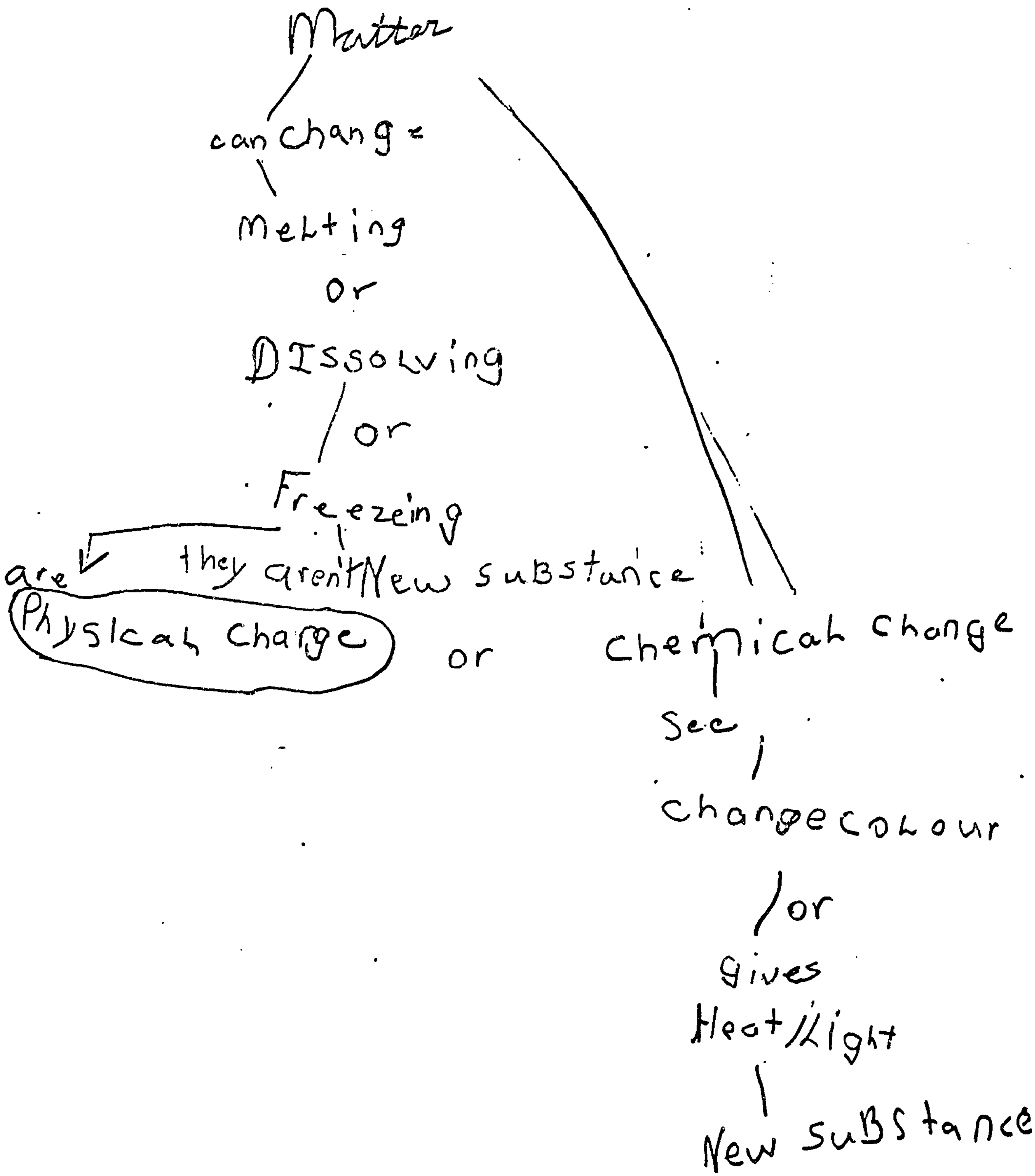
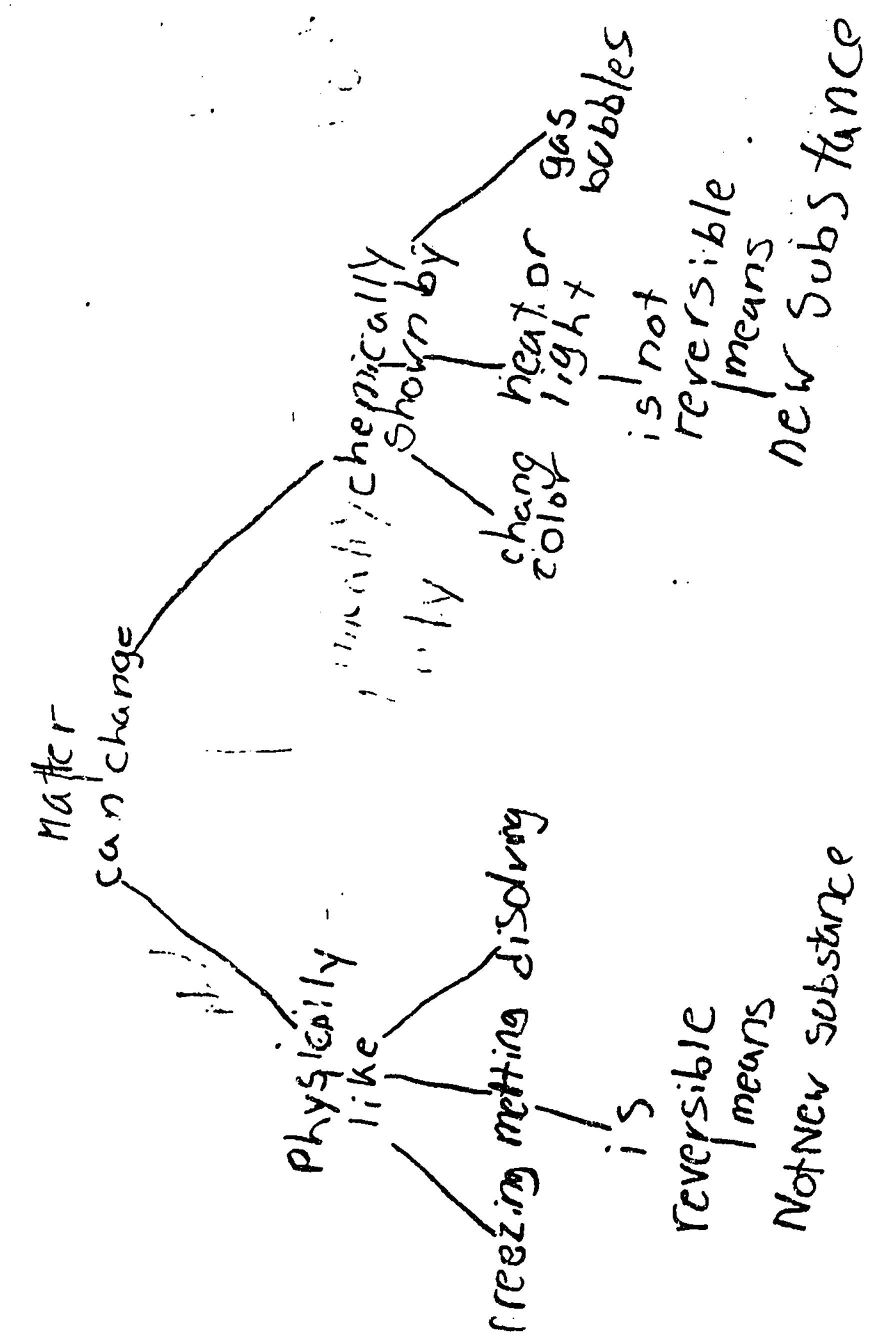


Student E19 - Map displayed in Table 12



Student F31 - Map displayed in Table 12



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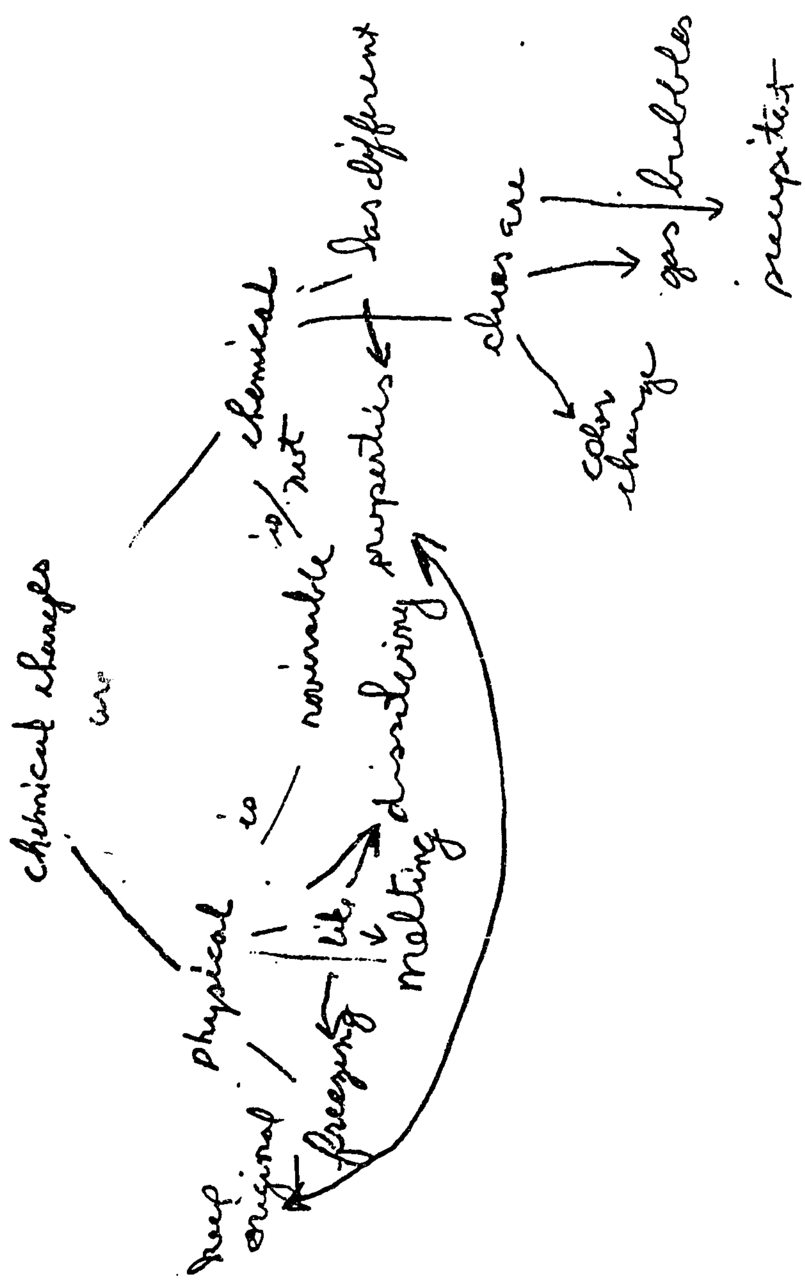

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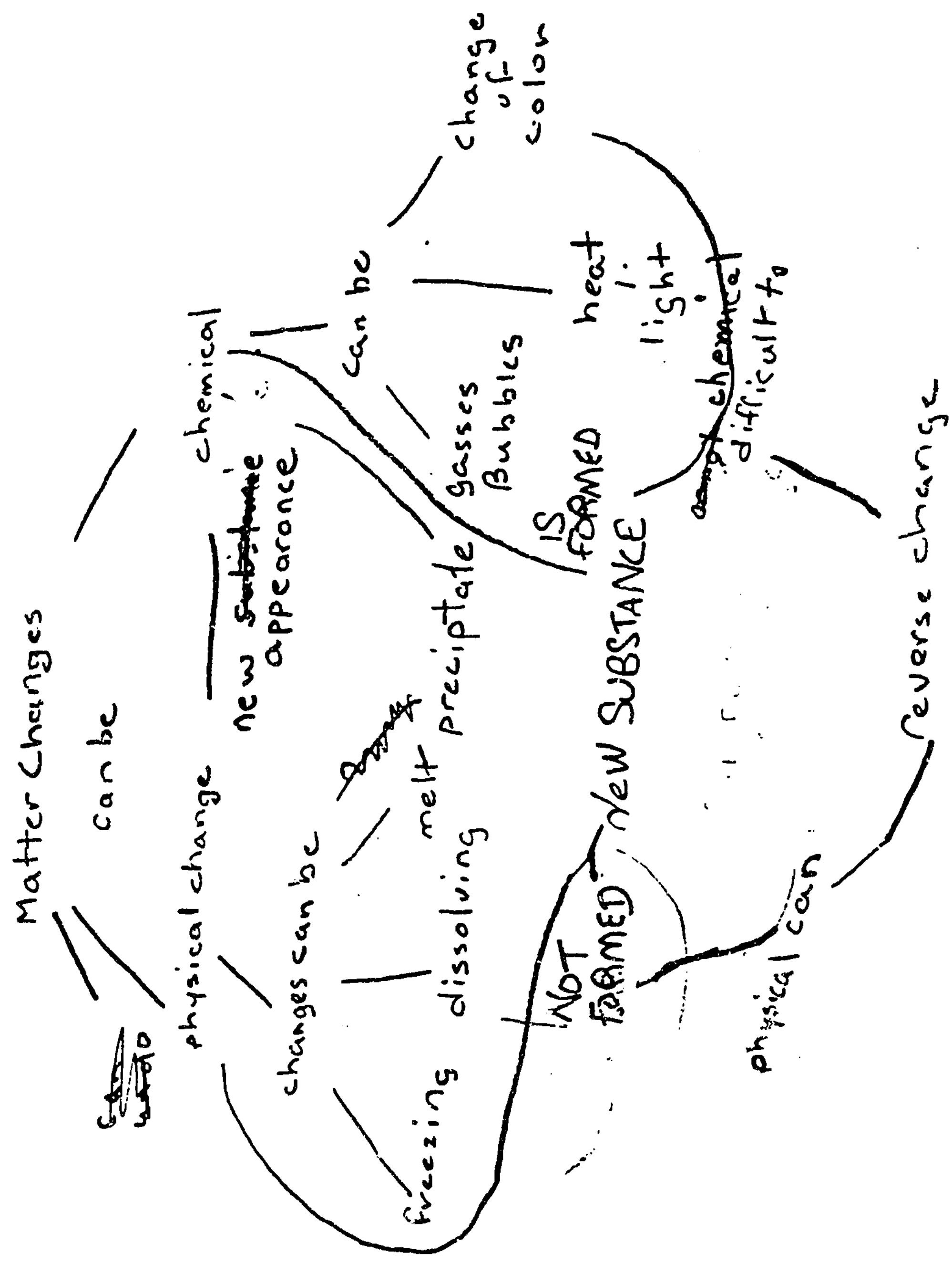

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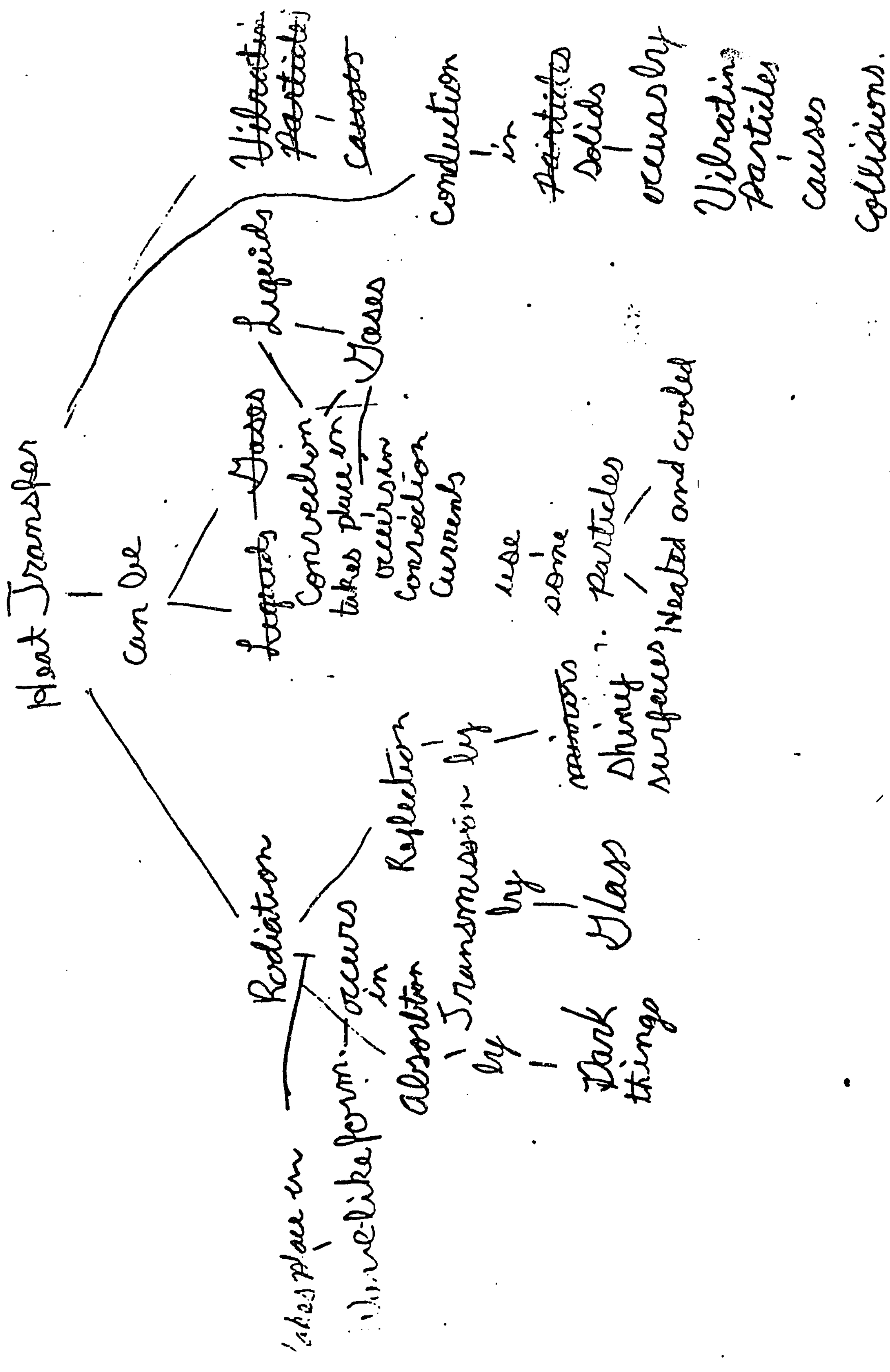

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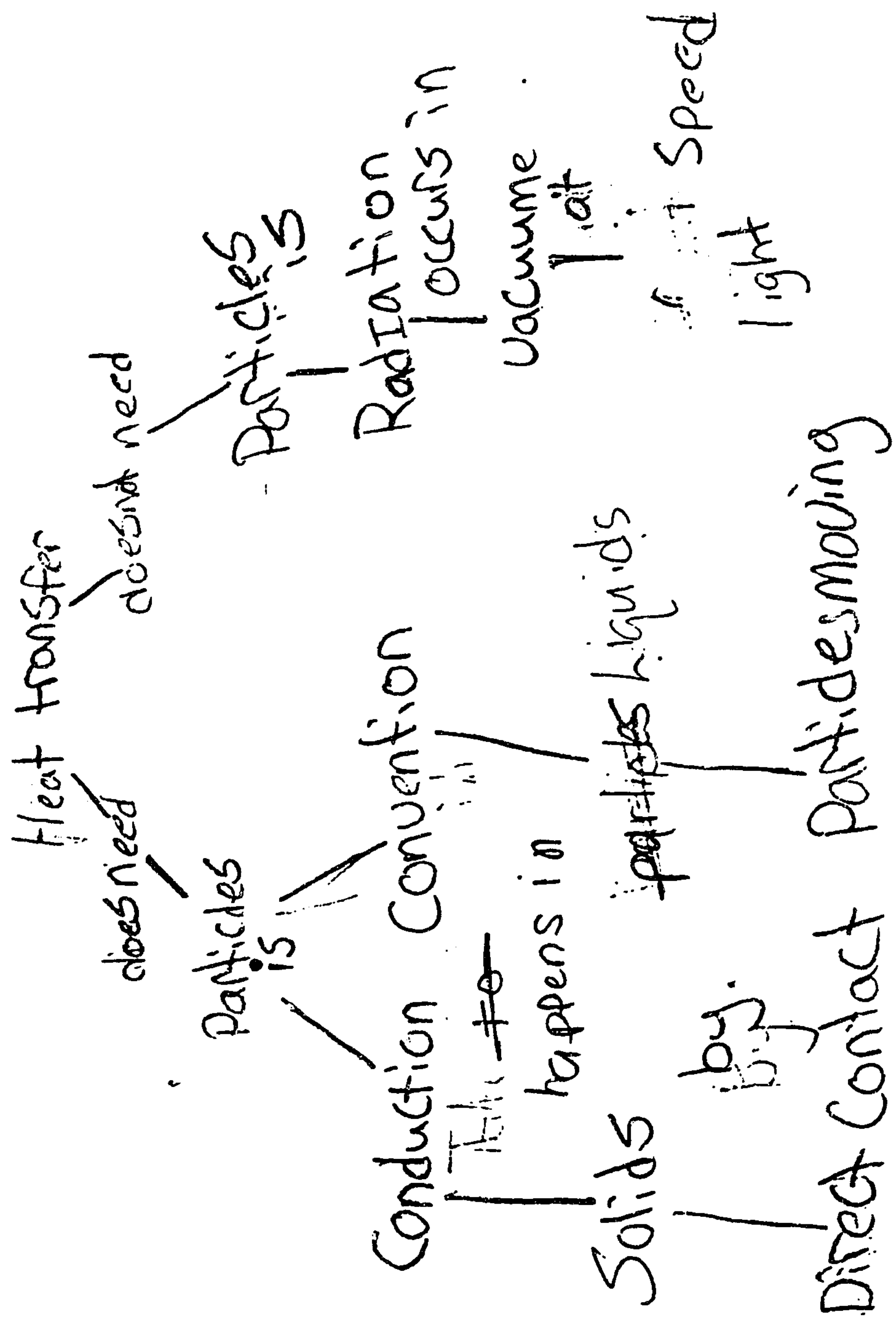

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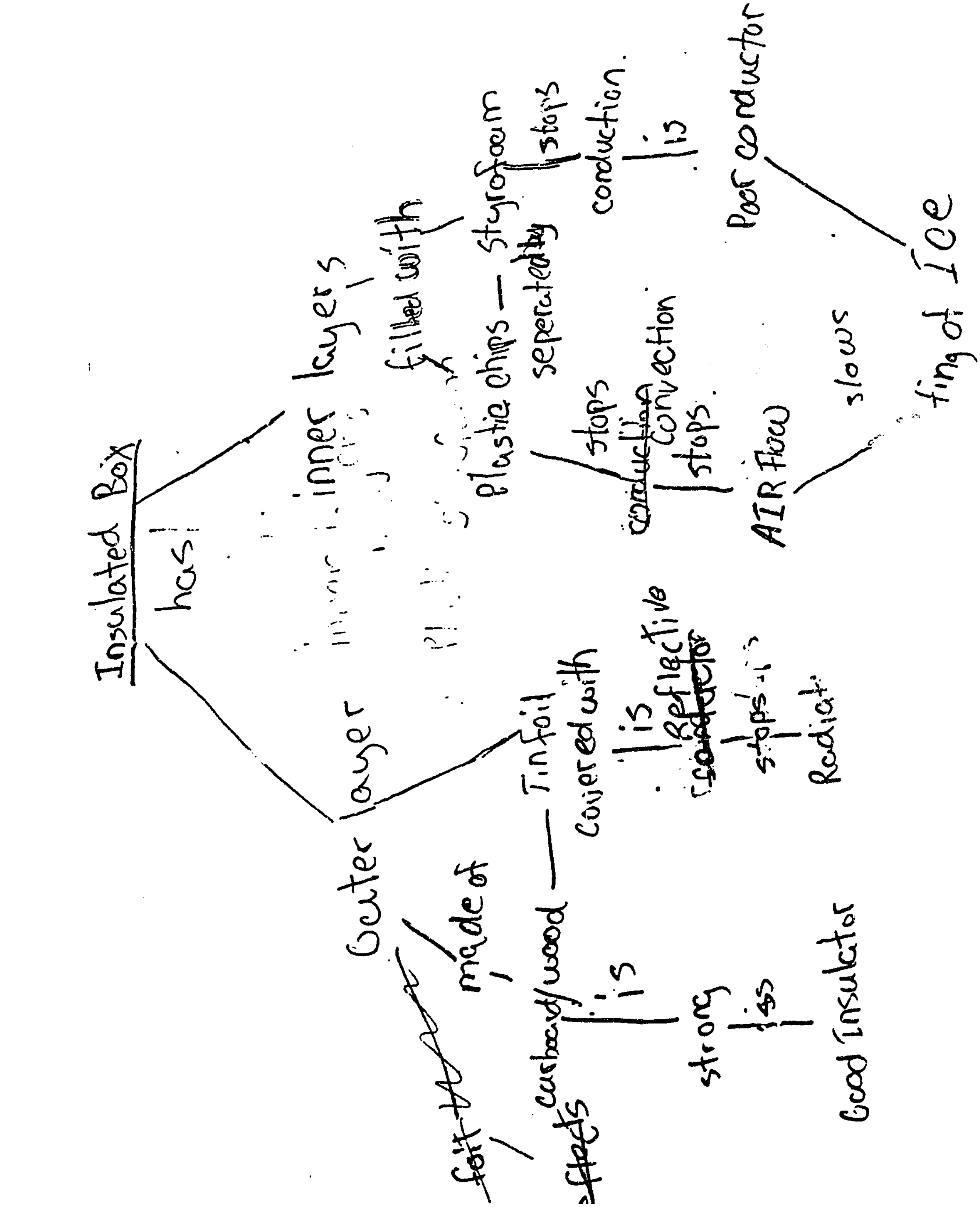

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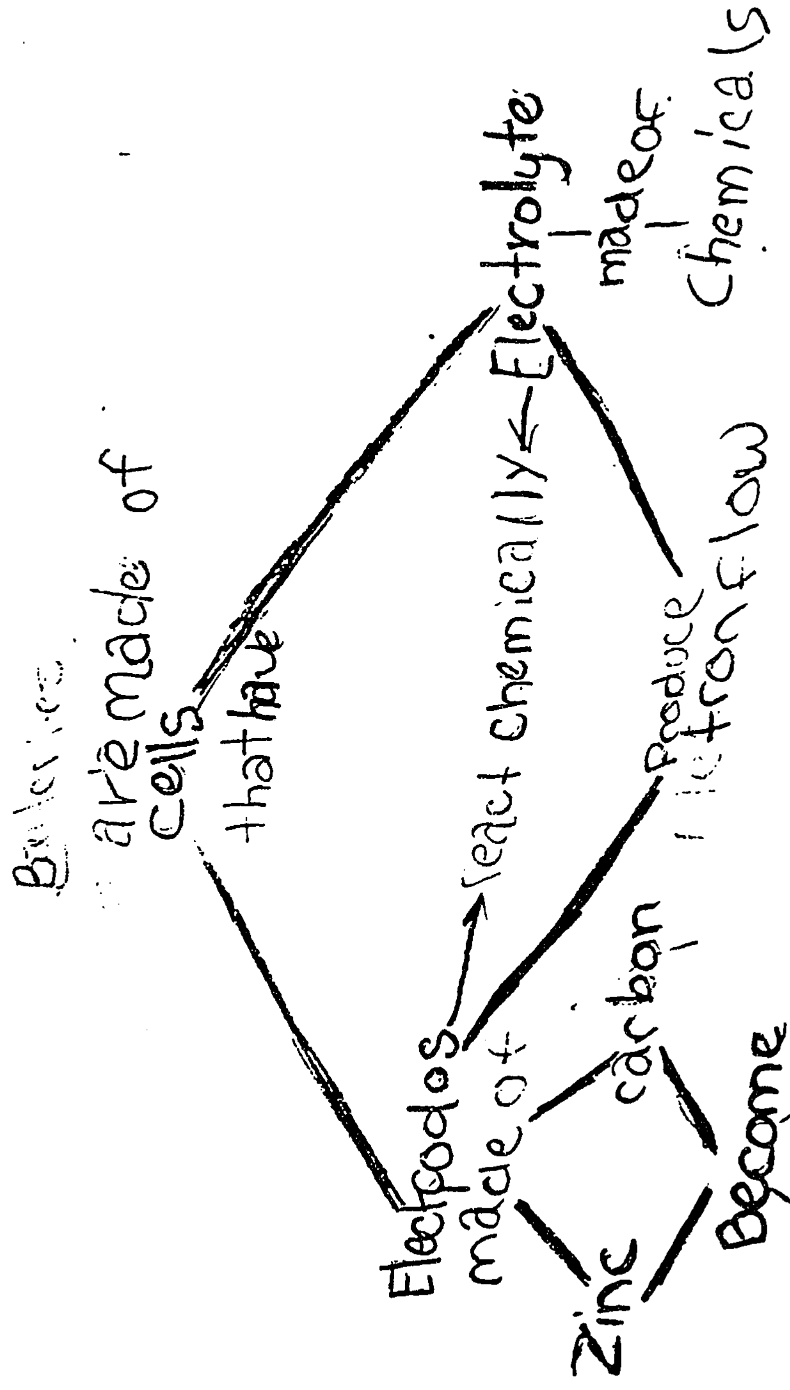

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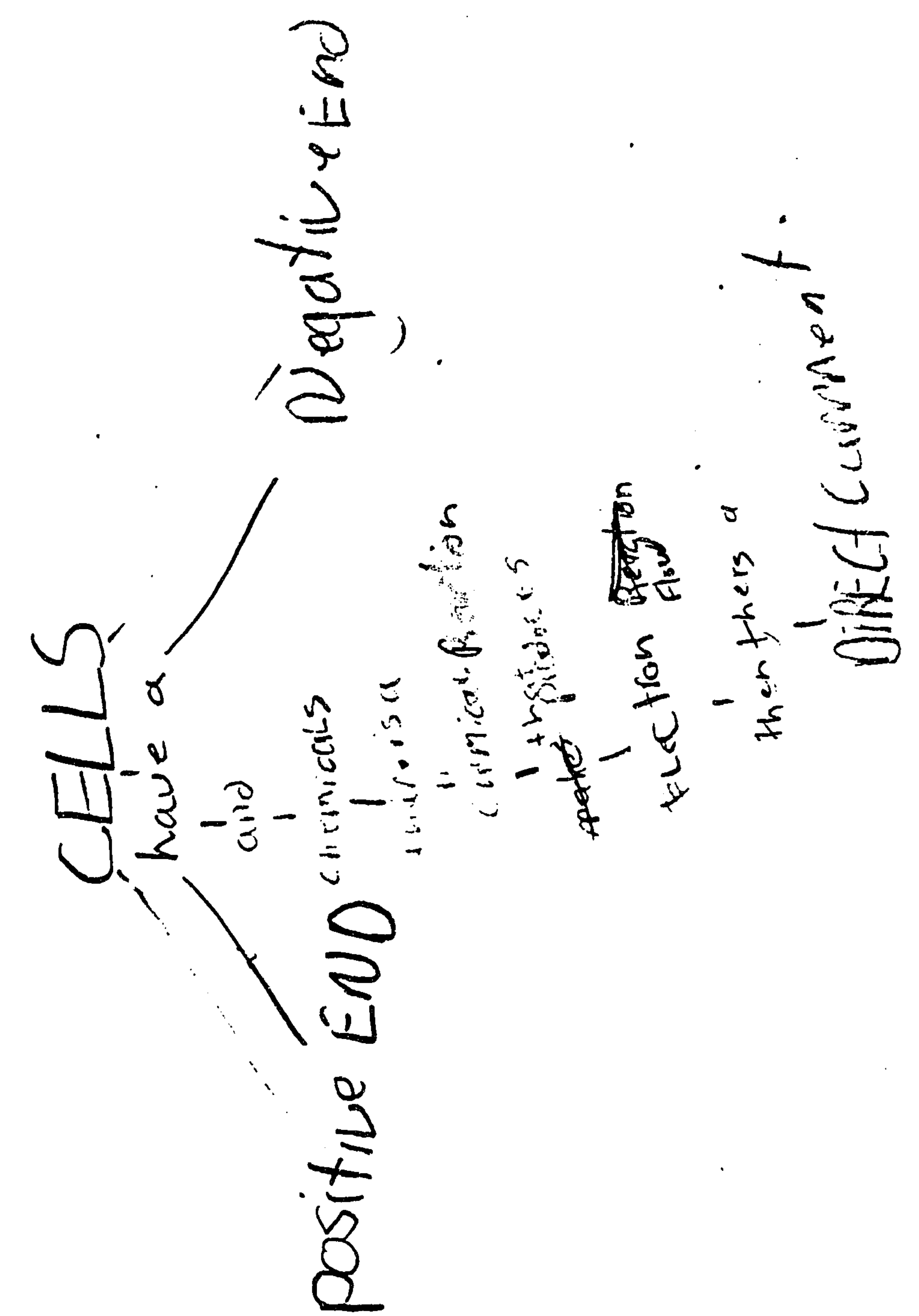

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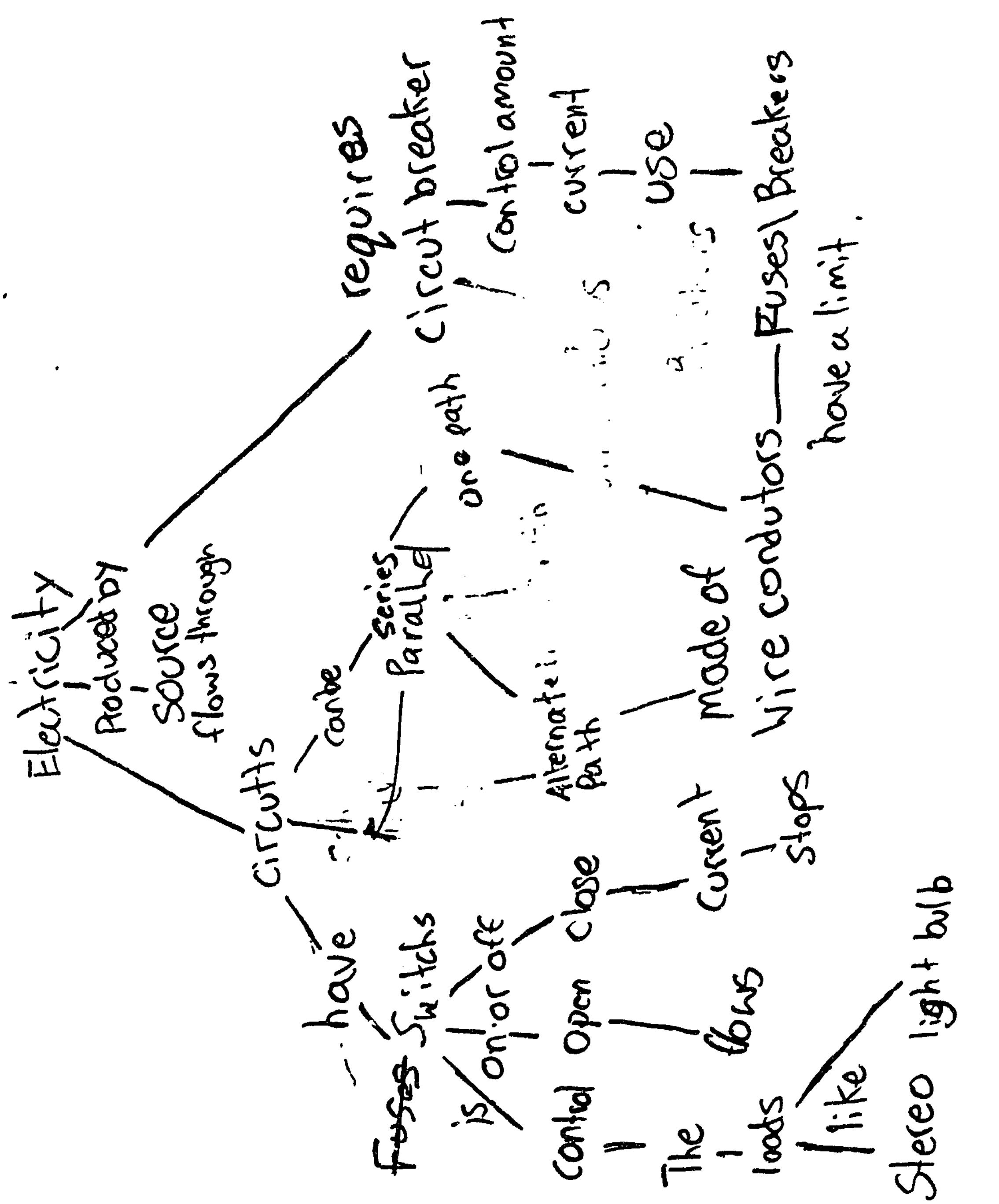
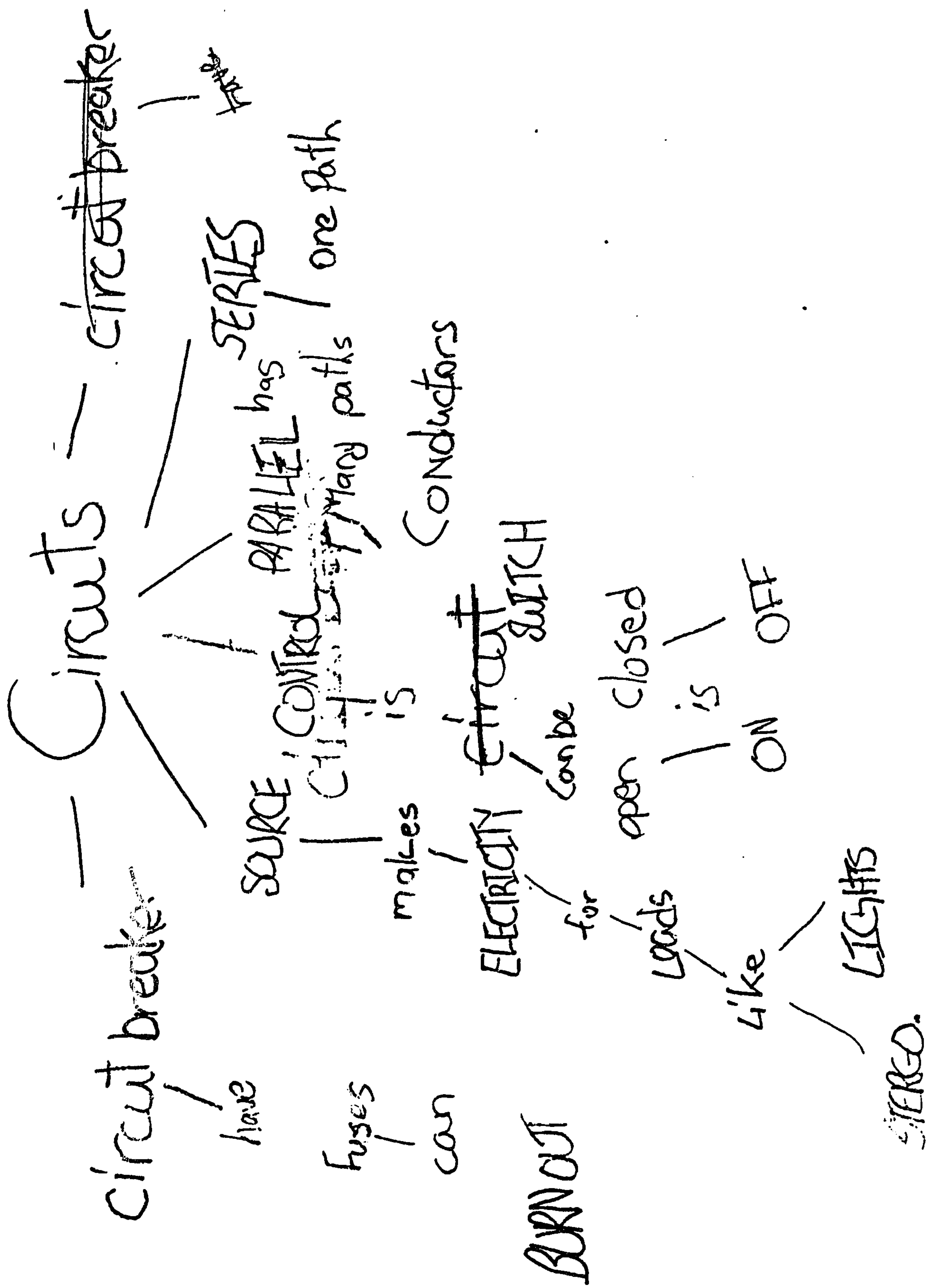
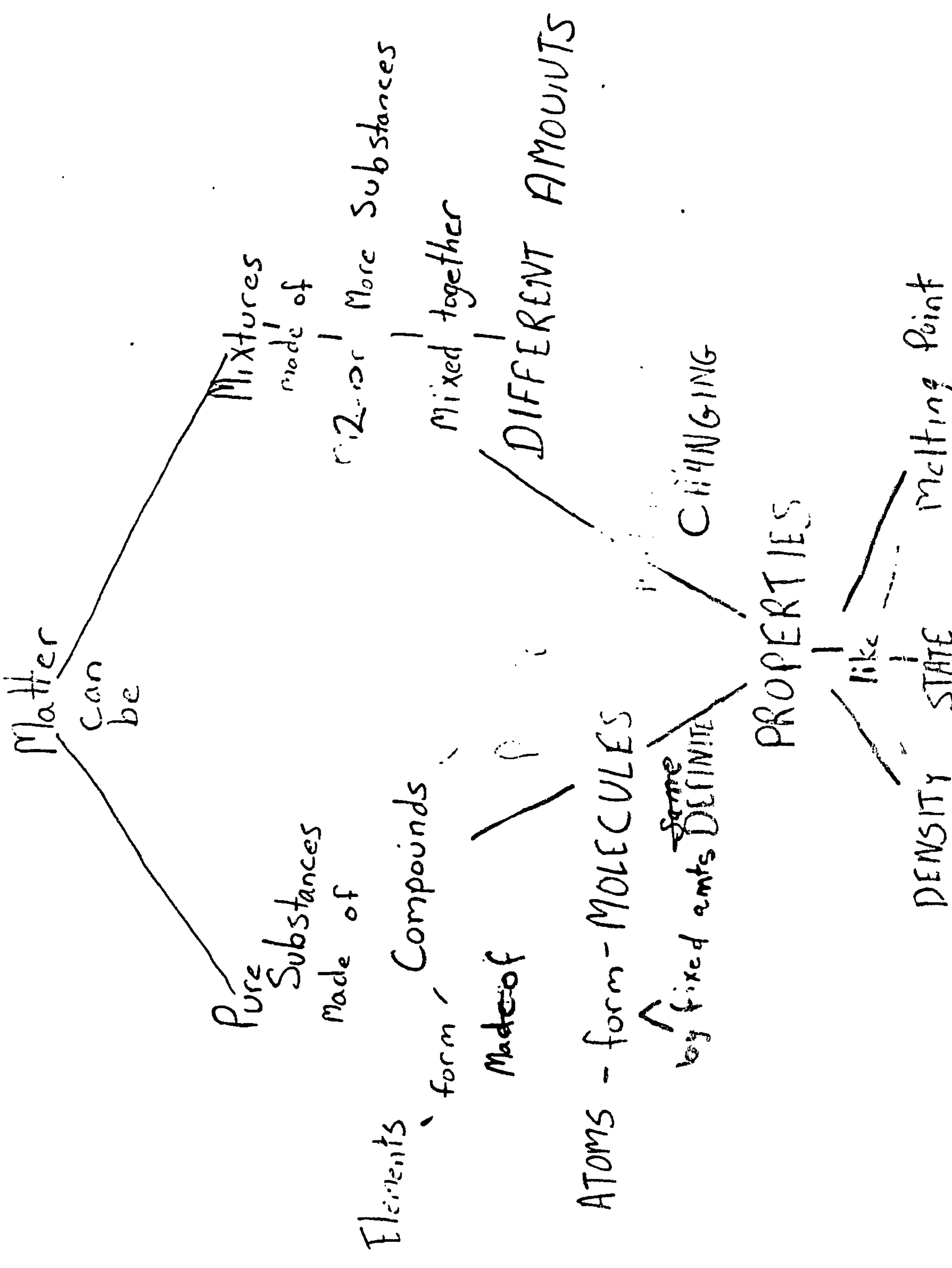


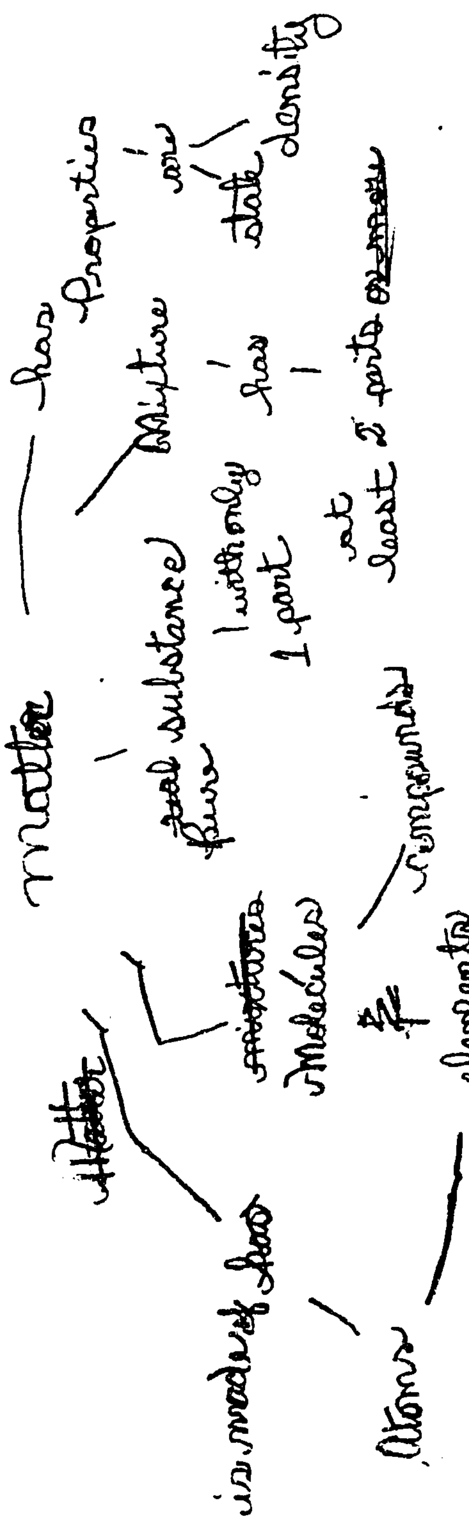
Student B15 - Map displayed in Table 22



Student F12 - Map displayed in Table 24



Student D23 - Map displayed in Table 24



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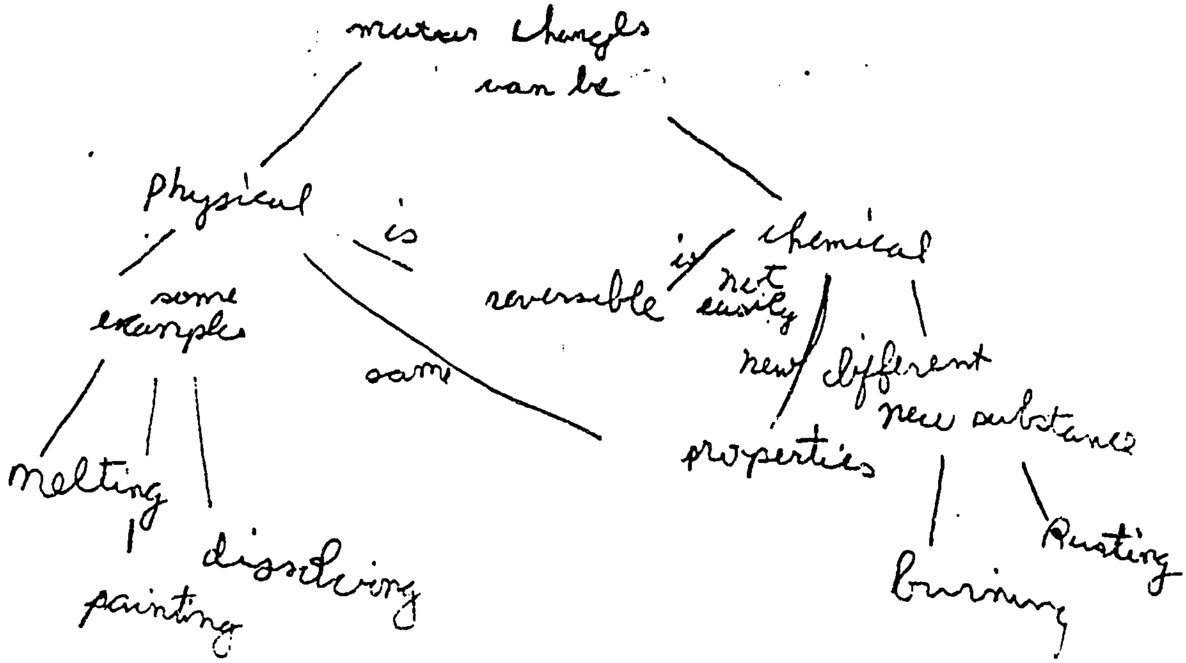

Student F13 - Map displayed in Table 26.