ARE THEY REALLY LEARNING? INVESTIGATING GRADE SEVEN SCIENCE STUDENTS' UNDERSTANDING OVER THE COURSE OF A UNIT THROUGH CONCEPT MAPPING ACTIVITIES

by

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ABSTRACT

Concept mapping is an activity where students present the knowledge that they have and how it is interconnected and related in a graphic format. This study attempts to determine what type of knowledge can be gained from examining grade seven Science students' concept maps generated over two units of instruction, one taught in an STS manner and the other in a transmissive manner. The maps were examined on multiple points: number of list words used, number of additional words used, number of maps generated, size of maps created, number of words in the links between key words, and type of information in the links between key words. Additionally, maps were examined for any correlations between the type of map created and the academic achievement of the student, as well as for any correlations between gender, manner of unit instruction, and type of map generated.

There are gender differences in map construction; boys tend to stick to using textbook definitions and the girls have more creative maps with personal comments and opinions on the topics. In terms of assessment, students who did not do well on the unit test created poor concept maps with few links and little scientific content. However, students who did well on the test did not always create concept maps that reflected their understanding of the subject. Students did generate different types of maps in the two different units. The Astronomy unit maps were often creative and imaginative in their answers, but not always scientific. The Chemistry unit maps reflected that the students had pockets of scientific information but they weren't always able to link those pockets together. It was not possible to determine if these differences were due to the innate differences in the content of each unit or whether this was reflective of differences in teaching style. Concept maps are an excellent tool to see what the students are interested in and to enable students to track their own academic growth.

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CHAPTER 1

INTRODUCTION

Background to the Problem

Teaching is composed of multiple dichotomies. It is both a profession and an art form. Teachers operate from strict guidelines and create highly structured activities for learning and yet must be innovative and flexible to adapt to the ever-changing needs and interests of their students. Strategies that work one day don't always work the next. Black-and-white learning outcomes must be constructed into vibrant, amorphous, and synergistic experiences that reach all participants. A student may appear to grasp a concept one day but by the following day that understanding is lost. Teachers must get tangible, assessable proof of the ephemeral connections and ideas inside students' minds. Indeed, teaching is simultaneously a most rewarding and frustrating profession.

For Science teachers, the tension created by these opposing forces seems more pronounced than for teachers in other disciplines. The provincial Intended Learning Outcomes (ILO) within the Intended Resource Package (IRP) documents for Science in B.C. focus in emphasizing what students need to know and be able to do (BC Ministry of Education, 1995). But Science is much more than rigour, laws and theories. Science has inspired and informed all the disciplines. Civilizations rise and fall based upon their technological advances and medical developments (Diamond, 1999). Artists and engineers alike are able to create their works based upon scientific principles or discoveries. Poets and writers are captivated by the natural world and the wonders of Science and technology. So why is it so difficult for Science teachers to inspire their students? Why do many students find Science classes so crushingly boring? More importantly, what can we teachers do to rectify this?

Haunted by these questions, I reflected upon my own journey from Science student to Science teacher, which seemed to mirror my students' experiences. In elementary school, Science lessons were the highlight of my week, an opportunity to flee the classroom to examine the world around me. Science classes fascinated me because they answered the questions that I found interesting or important. Where do the colours of fall leaves come from? How do salmon turn from eggs into fish? What happened to my snowman? Some aspects of Science I found less engaging as they involved acquiring facts from countless library books. These "bookish" projects, however, usually had a creative component from which I could draw, build, or create my own vision, presenting my understanding and beliefs about a topic.

Sadly, throughout high school and the early years of university, Science narrowed into a profusion of facts that needed to be collated, memorized, formulated into arguments, and regurgitated on tests and exams. There were a few intriguing lab activities, but too often the experiments felt rigid and contrived. We were well aware that there was only one correct answer, that completing our labs would have no impact on anyone, and that experiments were assigned simply to break up the monotony of lecturing and note taking.

It wasn't until third and fourth year university Science classes that learning became fascinating again in a way I had completely forgotten. We were required to do original research. Questions often had more than one correct answer and, sometimes, no known answer at all. We had a choice in the type and nature of the experiments we designed with the result that we really could do things that had a personal interest for us. I had regained that joyous feeling of working toward discovery in the miraculous world of Science that I had known in elementary school. Rediscovering the excitement in learning Science inspired me to become a teacher.

At the beginning of my teacher education studies, I was stunned by the complexity of what "becoming a Science teacher" involved. The seemingly paradoxical dichotomies of what being a "good" Science teacher required left many of us in teacher education classes in despair. Half of our time was spent reinforcing the organizational side of teaching: developing Science lesson and unit plans, accounting for the use of each minute of instructional time, poring over curriculum documents, practicing classroom management skills, and organizing the order of our classroom activities into the "correct" sequence. Our instructors emphasized the need to preview and continuously review the material we were teaching with our students; they told us that our students would require repeated exposure to the material and frequent practice activities so that they would be able to grasp the critical concepts. Although we understood that the information and skills we were acquiring were useful, this mechanistic approach to teaching Science dissipated much of our enthusiasm. Teaching seemed to be focussed on perspiration. Inspiration had no apparent place.

The other half of our courses focussed on facilitating student learning of scientific content. We were taught that rigidly sequenced activities were intellectually stifling and hindered the learning process. As "good" teachers, we must meet the individual needs and learning styles of each and every student. Additionally, we were expected to develop a plethora of activities that enabled the individual students to make meaningful connections with the course material so that they could construct their own understanding of the content. We were told that when we had our own classes, we would need to present information in ways that would take into account each student's idiosyncratic learning styles. Additionally, we would need to develop some method of assessment sensitive to each student's learning style and needs.

Then I assumed my job as a new Science teacher and was left to reconcile these two seemingly incompatible pedagogical approaches – the mechanistic organization and the student-centred learning approaches to teaching. Throughout my first year of teaching, I tried wherever I could to incorporate the creative, thought-provoking activities and strategies I had learned in my content courses while maintaining the structured, harmonious calm of a classroom running like a meticulously maintained machine. At times, I felt like a maestro; at others, a fraud. I wanted my students to both enjoy and be successful in my science courses, but at times I felt that my students, particularly those in grades seven and eight, learned little from their classes with me.

One particular frustration for me was that these eleven- and twelve- year old students seemed to learn concepts as discrete packets of information. They could successfully answer "low" level, fact-based questions – according to Bloom's taxonomy (Bloom, 1956) – but the "higher" level questions that I posed to my students in an effort to prompt them to synthesize ideas or to use concepts in combinations left them floundering. The teacher's guide for the grade 7 Science textbook I was using to teach my classes recommended using concept maps as a tool for reviewing concepts and helping students to see connections (Bullard et. al., 1995*)*. The authors of our text also suggested that "concept maps" would be beneficial for visual-spatial learners who learn best when material is presented in a graphic format

(Campbell et al., 1996). So, I began experimenting with free-form concept mapping[1] in my classes, and this approach seemed to help my students. Finally, it seemed that students were able to make connections between the concepts they had learned and integrate them together through links on the concept maps. I was amazed that the weaker students were trying to make sense of the jumble of facts in their heads. It even appeared that the class average was higher on the test at the end of that unit.

Observing the students while they worked on creating their maps, I noticed other differences. Boys tended to be very methodical and organized in their map building; they would write out key terms and use definitions to link their ideas. Girls seemed to use more words and added extra words and other concepts to their maps to show their understanding. They seemed really engaged in the concept mapping activity; this was wonderful to see as many girls at this age are no longer really interested in Science and Science-related activities. Maps generated by academically strong students of both genders appeared as dense webs of interconnected, detailed ideas. Weaker students' maps were sparsely worded and included many peripheral ideas but still showed a level of understanding that usually didn't appear when I used more traditional assessment methods.

My students created concept maps at the beginning and end of each unit. I noticed that although the students were initially apprehensive about creating the "right" concept map, they soon appreciated the freedom this activity gave them. The students loved the fact that the maps represented their personal understanding of the course material, and that, even if some of the facts used were "confused", the maps themselves could never be "wrong". The

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[1] Free-form concept map refers to an unstructured concept map where no hierarchical organization is imposed.

weaker students enjoyed being able to see that they had learned some of the material, indicated by the increase in the number of words and links they were able create between the two maps. The stronger students liked the challenge of how many words they could interlink in the given time period. The students did initially complain about the difficulty of the task, but they also acknowledged its usefulness when they were asked to use their knowledge to answer more challenging, abstract questions on their tests.

This informal experiment with concept mapping excited me. Still, I didn't feel I was the "good" Science teacher I wanted to be: one who inspired her students, left them informed, allowed them to be innovative, fostered responsibility, and engaged them in meaningful learning. I decided this feeling of inadequacy might be resolved by learning more about teaching, so I entered a master's program in Science Education, hoping to reconcile the tension between mechanistic and humanistic teaching.

In my graduate program, I learned about the theories that were the underpinnings of my teacher-training courses. The behaviourist, cognitive, and constructivist traditions that fuelled my practices and programming were easily understood, but still not easily reconciled. Then I read about an approach to teaching Science called Science, Technology and Society (STS). This teaching movement suggests that Science curricula need to be re-envisioned so that students can link the content and concepts from Science classes to personal experiences, understand the implications – social, societal, and environmental – of choices that involved the use of science or technology, and become responsible, well-educated, scientifically-literate citizens who could help to save and re-habilitate our world (Cross & Yager, 1998; Weeks, 1997).

The STS philosophy made sense on a fundamental level. Experience showed me, both as a student and a teacher, how activities that were meaningful and relevant held students' attention and interest for a longer period of time. Based upon my understanding of this teaching approach, I restructured some of my classroom activities so that they emphasized the relationships between the content and my students' lives. I was pleasantly surprised at the change in attitude and academic performance that accompanied my change in teaching style. The students were more alert during class time and participated more passionately in class discussions. They asked more questions, wanted to know the implications of the material they were learning, and even brought articles to class that they had found when voluntarily researching concepts that had sparked their interest.

I continued to investigate ideas associated with STS teaching. I learned about different ways of interpreting and incorporating this approach into classroom activities, and of the success of using the STS approach in schools. But few articles spoke to the issue of whether an STS approach aided students' learning on a deeper level. I felt, at an intuitive level, that my students learned "more" in my "STS" unit than in units I taught in a more traditional, "transmissive" manner. But intuition was not enough to justify altering my teaching approach. I had questions about the effect of STS teaching, such as, how and what were my students learning during their STS lessons? I thought that since I had used concept maps successfully before, they might be a useful tool in assessing my students' understanding of Science taught in an STS unit. I wondered if my students learned Science differently in an STS unit as opposed to in a traditional unit.

When the time came to design my master's research, I found that I had many ideas I wanted to investigate. Although I had read a lot about hierarchical concept maps, I could find little information on the use of free-form concept maps in classrooms. I felt that these maps were useful to my students, and research in this area would allow me to evaluate their actual utility. This became the foundation of my master's thesis. I was also interested in differences in the effects of teaching in an STS manner as opposed to a transmissive manner. I was intrigued by some of the gender differences I had observed when my students were concept mapping, and I was curious about how concept maps compared as an assessment tool to more traditional assessment forms. I realised that free-form concept maps could enable me to explore all of these questions.

Statement of the Problem

In this study, I investigated the use of concept maps with my Grade seven Science class. I was interested in the general research question:

- What do concept maps tell us about Grade seven students' understanding of Science?

A number of more specific research questions were also of interest to me at the outset of this study:

- Are concept maps a useful tool in assessing student understanding of Science? What do they show and how does this relate to "traditional" assessment tools?
- Do students' concept maps reflect instructional approach, i.e. traditional versus STS-based instruction? And if so, how?
- Since girls and boys are believed to approach learning Science differently, do grade seven girls' and boys' concept maps reveal gendered ways of understanding Science?

Definition of Terms

In education, as in many disciplines, language and terms are used to convey meaning in particular ways. In this section I define a number of terms that I use throughout this thesis and provide a brief explanation of how these terms are being used.

Constructivism – Constructivism is a view of learning that claims that learning involves students building their own understanding by assimilating or accommodating new ideas with what they already know (Duffy & Jonassen, 1992). This view of learning has direct implications for teaching. It emphasizes teachers should design lessons that assist students in making connections and generating their own, individual meaning and not on regurgitating the "right" answer based upon memorization. The majority of the information learned is retained because it has been integrated into the learner's matrix of previous knowledge due to its relevance to the learner.

Concept maps – Concept maps are a graphical tool for representing knowledge. They consist of concepts connected by links explaining the relationships that exist between concepts. A node is a focal point on a concept map where a key word, concept or idea is indicated, positioned in a box or bubble. Nodes serve as a point of connection. (Ruiz-Primo & Shavelson, 1996). A link is some text that describes the relationship between a set of two nodes. Links can be drawn as vector arrows that show the direction of the relationship or clarify the meaning of the text. Links can be bidirectional if the relationship between two nodes is the same in each direction or unidirectional if the relationship indicated is only sensible when considered by moving from one concept to another in a particular direction

(Ruiz-Primo & Shavelson, 1996). The words, phrases, or sentences on linking statements indicate how the concept mapper understands the relationship between various ideas and illustrates the interconnectedness of the concepts. (Mayer-Smith, 2003a; McClure, Sonak, & Suen, 1999; Novak, 1998, Ruiz-Primo & Shavelson, 1996). Concept maps have been discussed in the literature as occurring in two forms: hierarchical and free-form.

i. **Hierarchical concept map** – This term refers to a concept map that is organized into a tiered structure so that the larger, general concepts are placed at the top, or bottom, of the map page, and the more detailed, specific ideas that come from that central idea are placed further down, or up, on the map in order of increasing specificity (Novak, 1998). This results in the production of a tree-like structure. Hierarchical maps are useful for illustrating the mapper's views on the importance of the concepts by examining their position on the page.

ii. **Free-form concept map** – This term refers to a concept map that is unstructured; there is no hierarchy imposed upon the organization of the ideas (White & Gunstone, 1992). There may be one major concept at the centre of the map, or some other point, on the map that acts as a hub for linking the ideas, but even this level of organization is not necessary. This type of map is generated in a free-flowing manner; the creator can work with a set number of nodes and links these or can add additional nodes and links as needed to better represent their understanding. Use of this map form has not been heavily researched.

Science, Technology and Society (STS) – STS is an educational approach to teaching Science where the connections between the interdependent nature of Science, technology and society are explored so that the effect each has on the other can be identified and the effect on our own lives of this triangular relationship can be explored by students. The aim of STS teaching is to help students become well-informed, critical learners who will be capable of playing an active role as citizens of this planet. (Ben-Chaim & Joffe, 1994; Cross & Yager, 1998; Weeks, 1997)

Transmissive teaching – Transmissive teaching is a teaching approach in which the teacher transmits information and the student receives. Students are expected to learn the material presented because they have been asked to do so. They are expected to be able to give back the "correct" answer on tests and worksheets. This teaching approach is dominated by teacher-led activities and emanates from the behaviourist learning tradition (Duffy & Jonassen, 1992).

Significance of the Study

This study focuses on concept mapping to determine if concept maps are a useful tool to assess student knowledge and understanding of Science. I investigate the concept maps in order to examine growth in student understanding over the course of a unit, understand how new knowledge is being integrated with students' previous conceptions, illuminate how students' structure their knowledge – in a densely, interconnected web or in fragmented, isolated pieces – and reveal if different teaching approaches influence students' knowledge framework. There are many studies that investigate the use of concept maps to determine what information has been learned, how that information can be assessed, if the assessment valid, what type of concept mapping activity is the most useful, what students' attitudes towards concept maps are, and how concept mapping activites impact student achievement (Barenholz & Tamir, 1992; Campbell et al., 1996; Kinchin, 2000; Mintzes, Wandersee, & Novak, 2001; Novak, 1991; Okebukola, 1992; Weeks, 1997; White & Gunstone, 1992). These studies use concept maps as assessment tools, but they don't assess the utility of concept maps from the teacher's standpoint. Further, there is little published information on what the free-form style of concept maps show about the nature of student understanding. In my study, I use free-form maps to explore student understanding, investigate gender-related differences in student understanding, determine if differences in instructional approach are reflected in map format, and assess the utility of these maps as an assessment tool. This study will extend understanding on the utility of concept maps by providing information for other researchers and practitioners on how mapping can be used to explore the nature of grade seven students' understanding of Science.

CHAPTER 2

LITERATURE REVIEW

My study deals with three separate areas of education literature: concept maps, instructional approaches and gendered learning in Science. Before I could use concept maps as a tool in my study, I needed information about their use in other studies. I also examined the literature on teaching approaches to ensure I had a proper understanding of the differences between traditional and STS-influenced teaching. Finally, I surveyed the gender and learning in Science literature for evidence of gender-related differences in learning Science. These three fields of educational research literature provided the foundation that enabled me to frame my study.

Concept Maps

In reviewing the literature on concept maps and concept-mapping activities, I sought to answer several questions: what is known about their construction, what constitutes a good concept map, how have maps been used, and what are student attitudes towards concept maps? These questions and the research I studied assisted me in determining the parameters for concept map usage to implement in my study.

Novak (1977) developed the concept map almost thirty years ago. Concept maps helped to "show how someone sees the relationships between things, ideas, or people" (White & Gunstone, 1992, page 15). Concept maps are a graphical mode of representing knowledge where key words are presented in boxes referred to as nodes, the focal point on a concept map that serves as a point of connection. Nodes are connected together by lines which are referred to as links. Text is written on the links to show the relationship between various nodes, showing the interconnectedness of the concepts. Links can include arrows to show the direction of the relationship and clarify the meaning of the text written as a linking statement. A "good" concept map should have multiple connections between the nodes, and link statements should contain a good degree of detail and be logically organized; a "poor" concept map would appear to be linear or chain-like, with few links between key words, and the link statements would contain little or no information (Novak, 1998, White & Gunstone, 1992).

A serious learning problem observed by Novak (1991) is that "students learn to memorize definitions of concepts ... but fail to understand ... the relationships designated by the concept labels or formulas" (page 45). If knowledge is not embedded in a student's mental framework, the information is not useful (Weeks, 1997). In having to construct their own, personal concept map, students can find new ways to relate ideas together and discover new meaning in their ideas; as a result, the learning is meaningful and will last longer (Kinchin, 2000; Novak, 1991). I have observed both the learning problem observed by Novak and apparent increase in knowledge retention resulting from concept map usage in my classroom. Both of these observations provided inspiration for this study.

Concept maps assume one of two forms: hierarchical or free-form. Novak's original maps were hierarchical in their design and organization. The most central ideas are placed at the top of the concept map page; key words are shown in order of increasing specificity and decreasing importance below the central idea (Novak, 1998; White & Gunstone, 1992). Free-form maps are rarely mentioned in the literature but are intimated to have no imposed organizational structure; students begin these maps with whatever key idea seems the most appealing and continue adding concepts to the map in an organic manner (Bishop et al., 1997). I have chosen to use free-form concept maps in my classroom and for this study due to the flexibility and freedom they provide students in mapping activities. Also, free-form concept maps reveal individual students' understanding.

Mapping activities can be conducted in a variety of ways. Some educators provide key words and linkage phrases to assist students. Others may suggest lists of key words, or not provide key words at all (McClure et al., 1999; Novak, 1998; White & Gunstone, 1992). Although maps that have key words and link phrases pre-formulated have a higher degree of conformity with a teacher's master map, maps with only the key terms provided are deemed to be better at showing the individual student's understanding, knowledge structure, and misconceptions (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005).

Campbell, Campbell, and Dickenson (1996) indicate that concept maps are an excellent learning tool because they encompass many recall-enhancing factors; "key words are noted, associations and relationships are highlighted, conscious involvement is required, and subjective visual organization is imposed" (p. 106). These benefits apply not only to learners in the visual-spatial intelligence spectrum but also to the majority of students (Barenholz & Tamir, 1992; Campbell et al., 1996). The wide acceptance of concept maps as a useful pedagogical tool is evident by the numerous textbooks, written for both teachers and students, that recommend concept mapping as a learning activity (Bishop et. al, 1997; Chan et al., 1997; Novak, 1991).

Additionally, concept maps enable exposure to the student's prior knowledge, allowing the student to visualise what needs to be learned and, potentially, how that information can expand and support her/his current understanding of the topic (Barenholz & Tamir, 1992; McClure et al., 1999; Weeks, 1997). Okebukola (1992) found that concept mapping activities are beneficial regardless of whether the maps are generated by students as individuals or in groups. What is less clear from Okebukola's statement, however, was whether individual or group map generation is most effective. Because I was interested in tracking each student's individual progress, I opted to use individually generated maps in this study.

Maps have been used for student assessment in a variety of ways (Barenholz & Tamir, 1992; Kinchin, 2000; McClure et al., 1999; Mintzes et al., 2001; Ritchie & Volkl, 2000; Roberts, 1999; White & Gunstone, 1992). When generated at the beginning of a unit, maps can be used as a pre-test, enabling both student and teacher to identify what prior information, or misinformation, the student brings to the unit. Maps generated at the end of a unit can serve as summative evaluation. White and Gunstone (1992) note that comparing pre- and post- unit maps can show, not only the teacher but also the student, the amount of progress that has been made over the course of the unit, enabling both to learn about the development of the student's knowledge.

A major advantage of using concept maps for assessment is the fact that their open nature allows teachers to examine the individualistic and idiosyncratic structure of each student's knowledge (Kinchin, 2000; McClure et al., 1999; Mintzes et al., 2001). However, because of the subjective and personal nature of the concept maps, there are challenges associated with their use as a component of formal assessment (McClure et al., 1999). Novak and Gowin (1984) suggest maps can be meaningfully scored for evaluation purposes if examined for the number of links between concepts and the degree to which the links contain meaning. However, Campbell et al. (1996) caution that assigning a letter grade may result in students focussing on getting "the right answer" which can be counter productive. In my classroom practice, I have found that formally assessing the maps induces anxiety in many students that can constrain or even inhibit their ability to create a map. As a result, I do not assign a grade for my students' maps.

Researchers (Novak, 1998; Rye & Rubba, 2002) agree that the most revealing parts of concept maps are the text statements describing relationships between key concepts. However, scoring the maps to determine the quality of what students have presented in the links on their maps is difficult. McClure et al. (1999) discuss the challenges faced by teachers and researchers when assessing the quality of students' maps. In their study, they examined the efficacy and validity of three scoring methods. The holistic method judges concept maps in their entirety, but this method is mentally demanding for the assessor. The structural method rates maps upon their hierarchical organization. Although this method provides more guidance for markers, it's still cognitively complex. The final method, the relational manner, is the most structured as each individual link is scored independently. According to McClure et al., this method is the easiest for teachers and researchers to use and provides the best reliability of the three methods. Many educators use the relational scoring method, and I have also chosen to use it for my study.

The relational scoring method can be conducted in two ways: with or without a master concept map. Traditionally, most educators use a master concept map. This master map is created by the teacher and is based upon the class material or information in the textbook. Teachers assess their students' comprehension and understanding by scoring the maps using the relational manner described above. Students are told that they need to construct a map that includes as much content as possible and that their map will be scored against a master map. A student is usually awarded full marks if they are able to generate

75% of the links that the teacher has identified (Mayer-Smith, 2003b). These concept maps can function as a replacement or alternative to traditional quizzes.

White and Gunstone (1992) discuss relationships between concept maps and test scores. If a student produces a simple map and receives a low test score, this suggests that the student doesn't understand the material. The researchers' explanation is that the simple map would be indicative that the student doesn't understand the relationships between the key terms and, thus, would perform poorly on a test dealing with the same concepts. A simple map with a high test score may indicate that the student manages to do well with memorization but cannot articulate their understanding on the concept map. Producing a complex map and achieving a high test score intimates that the student has a deep understanding of the material and recognises the concept relationship.

Concept mapping activities can have multiple benefits for students. Novak (1991) claims that producing complex concept maps is a useful skill for students and can contribute to meaningful learning. Barenholz and Tamir (1992) conclude that academic performance increases significantly when concept maps are used as a component of that unit. Students who are active concept mappers are often significantly better problem solvers than non-mapping students (Okebukola, 1992; Tekkaya, 2003). Okebukola (1992) claims that concept maps help students to process information and mentally organize facts and knowledge in a manner that facilitates the application of that knowledge at a future time. Metacognition is also encouraged in the concept mapping process and students are better equipped to tackle new or unusual problems that cannot usually be solved by regurgitating facts (Okebukola, 1992). Other researchers indicate that if concept maps are generated before engaging in hands-on, manipulative activities, the knowledge learned will be retained for a longer period of time (Ritchie & Volkl, 2000).

Although students describe the process of constructing a concept map as difficult, they do acknowledge it to be quite beneficial, particularly for understanding challenging concepts (Barenholz & Tamir, 1992). Barenholz and Tamir (1992) suggest it is important to introduce this activity when students are young so that they accept concept mapping as a normal part of their classroom activities. There can be resistance to concept mapping if the activity is introduced to older students who are more set in their learning approaches. Santhanam, Leach, and Dawson (1998) found that although older students can recognise the advantages of using concept maps, few will actually take that knowledge and put it into practice by using concept maps as a part of their regular revision strategies.

Researchers do advise that concept maps should be used sparingly. McClure et al. (1999) comment that due to the intense mental energy that is required in constructing a good concept map, if students generate them too often, they will start creating less detailed maps and stop putting in so much effort. As a result, the maps may under-represent the actual knowledge that the students have, and the students may come to dislike the activity because of the mental exertion it requires.

Most research to date has focussed on the use of hierarchical concept maps. My study will explore a different area of concept mapping as it provides information about the use and utility of free-form concept maps. While these maps allow students the most freedom in their creation little is known about how and what types of information the students are integrating in free-form maps. My study will begin to examine these issues.

Teaching Approaches

Transmissive teaching

Transmissive teaching is a catchphrase that sums up teaching practices embedded in behavioural learning theory. Behavioural learning theory has influenced and informed a great deal of teaching practice, specifically lesson organization and specificity in learning outcomes (Davis, Sumara, & Luce-Kapler, 2000). Over time, strict behaviourist practices have become influenced by, and incorporated a variety of cognitive beliefs and practices, resulting in pedagogy that is referred to as teacher-directed instruction or transmissive teaching (Weeks, 1997). Lessons involve large-group, teacher-led instruction, teacher-selected activities, coverage of a large number of intended learning outcomes, breaking down concepts into small lessons, frequent student feedback on the progress of completing specific objectives, and leading students through to completion of a series of structured activities (Davis et al., 2000; Weeks, 1997). While teaching in this way can be used to generate student success in a variety of situations, it also leads to students adopting "non-conscious processes and automaticity in learning" (Davis et al., 2000, p. 59).

The learning outcomes, in the Provincial Science curricula of British Columbia, are phrased in terms of observable student behaviour: "students will be able to …" observe, measure, record, describe, define, list, etc (Weeks, 1997). Due to the time constraints of teaching a curriculum that is replete with required learning outcomes, many teachers (myself included) use transmissive teaching because it allows them to manage the pacing of the units' content, and address the entire curriculum. Students are successful in transmissive classrooms for two reasons. One reason is that students learn early in school how to do well in this structure through frequent exposure to it. Students appreciate the clear guidelines and stated requirements as these narrow the body of knowledge they need to learn. The other reason is that transmissive teaching encourages and supports mechanistic memorization which students find easy to do, as it requires little conscious processing of the information (Davis et al., 2000).

Although students learn to be very successful in behaviourist-grounded Science programs, there are some factors of this approach that "turn students off" from Science. Yager and Lutz (1995) identify six problems resulting from this form of pedagogy: an excessive focus on the textbook; too much emphasis on the pre-requisite knowledge or skills; little or no relevance to students as individuals; complete teacher-centredness; emphasis on knowing facts and little focus on being able to apply knowledge to other problems; and a view of Science as something that only requires a lab, teacher, and a textbook. Taken together these elements can result in students not learning the material on a deeper level. However, as it is the teacher's responsibility to present the full curriculum to the students, even though most teachers would prefer to emphasize learning the material, transmissive teaching is appealing and practical. Further, given the nature and number of the ILOs in BC's Science curriculum (see examples in Appendix C), it is often difficult to implement an alternative approach.

Science, Technology, and Society (STS)

The Science, Technology and Society movement developed out of the constructivist ideal that learning occurs when students are able to construct their own meaning by linking new information to themselves and their own experiences (Aikenhead, 2003a; Barenholz & Tamir, 1992; Eijkelhof, 1994; Weeks, 1997). Knowledge is pieced together and processed according students' own experiences (Davis & Sumara, 1997, Weeks, 1997). "The learner's basis of meaning is found in her or his direct experience with a dynamic and responsive world" (Davis et al., 2000, page 65). Novak (1991) claims that as individuals construct their own meanings based upon what they see around them, linking two or more ideas together provides a statement or definition of our experience with the world around us. Thus, in order to learn new material or facts, new constructs must be generated (Novak, 1991).

The STS teaching approach emphasizes examining the connections and links that occur between areas of Science, technology, our own society, and the world around us (Aikenhead, 1994; Aikenhead, 2003b; Bybee 1985; Eijkelhof, 1994; Fensham & Corrigan, 1994; Gaskell, & Hepburn, 1998; Solomon, 1994a). The elements of STS have been defined by Bybee (1985):

> Science – A systematic, objective search for understanding of the natural and human world. A body of knowledge, formed through continuous inquiry. Science is characterized by the use of an empirical approach, statements of generality (laws, principles, theories) and testing to confirm, refute, or modify knowledge about natural phenomena. (p. 86)
>
> Technology – The application of scientific knowledge to solve practical problems to achieve human goals. A body of knowledge, developed by a culture, that provides methods or means to control the environment, extract resources, produce goods and services, and improve the quality of life. (p. 86)
>
> Society – The collective interactions of human beings at local, regional, national, and global levels. Human groups whose members are united by mutual interests,

distinctive relationships, shared institutions, and common culture. The human setting in which the scientific and technological enterprise operates. (p. 86)

It would be a mistake to understand STS to be a unified field; it is not. STS has multiple strands and each strand has its own focus – some are more technological while others are more environmental; each strand has its own goals, agenda and value (see e.g. Aikenhead, 1994b; Aikenhead, 2003b; Hughes, 2000; Pedretti, 1996; Ziman, 1994). Ziman (1994) describes seven approaches to STS teaching: relevance, vocational, transdisciplinary, historical, philosophical, sociology, and problematique (p. 31). Researchers (Aikenhead, 1985; Ben-Chaim & Joffe, 1994; Eijkelhof, 1994; Fensham & Corrigan, 1994; Knamiller, 1985; Solomon, 1985) propose that STS is shaped by four main goals:

1. to present students with a fundamental understanding of the knowledge and processes inherent in natural science and technology
2. to develop student skill in problem-solving, critical thinking and related activities
3. to prepare students to take the responsibility of becoming active, decision-making citizens
4. to promote skills that will allow students to examine the multi-faceted relationships between science, technology and society.

STS-based teaching has been described as one approach that encourages students to examine aspects of their daily lives and analyse how they are related to Science, Technology and Society (STS). STS activities develop not only problem solving and critical thinking skills, but also attitude development, resulting in scientifically literate and critical learners (Aikenhead, 1994a; DeBoer, 2000; Fleming, 1985; Gaskell, 2003;Layton, 1994; Lucas, 1994; Solomon, 1994b; Solomon, 1987; Weeks, 1997; Yager & Brunkhorst, 1987). In STS classes, students are involved in active learning: making decisions about potential solutions, weighing up the costs of various proposals, and integrating multidisciplinary skills and knowledge (Carlson, 1985; Hickman, 1985; Solomon, 1994c; Yager & Lutz, 1995; Yehudit & Tal, 1999). Allowing students to study areas that relate to their personal interests and experiences is believed to result in greater long-term learning as the information can be easily added or adapted to their existing mental matrix (Aikenhead, 1994a; Aikenhead, 2001, Brunkhorst, 1985; Cross & Yager, 1998; Duschl, 1985; Mbajiorgu & Ali, 2002; Nashon, 2004; Solomon, 1994a; Thier & Nagle, 1994; Weeks, 1997; Yager & Lutz, 1995).

There are different ways that STS can be brought into the classroom. It can be: added to and infused into lessons, activities or units; used to generate a separate Science course; or serve as a lens for teaching Science to students (Aikenhead, 1994bb; Brinckerhoff, 1985; Jarcho, 1985; Layton, 1994; Pedretti, 1996; Solomon, 1994c; Yehudit & Tal, 1999). Adding STS material seems to be the most common approach in schools, as not all areas of the current Science curriculum can be meaningfully replaced with an STS emphasis (Pedretti, 1999). This is the approach I have used in my Science classroom. While it is easy to get students to personally relate to the environmental impact of chemical pollution, it is more difficult to link the relative temperature of stars or the properties of a black hole to their own experiences.

My study builds upon previous STS research. The classroom-based design will contribute information on the integration of STS into upper elementary Science, which, Layton (1994) pointed out, was a new area for STS implementation. Solomon (1994c) also indicated the need to understand "how it feels to be a student learning this new subject" (pp. 187). In my study, by using concept maps, I investigate student experiences and attitudes towards learning Science. Although my Science teaching is influenced by behaviourist philosophy – structured units, reviewing the material multiple times, frequent assessment and feedback – my instructional approach varies depending on the nature of the subject matter in the unit I am teaching.

The IRP's demand that content of the Chemistry unit be focused on the environmental effects of Chemistry. Through class discussions in the Chemistry unit, I try to emphasize the relationship between the unit content, the students, their lives, and their personal experiences. Thus I believe my teaching approach in this unit is consistent with the basic principles and goals of the STS movement. The Astronomy unit, however, contains topics that I find more challenging to relate to students' lives or experiences. As a result, I notice I teach the material in a more transmissive manner: these-are-the-facts-so-learn-them. Given the research indicating how students learn according to what instructional approach is used, I decided to conduct a study exploring if my teaching approaches and students learning approaches would be reflected in concept maps.

Gender and Science

Through my initial survey of Science education literature, I became more aware of gender-related differences in learning Science and wondered if and how those might be reflected in the students' concept maps. I was intrigued by the information on gender and attitude toward Science and perceptions of a gendered nature of different Science disciplines. These points informed my decision to include a gender investigation in this research study.

The research suggests that in overall achievement, gender differences are apparent by age 10, with the boys performing better academically in Science than the girls (Keeves & Kotte, 1996). The gender gap increases as the students progress through high school (Keeves

& Kotte, 1996). In addition to surveying academic performance, Keeves and Kotte (1996) investigated students' attitudes towards Science. The researchers discovered that girls have a less favourable attitude towards Science than the boys; this gendered difference in attitude increases as students go through high school. The researchers also noted that girls perceive Science as more difficult than boys, which may be linked to their less favourable attitude towards and performance in Science. However, as Keeves and Kotte noted (1996) these gender-related differences in both attitude and performance appear to be decreasing in Western countries.

Researchers investigating middle school students' attitudes and academic achievement discovered that for boys there was a strong correlation between their academic performance and their attitude towards Science (Mattern & Schau, 2002). The research indicates that boys who like Science perform well in Science class and those who don't like Science perform poorly in their Science courses. For girls, the relationship was less clear-cut, as their attitude towards the subject was not linked to their academic achievement in Science class (Mattern & Schau, 2002). The researchers found no relationship between the grades earned by girls in their Science class and the degree to which the girls "liked" Science. Girls who performed well in Science class liked and disliked Science in equal numbers. The same split in attitude towards Science was true for girls who performed poorly in Science class.

Boys and girls have gendered attitudes about the disciplines of Science (Taber, 1992). Boys consider Biology to be a less masculine and more feminine discipline (Hofstein & Cohen, 1996; Keeves & Kotte, 1996; Soyibo, 1999). Boys and girls consider Physics to be predominantly male in orientation, whereas they perceive Chemistry as being gender neutral (Hofstein & Cohen, 1996; Keeves & Kotte, 1996; Qualter, 1995). However, as Taber (1991) points out, the perceived gender-subject relationship could be an artefact of what topics and activities students find engaging; boys enjoy building models and solving physics based challenges whereas girls enjoy discussing and investigating aspects of human physiology and health. Thus, some researchers believe students' perception that subjects are feminine or masculine might stem from their socialization during childhood (Keeves & Kotte, 1996).

However, there is still much debate around the existence of, and reasons for, gendered approaches to learning Science. A variety of reasons are cited to account for gender differences. Traditional roles for men and women; society's attitudes as to what each gender can do; socialization with gendered toys at a young age – girls engage in play with dolls while boys play with technological based toys such as trains and blocks; boys exhibiting more aggressive behaviour and blocking girls from developing practical Science skills; and teacher expectations based upon their own socialization, have all been put forward as explanations (Gaskell, Hepburn, & Robeck, 1998; Keeves & Kotte, 1996; Weeks, 1997).

Gender differences in performance in Science may be related to boys and girls appearing to have different types of academic skills. In problem solving, boys tend to do better on practical-oriented, open-ended tasks; girls are better than boys in solving fixed-end problems (Okebukola, 1992). Soyibo (1999) found that girls were better at concrete Science activities such as labelling diagrams compared to their male classmates. She (2001) found that in high-achieving classes, boys dominated the girls in asking questions and obtaining answers and feedback; however, in low-achieving classes, the girls asked their teachers more questions than the boys.

Yager and Lutz (1995) found that although all students in elementary school enjoy Science and have a favourable attitude towards the subject, there is a marked decrease in the number of students who like Science in high school. This is true for both girls and boys. Whether students' enjoyment of elementary school Science is due to its hands-on nature and their antipathy to high school Science is due to the abstract and clinical nature of the topics is difficult to determine. Rose (1994) claims that many girls are turned off by traditional Science because girls feel there is no place for their emotions in a detached and objective course. She suggests that an approach that incorporates "practices of the hand, brain and the heart is a softer and gentler way into the natural and social worlds" (p. 166). Observations of Science classes taught with an STS approach support Rose's argument. Boys and girls both enjoy discussing the social implications of Science-based issues, but when such discussions are omitted from Science, girls, more than boys, feel disinterested in and disconnected from the material (Eisenhart & Finkel, 1998; Solomon, 1994c). Unfortunately, there is no equivalent explanation for boys' changing interests in Science. Further research is needed to understand how girls and boys approach learning Science in the classroom and whether an STS approach can reduce the gender gap.

Solomon (1994c) found that gender differences were revealed in the type of language used by boys and girls in Science activities. Girls' used language that phrased opinions and expressed their concerns and needs: "we must look for ... I think that ... people are worried about" (Solomon, 1994c, p. 145). Boys tended to use very impersonal, objective, and classically "scientific" language in their work: "methods of disposing of... Scientists are looking for ... Alternatives... are being looked into" (Solomon, 1994c, p. 145). As Solomon's research indicates that gender differences are evident in students' language usage on assignments, I anticipated that similar differences may be revealed when I analysed the type of content and language used by boys and girls in my class in concept map linking statements.

The literature indicates that by grade 7, boys and girls approach Science differently and find different aspects of Science appealing. Examining two units – one that is taught with an STS-based approach and one with a transmissive approach – allowed me to inspect how students engaged in Science classes that focussed on personal relevance versus those that focussed on the objective and distant aspects of Science. The findings of this study contribute to the debate on gender and Science.

Summary

My study builds upon and extends the research into students' understanding of Science on concept maps to investigate student understanding. My study examines units on Astronomy and Chemistry, which seem to be perceived as gender neutral. While research indicates that many high school students dislike Science, there is evidence students would be more interested in Science if a teaching approach, such as STS, were used, since it emphasizes the relationship between Science and students' lives. The two units that form the focus of this study were taught using different teaching approaches and research was conducted to see if students' responses differed in relation to the instructional approach. Concept maps appear to be an ideal tool for this type of an investigation. I selected the free-form format that had not been well studied or documented. Research indicates that concept maps, particularly the free-form maps, are an excellent tool, for probing student understanding. Additionally, the language used in the linking statements was analysed for potential gender differences. While previous studies investigated the "correctness" of students' concept map responses, this study investigated changes in student understanding over time. It also contributes to knowledge of gendered aspects of learning Science.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter I describe the students and school where the study was conducted. I describe how concept mapping was practiced by the students in my class, describe and explain how the data were collected and analyzed to answer my research questions. I conclude this chapter with a brief discussion of the limitations of my study.

General Purpose and Objectives of the Study

The overall purpose of my study was to determine what concept maps could tell me about grade seven students' understanding of Science. As concept maps are a recommended strategy in many textbooks and teacher resource books, the assumption that concept maps reveal student understanding was not examined in this study.

The specific research questions I investigated were: 1) what do the maps tell about student understanding of Science? 2) are concept maps a useful tool in assessing student understanding? 3) is instructional approach reflected in students' concept maps? 4) do concept maps reveal gendered differences in understanding Science? These research questions evolved through the process of conducting my study and examining the data. Initially, my research focussed only on the impact of teaching style on student learning. Concept maps were simply the tool I chose to assess student learning. However, over the course of the study, I discovered that concept maps themselves were exciting and worthy of an in depth study in and of themselves.

Context, Setting, and Participants of the Study

This study was conducted at Sunshine Academy (a pseudonym), a small independent school in a suburb of Vancouver, British Columbia. The school has students ranging in age from three year-old pre-schoolers to eighteen year-old Grade 12 students. The students have a broad range of socioeconomic and ethnic backgrounds. Additionally, the students enrolled at the school have academic abilities that cover the full spectrum from low to very high academic performance.

In 2003-2004, I taught two classes of Science 7 at Sunshine Academy. Each class had 19 students, for a total of 38 students in all. These students participated in my study. The school administrator randomly assigned students to each class. I asked the administrator to timetable the two blocks of Science 7 consecutively because I felt it would make it easier to teach both classes in as similar a manner as possible. The same content was taught to each class with essentially the same activities and examples.

My study involved regular classroom practice; there was no control or experimental group. Although there were 38 students that I taught in Science 7, data were included for only 16 of the 38 students (seven boys and nine girls). This was due to three factors: not all the participants returned their ethics permission forms, not all families gave consent, and not all students were present for all the days that data were collected.

Concept Map Use in this Study

For my study, I had my students complete three free-form concept maps for each of two Science units to track the development of their understanding in each unit. I engaged the students in concept mapping activities as we began each unit, a second time when we had gone through the content information in the textbook once, and a third and final time at the end of the unit, after the final unit test had been written.

The students were asked to prepare a concept map at the beginning of each unit in order to assess their prior knowledge for each unit of study. As the British Columbia K-7

Science curriculum is intended to be "spiral" in nature, I expected most students to have some Science content knowledge relating to the unit topic before they entered my class. Additionally, the content in grade seven Science covers topics that many students of that age may have interest in and experience with outside of school (e.g. volcanoes, space, nature, the environment, acids and bases). This reinforced, for me, the need to see what my students had previously learned or thought about the topic.

My students were asked to construct a second concept map halfway through the unit, when all the Science content material for the unit had been introduced through textbook readings and classroom discussion, but before the material was reinforced with activities and test preparation. This was done to see how much information the students had acquired, or remembered from previous learning, since the start of the unit.

Students prepared a third and final map at the end of the unit of study, after the unit test had been administered. I wanted to see if the students' grasp of the material had improved by being exposed to the material twice in class and a third time in studying at home for the unit test. This allowed me to examine the generally accepted assumption that students increase their understanding of a topic through repeated exposure to and examination of the required information.

For each concept map, students were presented with a sheet which had a pre-selected list of 15 words taken from the three textbook chapters that encompassed the instructional unit. Mapping instructions were included on the page so that the students didn't need to keep checking with me to make sure that they were doing things "right". At the beginning of each concept mapping session, I would read out the instructions, re-iterate that I wanted to see what they (the students) themselves knew and how they put things together. Also, I reminded my students that they were allowed to add as many other words as they wished or needed. More detailed information about the units of instruction and the concept mapping process are included in chapter four.

Data Collection Methods

Every student constructed concept maps as a part of regular teaching and learning practices in my course. As standard practice during the course of the school year, I collected the concept maps to see that they were completed, but I did not grade them. This procedure was followed to help reduce anxiety that was expressed each year by many students, who felt that they did not know how to complete a "correct" map. Once I had collected the maps, I made a photocopy of them. The girls' maps were copied onto pink paper and the boys' maps were copied onto blue paper to enable gender comparisons. Numbers generated from a random number table were used to create numbered labels, and these labels covered the students' names. The code was recorded by a non-involved third party and was not revealed to me until after the course and the study had been completed. This procedure was followed to assure that I had no idea which students had agreed to be involved in the study. Thus willingness to participate could not influence my work with students in the classroom or my analysis of the data. The data that were included in this study came from students who consented, completed the appropriate documentation, and had completed all six of the concept maps (three per unit) in this study. In my results section, the students are referred to using a pseudonym to assure their anonymity.

Methods of Data Analysis

For this study, I performed a qualitative analysis of each student's concept maps. Given the diverse nature of the free-form concept maps generated and the wide range of abilities of the students included in this study, a strict quantitative analysis would have been difficult. Further, I believed the rich detail provided by a qualitative analysis would help me to answer my research questions.

To make sense of the data I looked at each map individually, as a distinct entity. I examined the maps and analysed each one on the basis of four criteria: the number of words used as nodes in the map – both from the list and new words; the number and size of the maps that were generated; the number and nature of the links created in the map – non-worded links, one or two word links, and multiple word links; and, most importantly, the scientific content of the linking statements. A summary of my analysis is shown in Tables 3-10 in Appendix F.

A number of assumptions guided my analysis and the interpretation of my findings. First, I assumed that if a student used a given word from the list in the map, this indicated some degree of familiarity with the term and the concept. This degree of familiarity ranged from passing recognition to an in-depth comprehension of the concept. I also assumed that the greater the number of words chosen from the list, the greater the understanding of the subject by the student. Taken together, my assumptions were that if the student was capable of recognizing the terms and concepts and using them in their map, then the student had some degree of comprehension of their meaning and significance.

I further inferred that when a student added additional node words not on the assigned list to the map, this indicated that the student had recognized or experienced a sense of connection between the key content and ideas that they regarded as interesting or relevant to themselves. I felt this act of adding additional terms personally selected was significant as research suggests that if the student sees relevance in the subject matter, they will be more motivated to learn and more likely to retain knowledge (Davis et al., 2000).

For my analysis of the structure and form of the concept maps, I categorized the maps into three sizes: small – containing one to three nodes; medium – having four or five nodes; and large – comprising of six or more nodes. As the number of nodes increases, there are a greater number of possible relationships that can be identified. Small maps with few nodes and limited linking statements were assumed to be indicative of more limited knowledge and understanding. Larger maps were taken to indicate better comprehension of the material.

Although students were asked to create one concept map with the 15 assigned terms, in many instances they would create multiple smaller maps. For any assigned map activity, students either created one large map or a set of smaller ones. When students created a set of small maps, it was taken to indicate that the student was aware of some of the relationships between the concepts but could not see the larger picture or express how all the ideas were linked. The production of one large map was interpreted to indicate that the student had grasped the big picture and thus understood how to integrate the concepts into a whole. Medium sized maps were interpreted to mean that the student could categorize the information into two or three major groupings, but could not make the leap to see how those bigger categories were linked.

Analysis of the number and type of linking statements included in the map provided me with insight into the student's understanding of the units addressed by the concept maps. Non-worded links were taken to indicate that either the student was simply randomly drawing lines to connect the words together in an effort to generate a map, or that they could recognize that there was a relationship between the nodes but they were unable to articulate what the relationship was. These are quite different outcomes but the mapping activity did not help me to distinguish between them. Links of one or two words that consisted of simple phrases such as "and", "and the", "are also", "is a", "like a", etc. were interpreted to indicate the student can see and articulate simple relationships: "**stars** – *are in* – **constellations**"[2]. These types of links were also used to organize words into groups or chains, in very simple maps. Multiple word links consisted of three or more words or phrases that were generally descriptive and more informative. Such links were observed to articulate a more detailed relationship between two nodes indicative of deeper understanding: "**constellations** – *are specific patterns made up of lots of* – **stars**".

For data analysis purposes, the scientific content of the links was scored on a 0-3 scale. Links earning a scale of 0 contained no words. Links that contained a "few words with little or no scientific meaning to the nodes" earned a score of 1. Links earning a score of 2 illustrated concrete scientific knowledge in the context of linking statements between the nodes. Usually, such linking statements contained definitions or bits of trivia. A score of three was only assigned if the link indicated in-depth or reflective scientific understanding that went beyond a simple definition found in the textbook.

I also examined each map in relation to the other two maps generated by that student for a given unit. The first, second, and third concept maps from each unit were compared so that trends through the course of a unit could be detected. I looked at the maps to determine if the number of links increased as the unit progressed, if more key words were used, if extra words added, etc. The data were examined for evidence of specific trends and coded to

[2] The convention of using bold face and italics is to aid the reader in distinguishing between the nodes and the linking statements on the concept map. Nodes are written using bold face, and the linking statements are written using italics. The dashes emphasize the distinction between the linking statements and the nodes.

indicate increases or decreases in each trait from one map to another. Results were recorded in Tables 3 through 10 in Appendix F.

I investigated differences in the concept maps produced during the Astronomy and Chemistry units. To answer the question of whether instructional approach is reflected in concept map construction, I examined the data from the maps and compared the number of maps, number and types of linking statements, scientific content of the links and map structure in maps created for my Astronomy unit with maps for my Chemistry unit. I conducted these analyses to investigate what, if any, differences in the teaching methodologies were revealed in the concept maps.

Next, I analyzed the concept maps to see if the concept maps revealed differences in understanding of Science between boys and girls. This involved looking at both the Astronomy and Chemistry map sets for evidence of gender differences. My experience suggested that generally girls are better at seeing connections and making links between ideas, whereas boys are better at remembering facts. I was curious to see if this experience would be supported by variations in the maps produced by girls and boys in my classes.

Finally, to explore relationships between concept maps and assessment, I examined scores earned by the students on their vocabulary quizzes and unit test scores and compared these with the concept maps. I was interested in seeing if there was a relation between the level of information encoded in the concept map, particularly the final map, and performance on the unit test score. I expected to find that students who did well on the unit test should have very detailed maps and vice versa. This aspect of analysis took place after the course instruction was completed. At that time, it was discovered that the school's database from the

2003-2004 school year had become corrupted. Chemistry unit marks were unavailable and only the Astronomy test data could be recovered and used for this comparative analysis.

Limitations of my Study

This study has some limitations. First, the number of students involved in this study was restricted to those students enrolled in my classes who completed all the concept maps and had returned their ethics forms. A small group may not be representative of the greater population and thus potential generalizations are limited. With a larger sample, it would be easier to make comparisons to other settings.

A second limitation of the study is that the two instructional units being compared were taught at different points in the academic year. The Astronomy unit was taught in October 2003 and the Chemistry unit occurring in December of the same year. Thus, the results may have been influenced by variations in student motivation related to such things as fatigue, impending exams, and seasonal holidays. These variations in external stimuli could have influenced student performance and motivation, making it difficult to fairly compare the two units.

One final assumption needs to be mentioned. For this study, the concept maps have been interpreted to be representations of student understanding. If they are not representative of students' conceptual understandings of Science, then this would alter the findings and any claims of this study. However, these could provide some understanding of students' grasp of knowledge conveyed through concept maps.

CHAPTER FOUR

INSIGHT INTO CLASSROOM PRACTICES

In this chapter, I describe my regular classroom practices and explain my rationale for using concept mapping. I describe how concept mapping was introduced to and practiced by my students in my class. I then discuss the two units that were selected for this study and their differing natures.

My School and My students

I teach a variety of classes at Sunshine Academy from English to Science, Drama to CAPP (career and personal planning). I also teach students from grade 7 through grade 12. The students in grade 7 at our school are part of the high school or senior school and are not part of our elementary or junior school. This is intended to provide the students with an opportunity to adapt to high school life before encountering senior school level curriculum. Another reason is that it provides the students with more time to study their core academic subjects. In most elementary schools, students have Science class approximately three times a week for 40-minutes, a total of 120 minutes. The senior school of Sunshine Academy runs on a two-day format. Each day has four, 75-minute blocks, so the students in the senior school average 2.5 blocks of Science each week for a total of about 180 minutes. As a result, it is a lot easier for me and other teachers to cover the entire curriculum of a course with the increased amount of teaching time.

My regular teaching practices

Science 7 is a course that covers seven major units: Physics, Chemistry, Ecology, Astronomy, Life Systems (reproduction), Earth Science, and Applications of Science. The BC Ministry of Education instructs all teachers that teach Science 7 to cover all of this material. Because my classes are scheduled in a high school timetable, I have the time to cover all seven of these units. I incorporate aspects of the seventh unit, Applications of Science, into all of the units to try to connect the material being studied to my students' lives. Other aspects of Applications of Science are addressed separately when the students engage in designing and completing a Science Fair experiment.

Most of my units are 10 or 11 classes in length. This enables me to give each topic approximately equal time and allows me to address the large amount of content I need to cover over the course of the year. The order in which I teach the units is determined by when the holidays and term breaks occur and when field trip activities could take place. I try not to have units bridge a holiday such as Christmas or Spring break as I have learned that students tend to forget information over the holidays.

I have also learned through experience that no matter how well I think that I teach the material, I need to teach it multiple times so that the students have ample opportunity to process the information and sufficient exposure to the content so that they can develop their own understanding. In each unit, I try to cover the required material three times in varying levels of detail. The first time, I introduce the material, the second time allows me to explain it in more detail, and the third time permits reinforcement of key concepts, provides enrichment for the quick learners, and gives slower learners some extra time in order to grasp the concepts. Revisiting the content material multiple times also enables me to teach the material in different ways which means I can help students who have different learning styles. The first time I teach the material I use the textbook to aid those learners who learn best by reading. The second time I teach through discussion and by answering questions for those learners who learn best orally. The final time through the material usually involves labs or other activities for those students who learn best through hands-on activities.

My teaching approach changes depending on the unit I am teaching. For some units, such as Chemistry, I teach using a STS, how-does-this-information-relate-and-affect-you approach. Others, such as Astronomy, I teach in a more transmissive, these-are-the-facts-now-learn-them approach. Although I prefer the STS philosophy, it is not always easy to base my classes upon this pedagogy due to the nature of the material.

In my Chemistry unit, we deal with three chapters in the *Science Probe 7* textbook. These chapters includes topics such as acids and bases, neutralization, the water cycle, sewage treatment, acid rain, pH and environmental chemistry. These topics correspond to the ILO's for this unit (see Table 1). I begin the unit with three classes spent reading the three chapters in the textbook, learning the vocabulary from each chapter, and testing the students on the learned terms by using vocabulary quizzes. The next three classes are spent discussing problematic areas in the textbook and working on answering review questions from the text. The next three classes are spent doing lab activities: using litmus paper to test the pH of household substances, making an indicator using cabbage and other juices, and investigating neutralization using different amounts of vinegar and baking soda. The tenth class is usually a review day for any problems that the students still have and to work on preparing themselves for the test. The last class is their cumulative unit test, covering vocabulary usage, recall of key concepts from the text, and problem solving using knowledge learned from the lab activities.

Table 1

Intended learning outcomes for Chemistry, (Physical Science 7)

	It is expected that students will:
1.	Use the pH scale to classify a variety of substances
2.	Identify chemical reactions that are important in the environment
3.	Assess the impact of chemical pollution on a local environment
4.	Collect, analyze, and interpret data on environmental quality
5.	Propose and compare options when making decisions or taking action
6.	Analyze costs and benefits of alternative scientific choices related to a community problem

Class discussions in the Chemistry unit usually involve questions of how this material affects the students themselves. I frequently get questions from students about which acids and bases at home could harm them (and to what extent). I see the students look ill when we discuss where the sewage goes and why some of the local beaches get closed in the summer. Students ask me what happens when they dye their hair or how hair removal creams work. We talk about some of the ornaments in their gardens turning green due to oxidization and consider what causes the smog they see in the valley. Frequently, I have to end conversations before all the questions are addressed, because the students could chat and argue about their ideas for hours. Almost all the conversations focus directly on their needs, their lives, and their activities. This inward focus may be partly due to their age (eleven and twelve years old) and partly because they seem to find it easy to relate this information to their own lives.

Table 2

Intended learning outcomes for Astronomy (Earth and Space Science 7)

	It is expected that students will:
1.	Identify characteristics of known objects outside the solar system
2.	Outline the changes in human understanding of the universe from early times to the present
3.	Illustrate the seasonal position of various constellations
4.	Identify factors that have made possible or limited the work of particular scientists
5.	Describe how technology and science are related

The Astronomy unit also is dealt with in three chapters from the *Science Probe 7* textbook. The major topics for Astronomy as determined by the BC Ministry ILO's (see Table 2) include the colour and size of stars, the Big Bang theory, life cycle of stars, seasonal constellations in the Northern hemisphere, and how the Earth's rotation and revolution generate night, day and the seasons. My Astronomy unit is organized in a similar manner to my Chemistry unit. Three classes are spent reading the text and learning the important terms, three classes for doing textbook questions, three classes for activities, one day for review, and one day for the cumulative unit test. The lab activities include using water and food colouring to make spiral galaxies, building an astrolabe to measure distances, and using triangulation to determine relative sizes of objects. There is one additional day in this unit where the students go to the H. R. MacMillan Space Museum to watch a laser presentation on seasonal constellations, learn about how Chemistry enables astrophysicists to learn about the stars by the colour and quantity of light we receive from the stars, and study exhibits about life on other planets and in space shuttles. During outdoor school in the fall of 2003-04, we had one dry, clear night in which the students were able to stay up, locate, and identify the constellations. However, such practical, life-experiences in Astronomy are rare.

I have discovered that class discussions in the Astronomy unit are typically less animated than those in the Chemistry unit. Students tend to ask about aliens, the possibility of life on other planets, what life would be like on a space ship, and whether the Earth is likely to blow up. Students do seem to be interested in mysterious things such as black holes and pulsars but generally, they don't seem to engage in serious conversation, being more content to ask more goofy questions like "are aliens really green?" Getting an animated class discussion going in this unit is very challenging and requires a huge amount of effort. I believe the students' behaviour may be due to the fact that much of the material is abstract and students find it a lot more difficult to relate to. I try hard to make the lessons interesting but it's difficult. for students to see any "use" in learning, say, the temperatures of stars.

Introducing Students to Concept Mapping Activities

Each September, I ask my students if they know what a concept map is. Although half the students claim to have prior experience with concept mapping, it seems that all of their experiences have generated ideas about concept maps that are different from my understanding of concept maps. To show my students what I mean by a concept map, I draw a simple concept map on the board that relates to an easy to understand topic: classroom safety (Figure 1). I then talk with the class about using concept maps as a tool to help organize material, identify links between key concepts, and prepare for a test of understanding concepts.

I then give my students the opportunity to make additional links on the safety concept map I have drawn and to rearrange how the links have been made. At this point, I emphasize that there is no "right" or "wrong" concept map. A concept map is personal; it is an expression of how they, personally, see the information link together. I remind the students that they shouldn't necessarily expect to be able to map all of the words at the beginning of a unit because they may not be familiar with some of the concepts. I reassure the students, though, that by the end of the unit, they should be able to make links between more terms than they were able to use before. This makes concept mapping an activity that enables the students to see that they have learned something and, particularly for the weaker students, that they have made some progress.

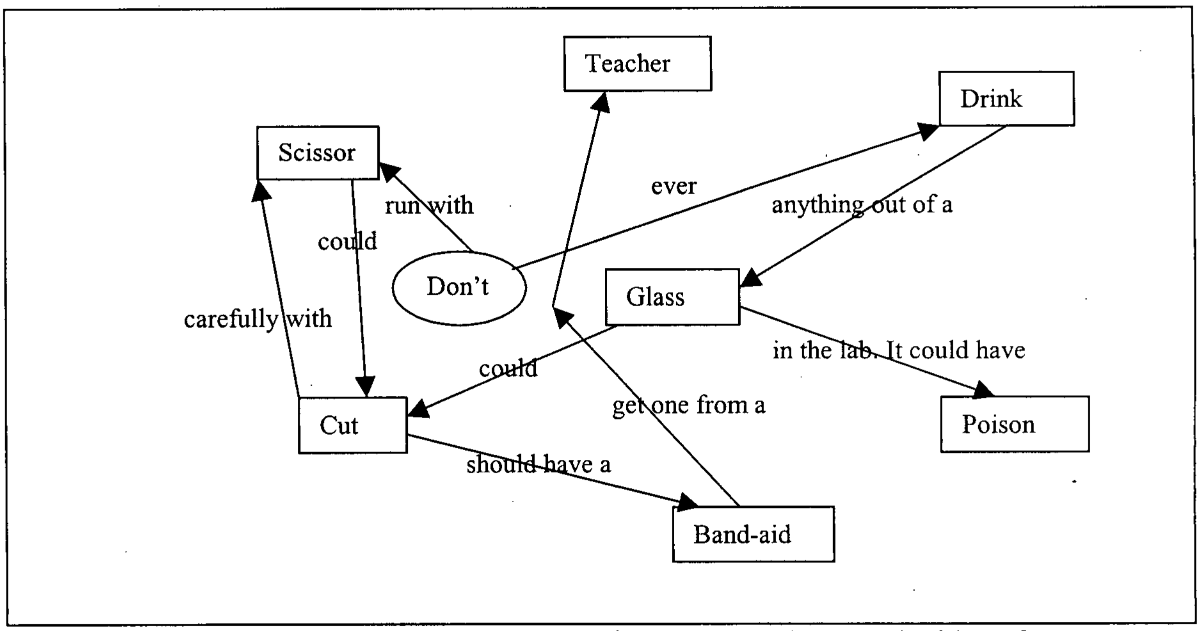


Figure 1. Simple concept map on safety used to introduce students to the idea of concept mapping.

After this initial talk, every student in the class experiments with developing a class concept map that relates to the recent summer holidays. The class collaborates as a group to generate a list of key words that they feel are relevant. The words are listed on the white board and the students then take turns suggesting how the words could be linked together. Figure 2 shows the map my Science class of 2003-2004 created. I show the students how key terms can be linked to many other words in more than one way. I also emphasize the importance of using arrows to show the directionality of the explanation lines. I tell the students that the arrows give the reader an idea about how to read the map. I then ask the students to copy the map and key word list from the board into their notebooks, and I encourage the students to add new key words of their own to the list of key words on their page. I ask the students to link the new words to words already on the map. Once given the "starter" concept map, most of the students are able to individualise their maps by adding their own ideas and links. The students compare their maps with those their friends have made, reinforcing the ideas that maps can and will differ.

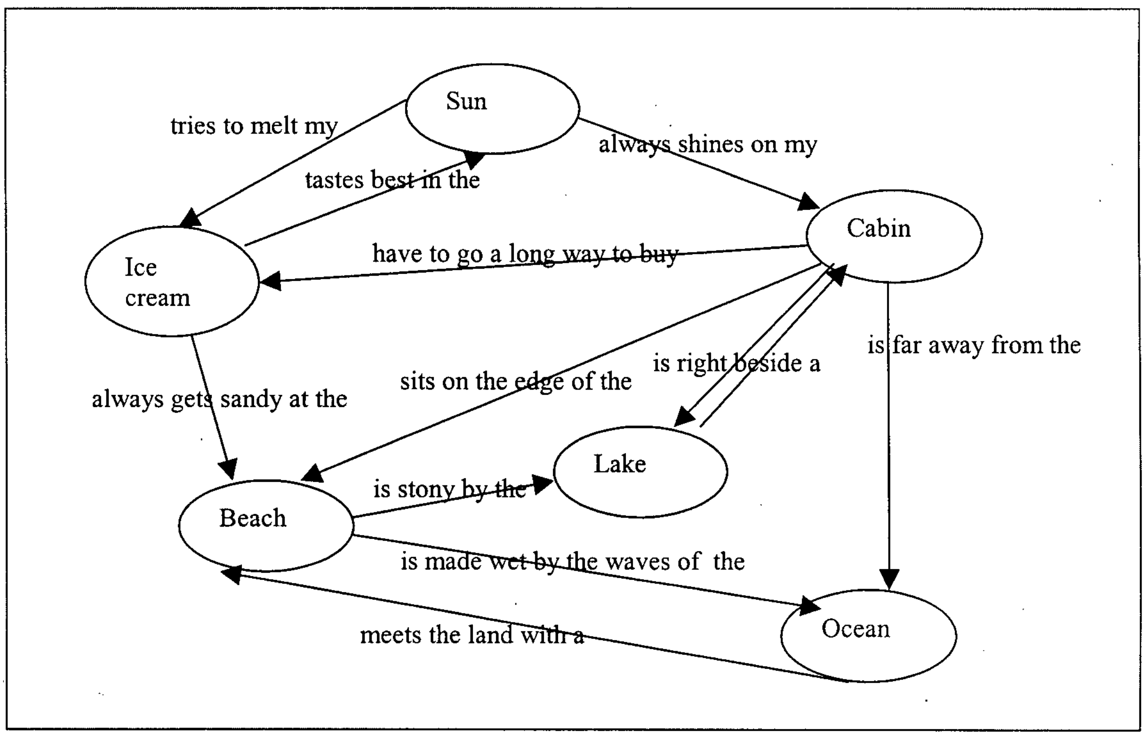


Figure 2. Sample map generated using class suggested list relating to summer holidays.

Having shared their maps, the students are asked to take out two pieces of blank paper. On the first piece of paper, I ask the students to copy the list of words from their first map. I then ask the students to see if they could generate a new concept map that looks different to their first map. The students get to be in complete control of this map, and, as a result, there is a great deal of variety in the maps generated. Once the students have completed this second map, I ask them to generate a new list of words that relate to the summer holidays on the second sheet of paper. Some of the words are allowed to be the same, but I encourage them to really personalise their list of words. I then ask the students to create a third map that uses this new list of words. The students are allowed to share their three maps with their classmates, often volunteering feedback (not always asked for) on their peers work.

After this next sharing period, I explain the purpose of creating the three maps. I want the students to realise that there are many different ways for concept maps to be created. I ask the students to examine their maps and to notice the differences within the three maps that they generated and the maps that the other students created. I point out again that there is no "right" way of creating a concept map as it is a reflection of how they understand the words and ideas to go together. This little speech usually sums up the students' first lesson in Science 7.

Many of the students feel uneasy when they first begin making concept maps, often requiring coaching or suggestions of a word to begin with. However, after a little prompting and reassurance, the majority of the students become comfortable with the mapping activity. Many students need multiple sheets of paper before they produce a map with which they are happy. Feedback from the students during mapping activities is interesting. Most students say that being given an initial list of words helps them to get started and to focus. Others suggest that if the bubbles and links were already present then they could simply fill in the words. I point out to the students that this approach would constrain their ability to link the words in any way they wanted. Some students are convinced that there is a single correct and incorrect way of creating a concept map and want me to provide the skeleton of what I wanted them to create.

The following class, students were asked to create another concept map, but this time the mapping activity is presented in the format that we will be using for the rest of the year. The students are not allowed to use their textbooks or notes to help them, only the information that they can remember unassisted. Map content is based upon the unit on the scientific method that all Science classes study at the beginning of the year, every year. This topic and map activity provides the students with a chance to become familiar with the format and wording of the instructions on the worksheet, as well as practice doing another map. The worksheet has the instructions written on the page, and includes the 15 terms pre-selected from the vocabulary list at the end of the first chapter (Figure 3). The students are asked to complete the map within a 10 minute time limit and to do their best. I create a time limit of 10 minutes for each map, as the longer periods of time were "torturous" (to quote several students). The slower students hated having the blank or nearly blank pages in front of themselves for longer periods of time, and the fast students often finished within 6-8 minutes and were twiddling their thumbs. I discovered that by placing the time limit on this activity two good things happened; the slower students were encouraged to take a risk and put something down on paper as this was such a short activity, and the faster students liked the challenge of seeing how much they could cram onto the page, so that they could compete among themselves (and each other).

Chapter 1 Concept Map

Name:______________________ Date:____________
______

Use the following words to make a concept map. You do not need to use all the words listed below, but please try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what the connection is. You may have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting Word List

science	classify	theory
technology	predict	variable
measure	communicate	model
observe	experiment	process
estimate	interpret	sample

Figure 3. Sample of the concept map task sheet used for the safety unit.

A few classes later, once we had completed the unit, the students completed the same mapping activity worksheet a second time. I had observed that the students were pleased with how much more they were able to put down on this second concept map. Still, there were always some students who had problems with the strategy and the format: they didn't like using arrows or lines to link the words, didn't know what to write on the links, or didn't see why it was important to write things on the links. Although these issues were repeatedly clarified in later mapping sessions, some of these issues were never resolved for certain individuals throughout the year.

The Units of Study

Concept maps are completed for all of the units taught during the year. For my study, I decided to examine the maps from two of the units I taught in Science 7: Astronomy and Chemistry. I selected these two units as they were the two units that seemed to be the most engaging for all students. In my previous experience in teaching this course, I noticed that the boys didn't seem as interested in the Ecology or Life Cycle units, and the girls were not as keen on the Physics or Earth Science units. Also, given my research question on teaching approach and the nature of students' learning, I wanted to examine two units where I used distinct teaching methodologies.

STS theory proposes that students learn best and integrate knowledge more deeply when they have a chance to practice with it and develop their own understanding. I am fundamentally a STS teacher and believe that students learn best when they can integrate the school material with their lives and daily experiences. The Chemistry unit intended learning outcomes are well suited for linking to the students' own lives (Appendix C). These learning outcomes are all based upon or related to a community or daily life context. It is easy to get students to bring in drinks, foods, and beauty and cleaning products and test their pH. Most of the students live within ten minutes of the school, so examining the damage done by and alternate solutions to local pollution has a great relevance to their lives. As a result, I teach Chemistry in an integrative, STS, here's-how-this-affects-YOU type of manner.

The concept map sheet for the Chemistry unit includes fifteen of the most important concepts in this three-chapter unit (Figure 4). The words are primarily abstract concepts – organic, biodegradable, environmental quality, and neutralization – with a few more concrete terms: sewage, particle, ozone, and solution. The chosen terms reflect the goals of the unit and three of the 5 ILO's provided (Appendix C). Additionally, these words are easy to use as starting points that will encourage the addition of other words. For example, water cycle has many associated words from the unit: solid, liquid, gas, sublimation, condensation, evaporation, melting, and freezing. These words were also chosen as they were also ones that were the most problematic or resulted in the greatest number of questions being asked and discussed. Thus, I believe that these are terms students should think more about and work with by incorporating and interconnecting them through mapping.

Chapter 8-10 Concept Map

Name:_________________________ Date:____________________

Use the following words to make a concept map. You do not need to use all the words listed below, but please try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what the connection is. You may have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting Word List

Solution	Chemical Change	Pollutant
Neutralization	Respiration	Environmental Quality
Acid Rain	Product	Particles
Water Cycle	Organic	Ozone
Change of state	Biodegradable	Sewage

Figure 4. Concept map task sheet used for the Chemistry unit.

Not every school subject is easily related to activities or experiences with which the students are familiar. The Astronomy intended learning outcomes are listed in Appendix C. Intended learning outcomes (ILO's) 1 and 3 that deal with objects outside our solar system and seasonal constellations are particularly challenging to relate to city students who have seldom been out at night and seen a clear, starry sky. As a result, I tend to teach these ILO's in a more transmissive, these-are-the-facts-now-learn-them type of manner. Students are conditioned through experience in school to be able to learn information visually through texts and orally through discussion, so they are familiar with this teaching style and are accustomed to learning in this manner. However, students may fail to develop deep understanding or personal connections with the subject matter in transmissive classes, so I use concept maps in this way to facilitate my students' learning processes at a deeper level.

The concept map task sheet for the Astronomy unit includes fifteen of the most important concepts in this three-chapter unit (Figure 5). The terms range from abstract concepts – rotation, revolution, and the Big Bang theory – to more concrete ideas: stars, nebulas, and quasars. The chosen terms reflected the goals of the unit and ILO's 1, 2, and 4 which deal with objects outside the solar system, changes in understanding Astronomy, and factors which helped Astronomers. Additionally, these words are easy to use as starting points for adding other words. For example, the students saw diagrams on posters, and in their textbooks of different constellations, which they could name and draw. As well, the students read in their textbooks about the three major types of telescope – radio, reflective and refractive. The words were also chosen as they were also ones that generated animated class discussion. Thus I assumed these words should be the easiest ones for the students to use when generating their maps.

The students used the lists of words I provided to create three concept maps in each unit. These maps were created at the beginning, middle, and end of each unit in order to produce snapshots of the student's progress throughout each unit. These six concept maps provided the data that were analyzed using the methods described in chapter three. The results of those analyses are discussed in chapters five, six and seven.

Chapter 14-16 Concept Map

Name:_______________________________ Date:_________________________

Use the following words to make a concept map. You do not need to use all the words listed below, but please try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what the connection is. You may have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting Word List

Astronomy	Universe	Quasar
Galaxy	Star	Constellation
Telescope	Nebula	Astrolabe
Space Probe	Supernova	Rotation
Big Bang	Black Hole	Revolution

Figure 5. Concept map task sheet used for the Astronomy unit

CHAPTER FIVE

WHAT DO CONCEPT MAPS TELL ABOUT STUDENT UNDERSTANDING?

This chapter examines my research question "What do concept maps tell us about grade seven students' understanding of Science concepts". I begin by discussing the results that pertain to map number and size, map format, language of linking phrases, content in the maps, and changes in content level in the maps. Following this, I describe general trends in the maps and discuss what this shows with regards to students' understanding.

Map Analysis

The 96 concept maps I examined for the two units encompass a broad spectrum of design, scientific understanding, and complexity of thought. To make sense of this diversity I analyzed the maps in terms of five attributes: physical organization of the maps, map style, language usage, content embedded in the links, and changes in understanding over the course of the unit.

Map Organization

I noticed that there was a great variety in the size and form of the maps the students created. Some of my students followed my instructions and created a single map that tried to interlink as many of the words as possible (Figure 6). This type of map illustrates that the students were able to find multiple ways to link the different ideas and concepts included in the list of words and that they could see how to integrate the concepts into a somewhat cohesive whole.

Other students created multiple maps, built around clusters of terms. These maps showed a broad range of scientific understanding that was organized into what seemed to be islands or isolated pockets of information that were separated both on the concept mapping sheet and perhaps in the student's mind. For some students, these multiple map sets contained non-worded links suggesting the student saw relationships between the terms but couldn't articulate the connections (Figure 7). Others created multi-map sets included linking statements consisting of rudimentary definitions (Figure 8).

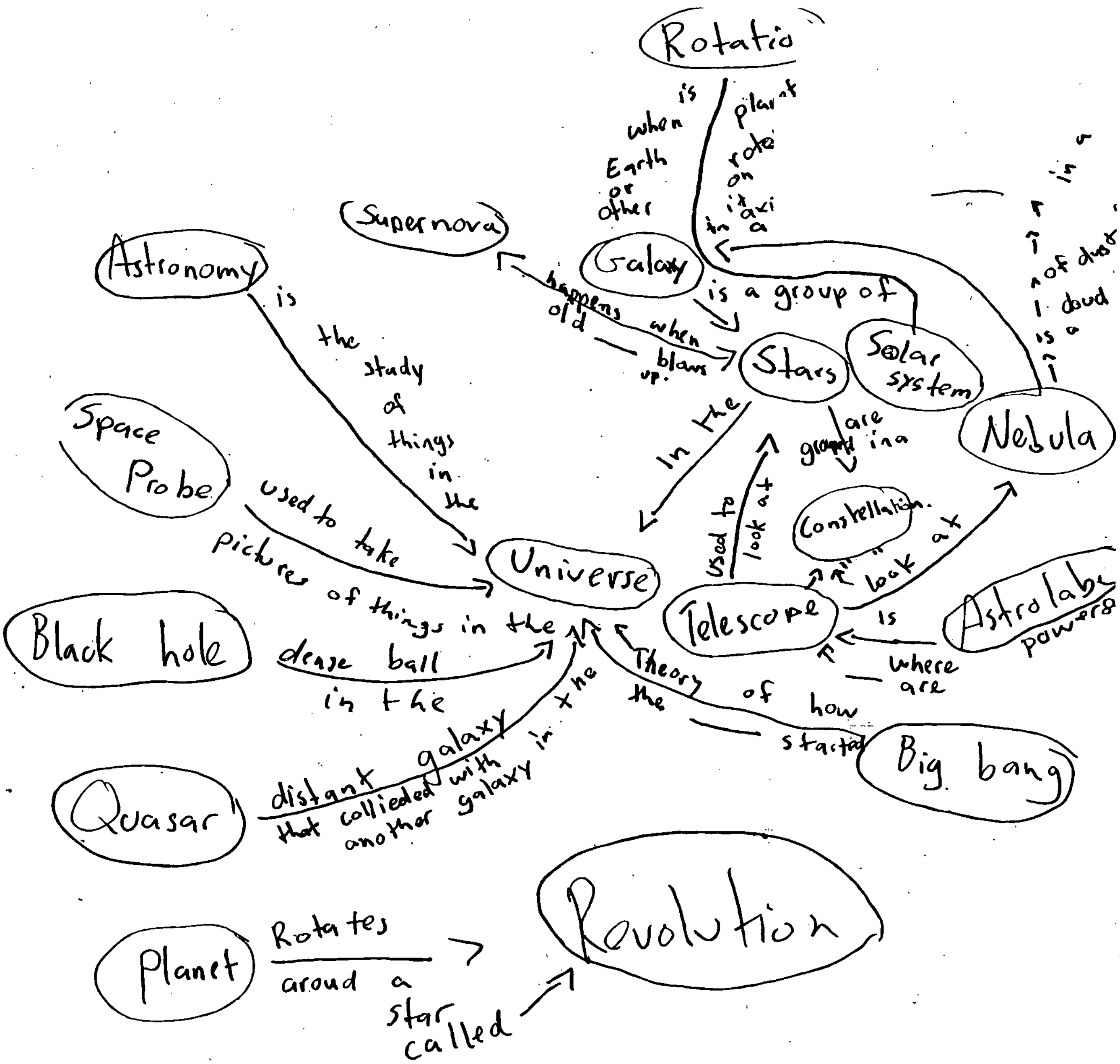


Figure 6. Example of a comprehensive map (Bob, Astronomy, Map 2)

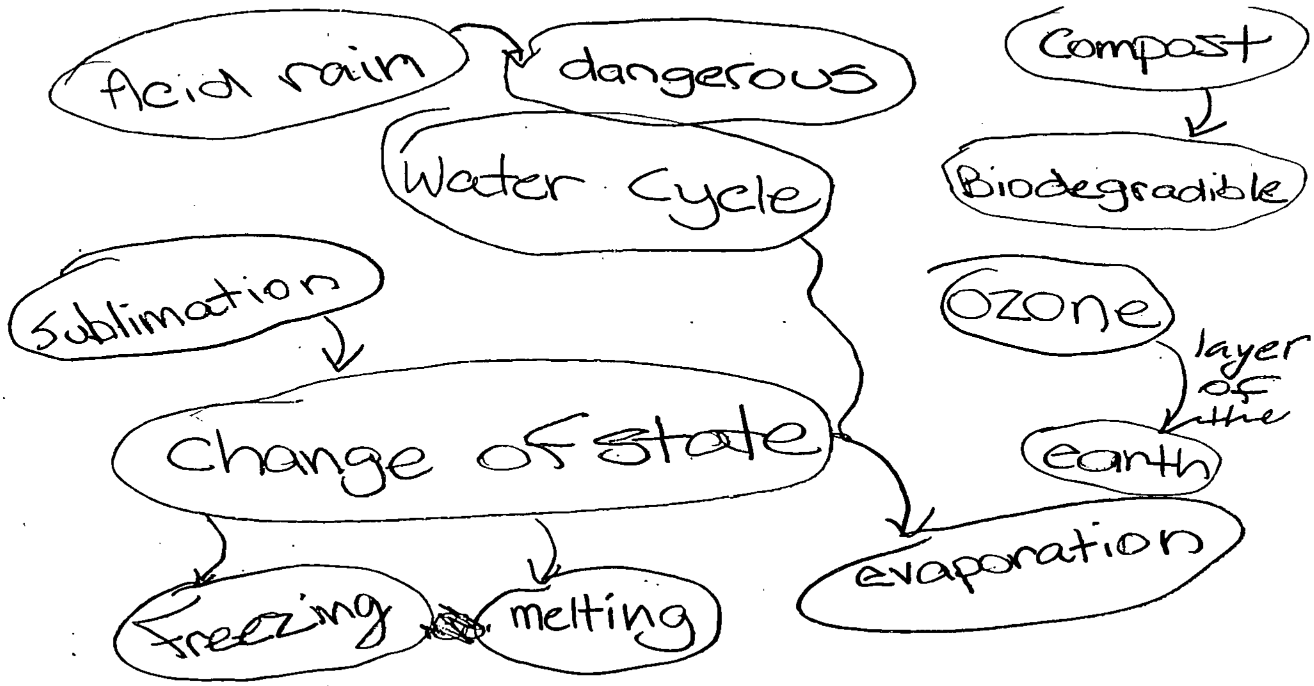


Figure 7. A multi-map set with minimal link information (Betty, Chemistry, Map 1).

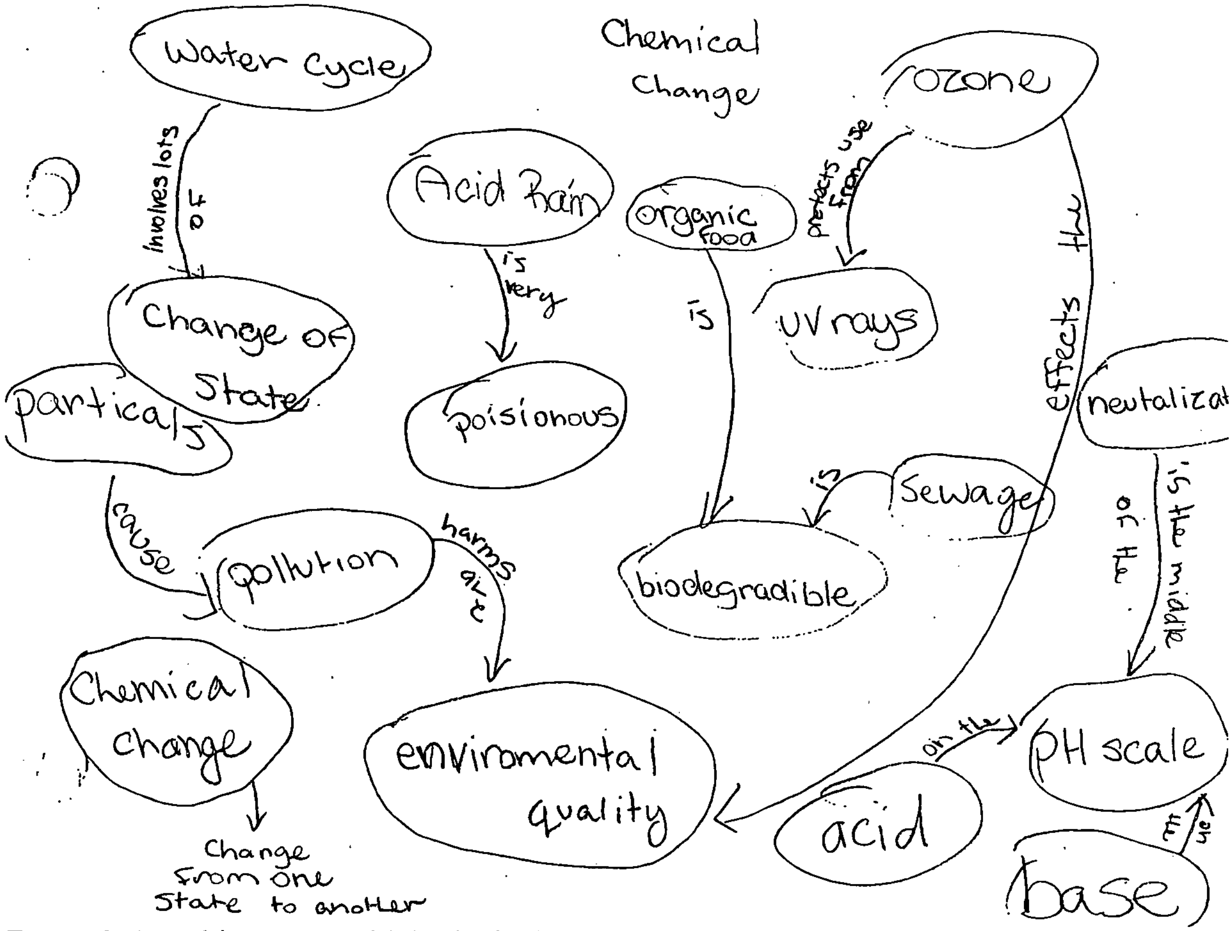


Figure 8. A multi-map set with basic linking information (Betty, Chemistry, Map 3).

There were students who reduced the number of maps they created over the course of the unit and coalesced the terms into one larger picture. This suggested that as the unit progressed, the students understood that there were ways that they could link their "islands" of ideas together. In the Chemistry unit, Betty's maps (Figures 7 and 8) and Geoff's maps (Figures 9 and 10) show this trend.

Map Styles

A number of students created maps that did not fit the example I had produced nor the criteria or directions I had given them. Although I had asked the students to create maps where the key concept words were shown in bubbles and where there were lines to link the bubbles, there were individuals in my class that seemed unable or unwilling to create maps that fitted within these parameters. Some students wrote in spirals, either from a central point outwards or an outside point inwards (Figure 11). Other students created their concept maps like a shopping list with none of the key words in bubbles and no lines joining any of the words together (Figure 12). These maps bore little or no resemblance to the maps that the class had created as a whole, or those that I had created as a model for the class on the board.

Although I had provided specific guidelines, I hesitated about interfering with the "novel" maps these students were creating. The main point that I had emphasized with the students throughout every concept mapping activity was that the maps were to be a reflection of how they, *personally*, understood the material. Although in some maps there was minimal scientific content, I realised that, given the students test scores, many students had scientific knowledge that wasn't appearing in their concept maps.

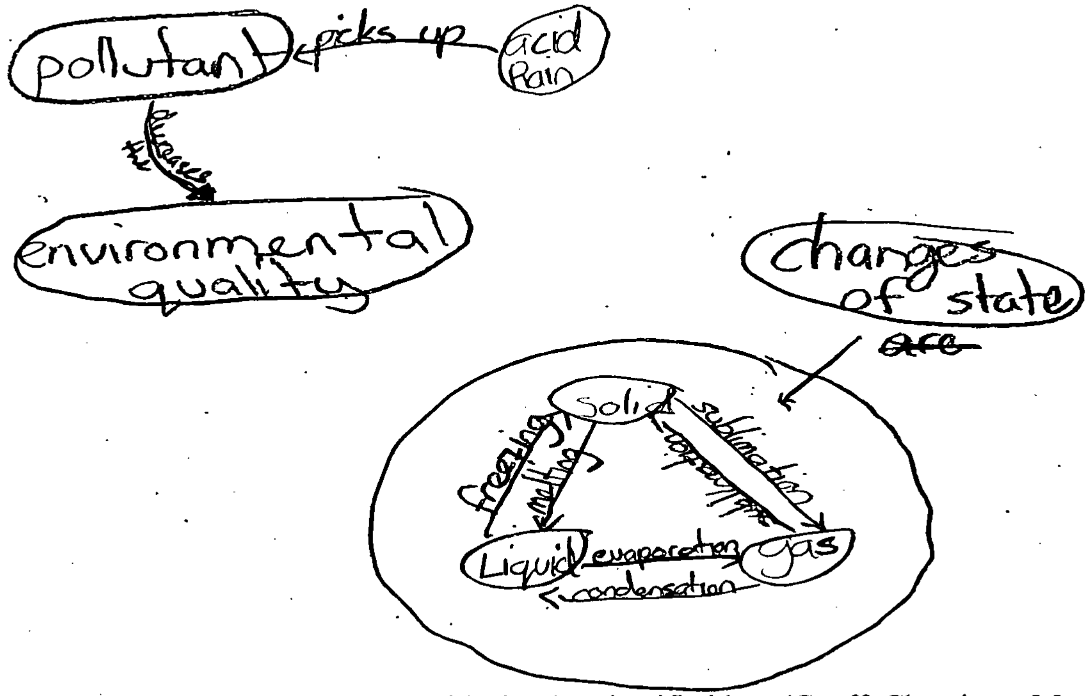


Figure 9. Example of initial maps with simple scientific ideas (Geoff, Chemistry, Map 1).

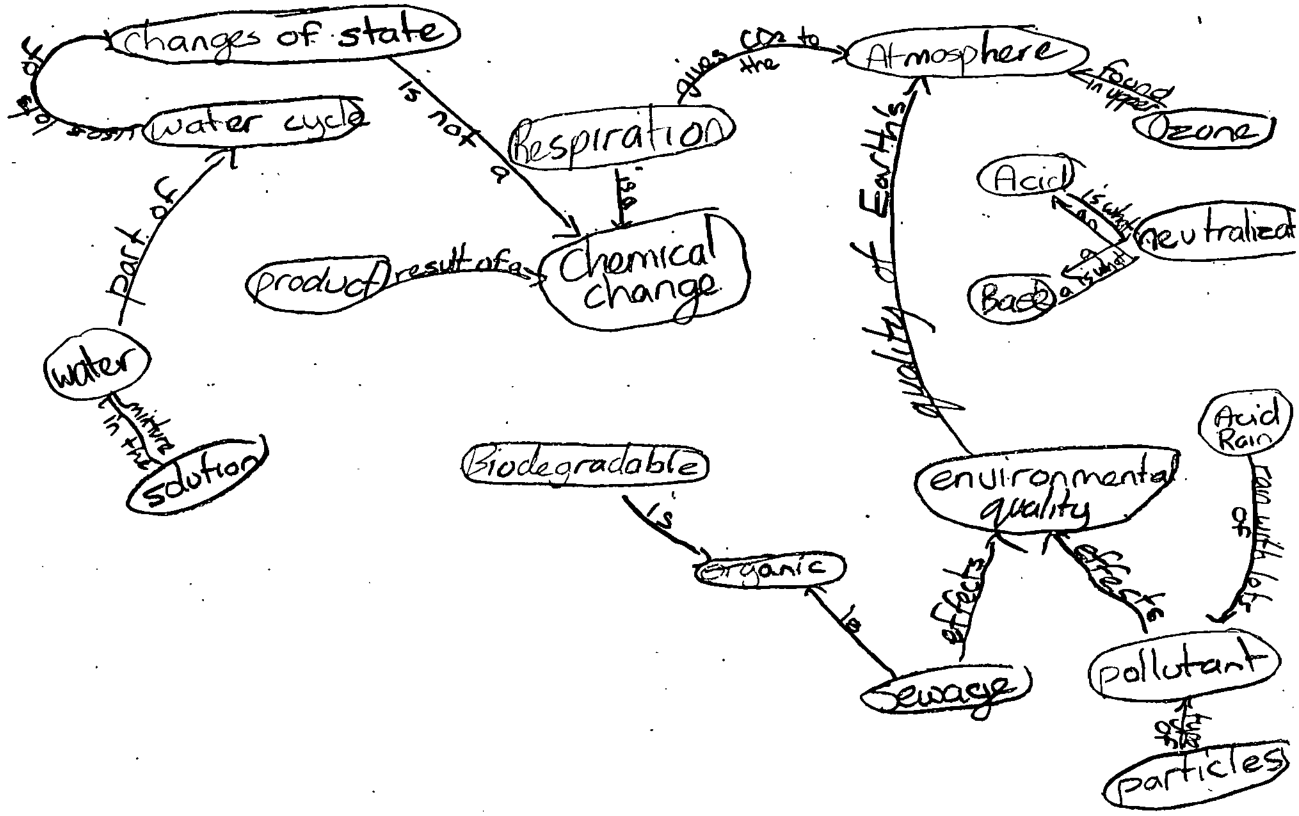


Figure 10. Example of unit's end map: detailed and coalesced (Geoff, Chemistry, Map 3).

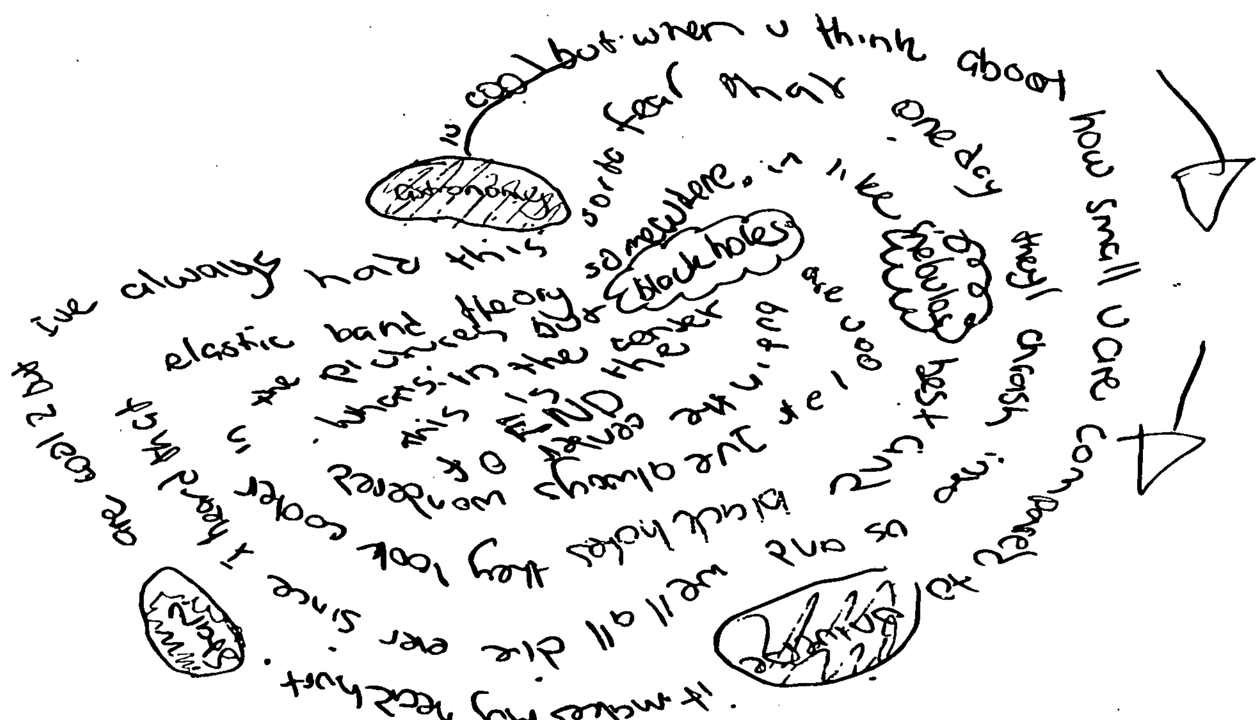


Figure 11. Examples of a Spiral Map (Hanna, Astronomy, Map 2).

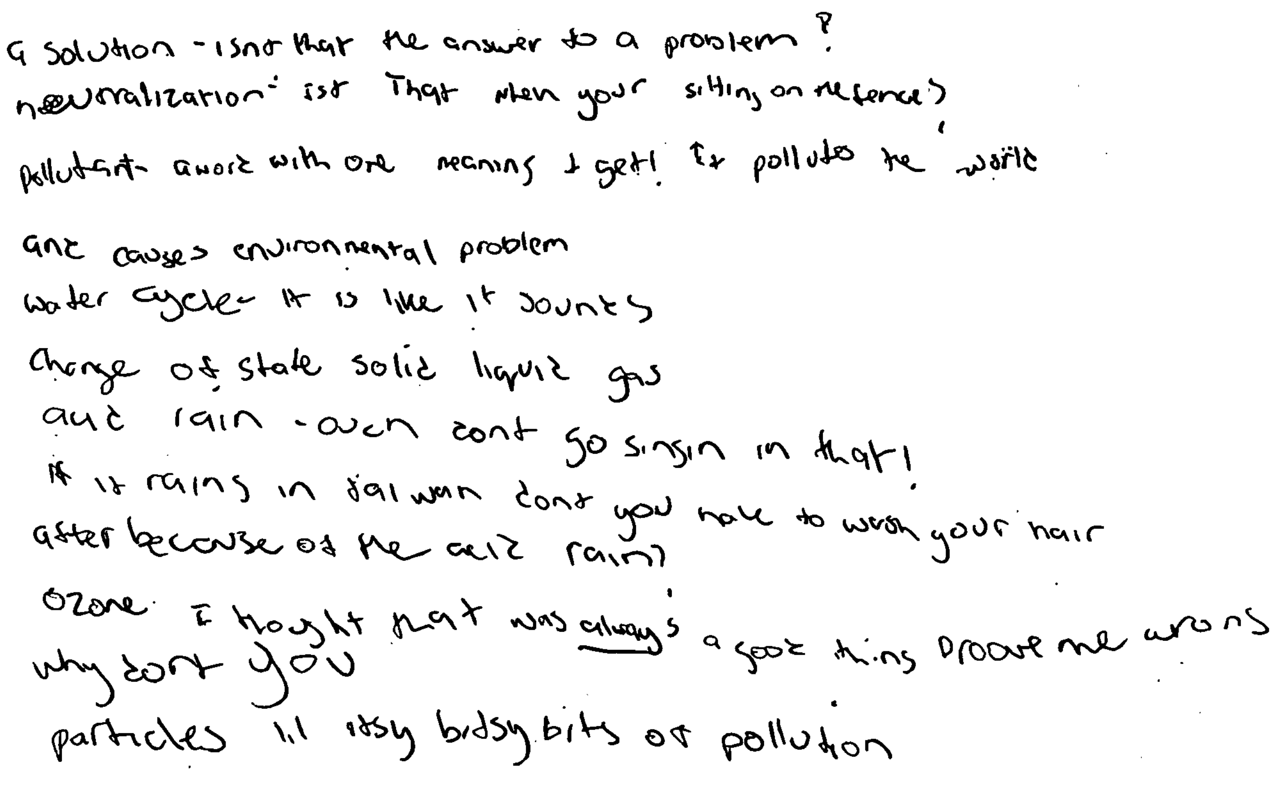


Figure 12. Example of part of a Shopping List Map (Hanna, Chemistry, Map 3).

I believe that if I had told these students to alter their concept maps so that they conformed to the pattern I had provided, I would have seen the information presented in a more systematic and "scientific" fashion. At the same time, I felt strongly that to direct my students in this way would interfere with their arrangement (or not) of the facts as they understood them. I wondered whether this activity was providing students with a means to express their creative side more freely and authentically than was the case with my other Science assignments. Thus, I opted not to manage or influence the students' map format, and I have no regrets about this.

I was quite surprised by a few students. Some students created single, large maps with predominately multiple word links using all the words from the list as well as adding words. However, these concept maps had nothing whatsoever to do with the actual content or meaning of the words. For example, one student's map told the story of an imaginary class in which we looked for black holes with a space probe that lived in our lab. Another student waxed lyrical about the different tastes and flavours of the universe if everything was made of candy. While showing that these students had a great imagination, these maps didn't tell me anything about whether they understood what the concepts meant in a scientific context. This was somewhat disconcerting.

Language Usage and Style

I saw a great variety in the type of language used in the concept maps. Many students primarily stayed with the impersonal language of the textbook definitions while others provided the same information but translated the objective definitions into more colloquial phrases. For example, Geoff's statements reflected textbook phrases: "**water cycle** – *uses lots of* - **changes of state** – *is not a* – **chemical change** ← *is a* - **respiration** – *gives CO2 to the*

- **atmosphere**" (Geoff, Chemistry, map 3). Other students chose to use very informal language. For example, Carly wrote: "**environmental quality** – *ewwwwwwwwwwwwwww* – **sewage**" (Carly, Chemistry, map 3). While not conveying any specific scientific content, Carly's words do convey the student's emotional reaction and relationship to the words.

The majority of students used language in the links to convey their academic, scientific understanding of the material. The syntax of the phrases made sense when read from one link to the other. There was a small percentage of students who used the maps to express their opinions of the science content or to share their experiences with the material in the unit. For example, Carl wrote: "*in our* – **universe** – *we have different kinds of* – **stars** – **black holes** – *we can only see them if we use a* – **telescope** – *and if you are lucky you might see a* – **constellation**" (Carl, Astronomy, map 2). Carly wrote: "**pollutants** – *are bad stuff 'cause they hurt the* – **ozone**" (Carly, Chemistry, map 1).

The degree of formality of the language helped me to judge which students had simply memorized the definitions in the textbook and which students had a more refined understanding of the definitions. The nature of the wording in the linking statement also reflected whether the student was responding to the topic in an academic or emotional manner, such as Carly's reaction to sewage. Additionally, the nature of the opinion provided insight into whether the student was merely reacting to a word, such as sewage, or relating the word to their personal experiences as in the case of Hanna: "**biodegradable** – *when we went camping my friend gave me biodegradable shampoo and we were the only ones with clean hair he he he*" (Hanna, Chemistry, map 2).

Content Embedded in the Links

I read, compared, and analysed every concept map linking statement for evidence of content understanding. Linking statements with few words were interpreted to mean that the students did not comprehend much about the topic being studied. At the other end of the spectrum, I saw maps where it appeared that students had a solid understanding of the concepts being studied. These maps appear as complex illustrations with multiple multi-word links containing substantial scientific content joining most of the list words (Figure 6).

Most often maps had linking statements that reflect the definitions the students had had to learn for their vocabulary quizzes. These statements showed a range of understanding. Most students never moved beyond using textbook definitions for their linking statements. However, a few students provided examples from class experiments, content from common knowledge, or ideas from their own experiences or that they had read in other sources. These links showed that students were actively connecting new information with their own body of knowledge. It was informative to see what students saw as significant or interesting as it illustrated their passions.

I noticed that the full range of comprehension was evident on maps produced in both of my classes and in both units that I taught. Interestingly, although a student might produce a large and comprehensive map with extensive linking statements in one unit, it did not follow that the student would be able to do so in the other unit. Sometimes students who showed poor comprehension in one unit, showed a good level of understanding in the other unit. Overall, there was an equal number of students who created detailed concept maps in the Chemistry unit as those in the Astronomy unit.

Changes in student understanding

My analysis of link content suggests that for most students, understanding of the concepts increased between the first and second concept maps in each unit. I found this to be comforting, as this is the intent of teaching. I had expected that there would be evidence of a similar increase in knowledge or understanding between the second and third maps, and to a certain extent this was true. More than half the students were able to better articulate their understanding of the connections or were able to increase the level of detail in their links, the number of words included in the map, or increase the number of connections within their map. However, there were a sizable number of maps for both units that actually showed a decrease between the second and the third maps in terms of the number and quality of linking statements. Initially, I was amazed by this finding until I reflected back on conversations with my students after the third concept mapping activity. Many students had disclosed that they were "tired out" by the process of taking the test and, as a result, had already written all they knew on the test and felt that they had "nothing left to give". I think that if I had asked my students to create their concept maps before the test with the understanding that they could use them during the test, the concept maps would have shown a greater level of understanding and a greater degree of complexity as the students would have been less tired and would have been better able to concentrate on the concept mapping activity. This is a strategy I plan to experiment with in the future

The Bottom Line

Analysis of the concept maps indicated that students could, over time, increase their understanding of the key concepts in a unit, become more comfortable with using the key terms, and increase the number of words and complexity of thoughts presented in the links.

Maps generally became more complex in terms of the numbers of words used, words added, and links created. The content of the linking statements showed a lower comprehension level than I had expected. Most of the linking statements were simple textbook definitions. There was extensive variety in the maps. No two students created the same style of map, regardless of the instruction given or the examples viewed. Each student's map was unique and a reflection of how they, themselves, chose to depict the connections between the key concepts at a given point in time. In the next chapter I examine issues of concept mapping that pertain to unit design and gender.

CHAPTER SIX

INSTRUCTIONAL APPROACH, GENDER, AND CONCEPT MAP CONSTRUCTION

This chapter considers the research questions "Do concept maps reflect the instructional approach used in the unit" and "Do grade seven girls and boys' concept maps reveal gendered ways of understanding Science?" I begin by examining the relationship between instructional approach and concept map construction. I then analyse the structure and form of maps drawn by boys and girls. I compare number of words used, size of map, and quality of links. I also examine the content contained in the links of the Astronomy and Chemistry unit concept maps. I conclude this chapter by discussing the relationship between map structures, content and gender.

Concept Mapping and Instructional Approach: A Comparison of Astronomy and Chemistry Maps

I investigated differences between concept maps generated in the Chemistry and Astronomy units to determine if instructional approach is reflected in concept map construction. I first compared the number of links, words, and the content of maps produced for the Astronomy unit I taught in a transmissive manner with maps from the Chemistry unit taught with an STS approach. I conducted these analyses to investigate if there was any difference in the concept maps that could be related to the teaching methodologies used in the two units. I expected that the STS instructional approach taken in the Chemistry unit would result in concept maps that contained linking statements indicating connections with the students' lives and interests. I expected that the transmissive instructional approach taken in the Astronomy would result in concept maps that contained linking statements indicating rote learning. As STS instruction has been reputed to facilitate deeper understanding of Science, I also expected that the Chemistry unit concept maps would include a greater number of list words and more higher level links. Table 3 presents a synopsis of my map size and link analysis of Astronomy and Chemistry concept maps based upon the data in Appendix G.

Table 3

Comparison of Concept Map Trends in the Astronomy and Chemistry Units

	Unit	Map 1	Map 2	Map 3
Number of Large maps	Astronomy	16	15	13
	Chemistry	7	9	8
Average number of list words used	Astronomy	10.3	10.5	9.9
	Chemistry	6.7	8.7	9.8
Average number of level 2 links used	Astronomy	1.5	4.4	3.4
	Chemistry	2.8	4.3	4.6

As shown in the table, the average map size in the Astronomy unit was consistently larger than the Chemistry unit. However, the average number of list words used in Astronomy stayed approximately the same over the course of the unit whereas there was a trend of increasing usage of list words in the Chemistry unit. A repeated measures ANOVA statistical analysis indicated no statistical difference between maps 1, 2, and 3 in the number of list word used in the Astronomy unit ($p = 0.708$), but there was borderline significance in increasing list word usage for maps in the Chemistry unit ($F(2,30) = 6.494$, $p = 0.005$). There was a statistically significant trend of an increase in the average number of level 2 links used in both units (Astronomy $F(2,30) = 9.808$, $p = 0.001$; Chemistry $F(2,30) = 5.00$, $p = 0.013$). Additionally, when the units were compared, maps of both units showed change in level 2 link usage over the course of the units $(F1,15) = 20.215$, $p = 0.000$) but the change shown in each unit was not significant over change in the other unit ($F(1,15) = 9.907$, $p = 0.007$).

I was surprised that there was no significant difference between the concept maps for the two units as I felt my instructional approaches were quite different and anticipated this would be reflected in the maps. One explanation for the lack of difference in the Chemistry and Astronomy maps could be the limits of my single unit intervention. Although the classroom activities and discussions were different in nature and focus, the highly structured organization of my course may have been more influential than my unit approaches. It could also be that by this point in their schooling, my students were so adapted to particular ways of learning and displaying their knowledge that a teaching intervention may not have had a significant affect. Overall, it appeared that my teaching approach did not influence concept map construction. However, when I analysed the maps in terms of gender, I noticed that indeed there were distinct differences between the two units.

Gender and Concept Mapping

I analyzed the concept maps to see if there were any differences between the concept maps generated by the boys and the girls. I looked at both the Astronomy and Chemistry map sets. My experience as a teacher has led me to believe that girls are better at seeing connections and making links between ideas, whereas boys are better at recalling previously learned material. I was curious to see if this belief would be supported by variations in the maps produced by girls and boys in my classes. Chemistry and Astronomy are considered as gender neutral Science subjects in the literature (Hofstein & Cohen, 1996; Keeves & Kotte, 1996; Qualter, 1995). Thus, I wanted to see if maps produced in my classes for these units supported these claims. The tables showing the results of my analyses for each student are found in Appendix H. I discuss these results in the sections that follow.

Astronomy Unit – Boys' Maps

Concept maps drawn by the boys in my two classes showed an increase in the use of list words by the end of the unit (Table 4). The average number of level 2 links increased from map 1 to map 2, but declined in the final map to an average of 4.0 level 2 links. Boys' maps generally conformed in format to the instructions given in class; key words were written in bubbles and linking statements were present on the majority of the linking lines. The single most noticeable trend for the boys' Astronomy maps is that linking statements were largely definitions. Simple maps, defined as those with few multiple worded links or level 2 links, included rudimentary or semi-complete definitions, whereas complex maps, defined as those with multi worded, level 2 links, had full and detailed definitions of the key terms. There were few exceptions to this trend.

Table 4

List Word Usage and Level 2 Links for the Astronomy Unit by Gender

	Average List Word Usage			**Average Number of Level 2 Links**		
	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3
Boys	8.7	10.0	10.6	2.0	5.9	4.0
Girls	11.4	10.9	9.3	1.1	3.2	3.0

The linking statements produced later in the unit contained more information. For example, Bob's first map had simple definitions, such as "**Big Bang** – *created* – **black hole** – *has lots of* – **gravitational pull**" (Bob, Astronomy, map 1) whereas his second map included more details, such as "**quasar** – *distant galaxy that collided with another galaxy in the* – **Universe**" (Bob, Astronomy, map 2). However, most of the boys' links, even those on later maps, did not illustrate a deep understanding of the key concepts or how they were related. One example is Andy's linking statement on his third map: "**telescopes** – *are good tools for studying the* – **galaxy** – *and* – **astrolabes** – *are another good tool. We also use* – **space probes**" (Andy, Astronomy, map 3). Some map links communicated misconceptions or confused ideas, like "**telescope** – *used binoculars to see* – **constellation**" (Dave, Astronomy, map 1). There were also maps with clusters of related terms strung together with non-worded links, such as Dave's lists in his second and third maps "**telescopes** – *can study* – **quasar** – **galaxy** – **stars** – **supernovas** – **black holes** – **nebulas**" (Dave, Astronomy, map 2). For these maps, it was difficult to judge whether the student was grouping terms as a shortcut or whether the student could not articulate relationships between the concepts.

The majority of the boys showed little personal connection with the material in the unit. Carl's second map was one of the few exceptions. His map provides a glimpse of how he "feels" about star gazing: "*in our* – **universe** – *we have different kinds of* – **stars** – **black holes** – *we can only see them if we use a* – **telescope** – *and if you are lucky you might see a* – **constellation**" (Carl, Astronomy, map 2). Carl's first map was also unique as it was the only boy's map in the unit that demonstrated a creative response to the concept mapping assignment. That map contained a story about a mythical Astronomy class where we tried to use a space probe in my classroom.

Four of the seven boys' maps showed an increase in comprehension of Astronomy concepts over the course of the unit. This was determined by examining their maps for increases in link complexity and increased level 2 link usage. The three other boys' maps showed an increase trend in terms of scientific understanding between the first two maps, but their third maps were weaker, resembling the first maps generated in the unit. Because their maps showed improvement but then declined, I nicknamed these boys the "rainbow group" to reflect the trend I observed their maps. One of these rainbow boys, Geoff, earned an "A" on his Astronomy test and another, Dave, received a high "B" so their lacklustre maps did not mirror their test performance. I wondered whether the effort of taking the unit test before generating the final concept map left the rainbow boys feeling tired and uninspired. Given that a number of students made comments during the final mapping activity such as: "but we've just told you all we know – there's nothing left!", it may well be that this last map was not a good indicator of what the students had come to understand at the end of the unit.

Astronomy Unit – Girls' Maps

Girls' Astronomy maps showed variety in form, with some students adopting alternative formats including spirals and sentence chains. The average number of list words decreased from 11.4 on map one to 9.3 on map three (Table 4). Maps contained some basic definitions, suggesting surface comprehension of the material, but the majority of the linking statement content was opinion.

From a read of linking statements, it was impossible to determine if the girls understood the scientific concepts or the deeper relationships among them. Betty linked concepts together with simple, logical phrases that lacked scientific depth, such as: "**space probe** – *helps* – **Astronomy** – *study of the* – **universe**" (Betty, Astronomy, map 2). A couple students wrote links paraphrasing textbook explanations. One of Diana's maps focussed on the life cycles of stars and the universe: **universe** – *started out as a ball and then there was a* - **big bang** – *10 billion years later our own* – **galaxy** – *was created and the big* – **star** - *the sun"* (Diana, Astronomy, map 3).

Interestingly, a number of maps were creative in nature, showing an imaginative and creative relationship with the topic. Most revealed a personal approach to the material. Many linking statements focussed on the girls' relationship with the material in ways that reflected anticipation of what they were going to learn or what they thought was "cool". Gina commented: "**constellations** – *which are very interesting but not as much as a* – **supernova** – *and* – **nebula** – *and* – **quasars**" (Gina, Astronomy, map 2). Some students, like Hanna, used their maps to reflect about the content: "**constellations** – *are what floor me. I mean some body (sic) has either a* - **fantastic** – *imagination to see the horse or the bear*." (Hanna, Astronomy, map 3). Other students, such as Carly and Farah, offered insights as they disclosed their concerns or apprehension about the content: "*I don't want to go near a* – **black hole or a supernova**" (Carly, Astronomy, map 3) and "**Constellations** – *are cool in a universe*" (Farah, Astronomy, map 2). A few girls commented on the activities and learning approaches that they engaged in during the unit. Carly wrote: "**astronomy** – *I memorized words like* – **space probe** – *and* – **nebula**" (Carly, Astronomy, map 3). Two girls drew maps that reflected a creative and poetic approach to the material; their links, however, contained little scientific content. Ingrid wrote: "**Have you ever tasted** – *Astronomy? I've never because I'm afraid it might taste like* – **black holes**" (Ingrid, Astronomy, map 3).

In the Astronomy unit, the maps of four of the girls showed a pattern of increasing level 2 link usage over the course of the unit. Four other girls' maps showed a "rainbowing" pattern similar to the boys – an improvement between the first two maps, with the final map being less complex than the second one. What was interesting was the presence of non-worded links in the third maps, which I had been interpreting as indicative of an inability to see or articulate a relationship between the key terms. As this type of link had not been present in the initial maps, I was concerned that the girls, like the boys, were too tired or uninspired after their test to be able to articulate their understanding.

Also concerning was Gina's distinct downwards trend in her three maps. Each map contained fewer level 2 links than the previous. The decrease in the number of level 2 linking statements first suggested Gina had learned little over the course of the unit. However, a closer examination of her linking statement content revealed that Gina's understanding of Astronomy did, in fact, increase. In her first map, the longest, coherent, Science-based chain was "*- in the –* **universe** *– there are lots of –* **stars** *– which you can see with a telescope*" (Gina, Astronomy, map 1). Gina's third map showed evidence of scientific knowledge not seen in her earlier maps: "**supernovas** *– are when a -* **star** *– get (sic) old and –* **explodes**", "**nebulas** *– are a large cloud of gasses and –* **dust**", and "**star** *– can form –* **constellation** *– and you can see them with a telescope*" (Gina, Astronomy, map 3). Experience I gained through this study indicates that tracking a particular type of link or word use may be an inadequate and possibly misleading measure of concept mapping performance. To assess changes in student understanding on concept maps, a detailed evaluation of the content of the linking statements is needed.

Chemistry Unit – Boys' Maps

Textbook definitions made up the majority of the content on the boys' Chemistry maps. Although these students were able to articulate some degree of understanding of the topic concepts, in terms of words found in the textbook, most had difficulty exploring in their own words how the Chemistry concepts were linked together. The boys generated multiple maps for this unit, usually ranging from two to five sub-maps per task sheet. Sub-map sizes varied, including combinations of small, medium, and large-sized maps. The number of list words used by the boys in the maps increased noticeably, from an average of 5.6 on the first map to an average of 9.7 by the end of the unit. Boys' Chemistry maps also showed a gradual increase in the number of level 2 linking statements used, from an average of 3.3 in the first map to 5.4 in the third map (Table 5).

Table 5

List Word Usage and Level 2 Links for the Chemistry Unit by Gender

	Average List Word Usage			**Average Number of Level 2 Links**		
	Map 1	Map 2	Map 3	Map 1	Map 2	Map 3
Boys	5.6	8.2	9.7	3.3	5.0	5.4
Girls	7.6	9.0	9.9	2.4	3.8	3.9

In linking statements, the boys used the key words in their scientific sense and incorporated phrases from definitions they learned in class or from the textbook. For example, Geoff wrote: "**acid rain** – *rain with lots of* – **pollutant** – *effects* – **environmental quality** – *quality of the Earth's* - **atmosphere**" (Geoff, Chemistry, map 3). Misconceptions and incomplete understanding were evident in the links. Andy's definition of a solution shows his confusion: "*a* – **solution** – *is when a base and a liquid mix together*" (Andy, Chemistry, map 1). Evan's map of small chains and loops indicates vague ideas about organic Chemistry and pollution: "*things that are* – **organic** – *are better for* –

environmental quality – *has a lot to do with* – **pollutants** – *and the* – **ozone**" (Evan, Chemistry, map 2). So while it was evident that these students were attempting to use the scientific definitions that they had learned in the unit, there were problems in understanding being communicated through the boys' maps.

For the Chemistry unit, five of the seven boys demonstrated consistent growth in knowledge over the three maps in terms of increases in their level 2 link usage, and two students were part of a "rainbow" group. One of these two students, Geoff, had also been a "rainbow" group member in the Astronomy unit. This "rainbowing" trend again may be due to fatigue, lack of concentration, and the low motivation students expressed at the end of unit tests.

Chemistry Unit – Girls' Maps

Girls tended to create one large map in this unit. Only a couple of individuals used a multi-map approach with a combination of small and large maps. The number of list words used by the girls in the maps increased slightly from an average of 7.6 in the first map to 9.9 on the third map (Table 5). While responses for the most part suggested that the students were interested in the topic, generally they showed minimal evidence of deep scientific understanding of the Chemistry topics. The average number of level 2 Science links increased from the first map (2.4) to the third map (3.9). Language used for the linking statements was informal and conversational in nature and primarily based upon opinion about, or personal comment on, the topic.

Similar to the girls' concept maps for the Astronomy unit, a number of the Chemistry maps contained little scientific content in link statements. Betty's links with few or no words are suggestive of simple concept relationships, partially articulated: "**particals (sic)** – *cause* –

pollution – *harms are (sic)* – **environmental quality** – *effects the* – **ozone** – *protects use (sic) from* – **UV rays**" (Betty, Chemistry, map 3). When girls did present basic scientific ideas, they tended to use informal language that was conversational in tone and colloquial in nature: "**Sewage** – *can also be a* – **pollutant** – *does not do well for* – **environmental quality** – *has to do with* – **acid rain** – *has lots of* – **acid** – *can also cause* – **neutralization**" (Diana, Chemistry, map 2) or "**neutralization** – *is when you can cancel out* – **acids** – *and* – **bases** – *by pouring each of them on top of each other*" (Gina, Chemistry, map 3). Evidence of student misunderstanding or misconceptions was evident in a number of maps. Farah's statement illustrates her confusion regarding the relationship between the concepts: "**organic products** – *are very good for the* – **ozone** – *and for our* – **sewage**" (Farah, Chemistry, map 2).

The girls' linking statements again showed evidence of making sense of the concepts through personal experience and relationship with the material. Hanna's maps illustrate this approach. Her link statements are thoughtful and full of personality but contain minimal Science. In some instances, she framed questions about the list concepts in non-scientific context: "**a solution** – *isn't that the answer to a problem*" (Hanna, Chemistry, map 2); "*I thought* – **oxygen** – *was healthy not poisonous*" (Hanna, Chemistry, map 2); and "**neutralization** – *is that when your (sic) sitting on the fence*?" (Hanna, Chemistry, map 3). Other times she responded to the concepets based on her prior experience: "**biodegradable** – *a life saving shampoo when your (sic) camping*" and "**organic** – *vegetables mmmmm organic! sometimes they have dirt or bugs in them thogh (sic)*" (Hanna, Chemistry, map 3). Elaine wrote descriptive sentences revealing a popular understanding of Science concepts: "**ozone** – *is a pale blue gas and protects from frying from the sun. It is getting holes in it though from* – **CFC's** – *are produced from refrigerator and air-conditioning coolness*"

(Elaine, Chemistry, map 2). Ingrid's maps contained her commentary about the social impact of garbage on the environment: "*In the* – **sewage** – *there is lots of* – ***garbage*** – *it is also very* – **pollutant** – *it reuins (sic) the* – **environmental quality** – *try not to pollute the environment*" (Ingrid, Chemistry, map 1).

In the Chemistry unit, five of the girls displayed a trend of increasing level 2 linkages in their concept maps. Three girls showed a "rainbowing" pattern similar to the boys – an upward trend for the first two maps, with the final map being less complex than the second one. Again, there was one girl, Carly, whose maps displayed a distinct, downwards trend, each map containing less scientific information than the one before. In the first map, the majority of Carly's links were framed as questions "*what is* – **neutralization** – *and* – **acid rain** – and – **respiration** – *and* – **product**" (Carly, Chemistry, map 1). Only one of her linking statements showed any evidence of scientific content: "**pollutants** – *are bad stuff 'cause they hurt the* – **ozone**" (Carly, Chemistry, map 1). In her second map, Carly's links were limited to personal commentary: "*I like* – **organic** – *things*", "**environmental quality** – *evil* – **acid rain** – *and* – **pollutants**", and "***I know*** – *what* – **change of state** – *means*" (Carly, Chemistry, map 2). By the third map, her links contained minimal information of any kind: "**chemistry** – *has* – **solutions**", "**pollutants** – *have* – **particles**", and "**environmental quality** – *ewwwwwwwwwwwwww* – **sewage**" (Carly, Chemistry, map 3). It seemed that, although she was capable of generating level 2 links as evidenced on her Astronomy maps, by the time we got to the Chemistry unit, our final unit before the Christmas break, Carly wasn't interested in concept mapping.

Summary of Concept Mapping Across the Units

Across both units, the trend was for the girls to produce a single large map. The girls appeared to be more concerned with including the key words, as evidenced by the greater number of list words used in their maps, and interested in trying to generate a cohesive picture. The boys adopted different mapping approaches for each unit. In the Astronomy unit, like the girls, the boys generally created one large map. But in the Chemistry unit, many boys created multiple maps of varied sizes. When the data was analysed for gender differences in list word usage, there was no statistically significant difference (Astronomy $p = 0.594$, Chemistry $p = 0.611$). There was, however, a gender interaction in the Astronomy unit. The boys increased their list word usage over time whereas the girls decreased their list word usage ($p = 0.041$).There was no significant gender difference in level 2 link usage in either unit.

An interesting trend was the number of more imaginative maps that were created in the Astronomy unit. Some students, such as Carl, used the terms to create a story about a magical Astronomy class where we were using space probes to explore the universe (Figure 13). Other students, such as Ingrid, discussed interacting with the universe, such determining the flavours of different items (Figure 14). Although some Astronomy maps were creative or imaginative in form, few students made any direct link between the content and their lives. This separation between the students and the content reflects claims made in literature regarding about the impact of a transmissive instructional approach, such as the one used in this unit. Given those claims, the creativity and imagination present in some of the concept map responses surprised me. Perhaps the abstract nature of the material stimulated the students in a way I hadn't forseen and seemed to inspire maps that were reflecting influences from science fiction books, TV programs, movies or video games set in space.

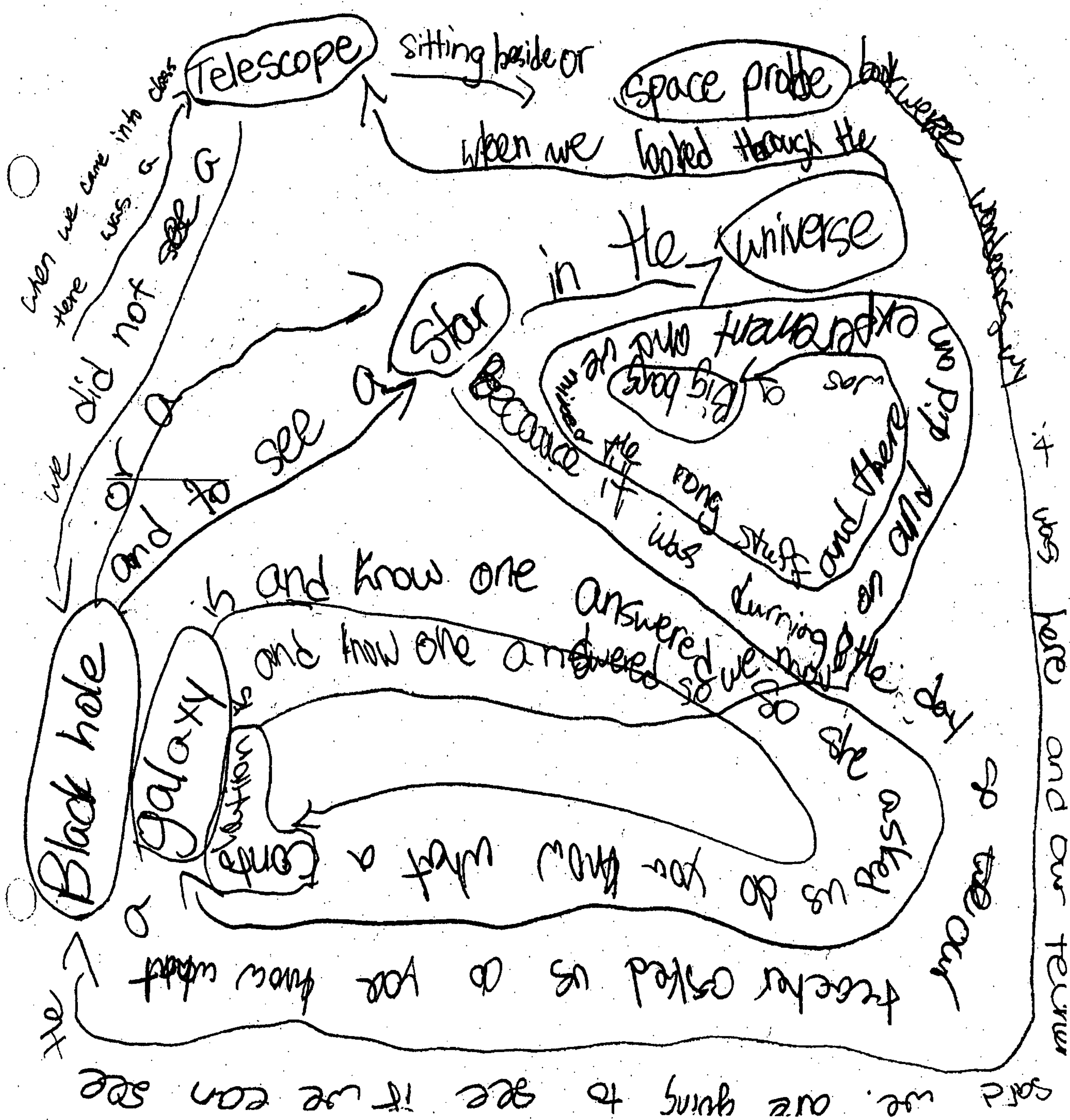
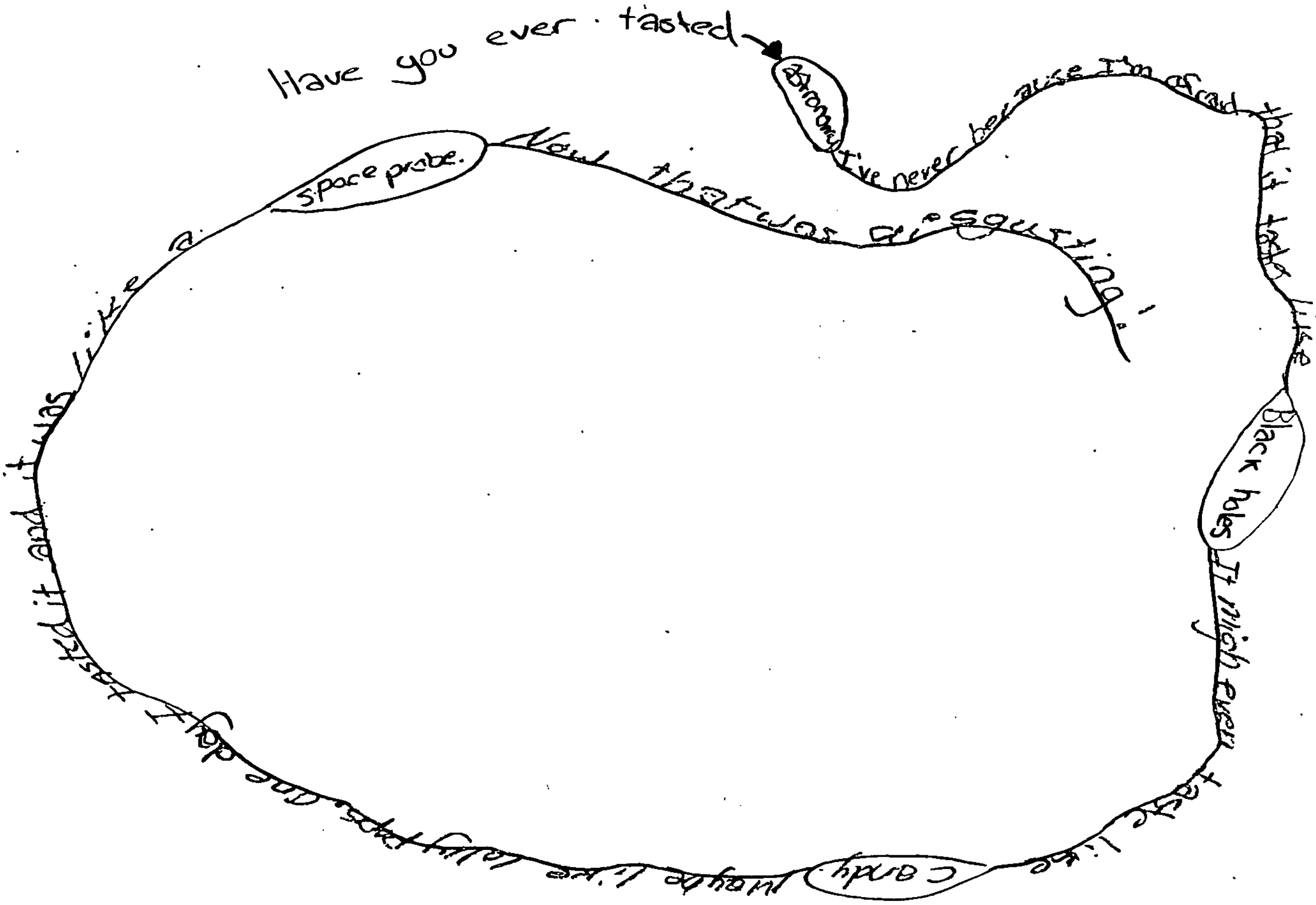


Figure 13. Carl's creative story in his first Astronomy concept map.

Figure 14. Ingrid's third Astronomy concept map.



In the Chemistry unit, a number of more personal maps were created. These maps revealed connections between the content and students' lives. In their linking statements, students commented on products they had used (biodegradable shampoo) or shared their reactions to unsavoury compounds (sewage). The STS instructional approach, such as the one used in the Chemistry unit, may have encouraged students to look for and see relationships between the science concepts and themselves, and present them in their linking statements. This response is in line with educators' claims that STS promotes students' abilities to see meaning and forge personal connection with the material they are studying. While it was not possible to determine if the Astronomy or Chemistry map differences I observed were due to my instructional approach or merely to students' response the subject matter, this would be an interesting area for future investigation.

Summary of Gender and Concept Mapping

My analysis suggests that there are gender differences in how students engage in the concept mapping activities. The boys generally followed the instructions of the activity: they used the maps to portray what they saw as scientific connections among the concepts and used textbook definitions for the majority of their linking statements. The maps showed logical organization and illustrated a moderate level of Science content. The boys' maps also revealed a preference for the scaffolding provided by the language used in the textbook; boys seldom included their own opinions or thoughts about the topics. The boys' use of level 2 linking statements highlights their focus on recall of facts. Maps showed little or no personal relationship with the material, linking statements used definitions from the textbook, and observations from labs and activities. In only one of the boys' maps was there a creative story (Figure 13).

Girls wrote linking statements that voiced their opinions, illustrated their experience with the unit and its content, and provided editorial comments about which topics they liked, found disgusting, or boring. When the girls used definitions in their links, the wording was informal, conversational, and idiomatic. The girls were also more varied and original in their map construction. While structurally the girls' maps in the Astronomy unit were reminiscent of the class sample we co-created, the majority of their maps for the Chemistry unit were not similar in form to our practice maps. They ranged from lists to paragraphs to spirals around the page. Chemistry maps were often written as paragraphs with the key words circled for emphasis. Most often list words were used in a non-scientific sense. Astronomy maps were creative and imaginative and the Chemistry maps contained opinions and commentary on the key terms.

In the next chapter, I examine concept maps as an assessment tool and compare them with traditional forms of assessment.

CHAPTER SEVEN

UTILITY OF CONCEPT MAPS AS A FORM OF ASSESSMENT

This chapter examines the data that pertains to my research questions: "Are concept maps a useful tool in assessing student understanding of Science? What do they show? How are they similar to or different from "traditional" assessment tools?" I compared test scores earned by the students on the Astronomy unit test with their Astronomy concept maps. I was interested in seeing if there was a relationship between the level of information encoded in the concept map, particularly the final map, and the results of the unit test. I assumed that concept map results would provide an additional lens for examining students understanding and that students who did well on the unit test should have very detailed maps and vice versa. I wondered whether there might be students in my class who understood Astronomy concepts but for whatever reason, were not doing well on the unit test and hoped my concept mapping study would assist me in judging whether unit tests were assessing student understanding.

Traditional Assessment Practices

In my classroom, I use a variety of assessment practices. To prepare my students, I ask them to create note cards based on the chapter's vocabulary list. These cards have each vocabulary word written on one side and the related definition written on the other. I require the students to have these cards completed for each chapter we read before I administer a vocabulary quiz. The students use the cards as a study aid for mastering the basic terms. For the vocabulary quiz, the students are presented with a list of ten definitions, identical to the ones on their study cards. Students are asked to write down the correct vocabulary word beside its definition. I do not provide a word bank so that students are less likely to guess.

randomly to obtain a correct answer. Scores earned on the vocabulary quizzes for each of the three chapters in the Astronomy unit are shown in Table 11.

Table 6

Student Achievement on the Astronomy Unit

Gender	Study Student Pseudonym	Chapter 14 Vocabulary Quiz /10	Chapter 15 Vocabulary Quiz /10	Chapter 16 Vocabulary Quiz /10	Unit Test %
Boys	Andy	10	10	10	81
	Bob	10	9	10	94.6
	Carl	5	10	9.5	41.9
	Dave	8	10	9.5	89.5
	Evan	10	10	10	85.2
	Frank	9.5	10	10	77.1
	Geoff	10	9	9	81.9
Girls	Anne	10	10	10	54.8
	Betty	10	10	10	79.0
	Carly	9.5	10	8	74.3
	Diana	10	9	10	84.8
	Elaine	10	10	10	78.1
	Farah	10	10	10	63.8
	Gina	10	10	10	64.3
	Hanna	8	10	6	85.7
	Ingrid	10	10	10	42.9
Study Students' Average n=16		**9.4**	**9.8**	**9.5**	**73.6**
Entire Class Average n=39		**8.3**	**8.5**	**9.1**	**67.3**

Students had very high scores on their vocabulary quizzes suggesting that they had rote knowledge of the basic definitions for the key concepts in the unit. The few lower scores were due to a lack of preparation, disclosed to me by the students themselves.

Comparing Concept Maps and Vocabulary Quizzes

Most students earned high scores on all their vocabulary quizzes. This pattern of achievement was not evident on the concept maps. The first map was completed by students prior to any unit instruction, so a low level of concept comprehension was expected. The second map was completed after the material had been covered once, and the third map was drawn after the unit test. Given this mapping schedule, it seemed reasonable to consider that concept maps could be used as an assessment tool for mastery of basic concept definitions. By the third concept map, most students were able to use the definitions in their maps to some degree. However, if the third map was scored using the vocabulary quiz key or even a rubric more closely aligned with the concept mapping task, most students would have obtained a failing mark. Even taking into consideration students' creative and informal rephrasing of definitions, most maps displayed only small amounts of concrete scientific knowledge.

Comparing Astronomy Concept Maps and Unit Tests

All students wrote the same test at the end of the unit. The unit test assessed the students on a variety of skills (see Appendix I). There were some short answer questions that specifically required vocabulary recall. The rest of the questions required that the students understand the concepts and be able to use their knowledge. The final column of the Table 11 contains the students' unit test scores, recorded as a percent for ease of comparison. For analysis purposes, students' test scores were used to establish four achievement groups:

failing achievement (41.9 to 54.8%), low-average achievement (63.8 to 74.3%), high-average achievement (77.1 to 81.9%), and high achievement (84.5 to 94.6%).[3]

To determine what, if any, relationship existed between student test scores and their concept maps, I analysed each student's maps and compared these with her/his test results. I then analysed the grouped maps for trends and noted any anomalies. In what follows, I discuss the concept maps of students in each achievement group.

Failing Achievement

Three students failed their unit test: Anne earned 54.8%, Ingrid 42.9%, and Carl 41.9%. Their first maps show little evidence of scientific content. Anne had some rudimentary scientific content that related to popular ideas about the process of Astronomy: "*you study* – **Astronomy** – *from a book or through* – **the telescope** – *to see the* – **stars** – *make the* – **constellations**" (Anne, Astronomy, map 1). Ingrid and Carl both used the list words in a creative context. Ingrid talked about familial relationships "*It's* – **black hole** – *cousin is the* – **Big Bang** – *is quite the* – **star**" while Carl created a story about a fantasy Astronomy class.

The second concept maps contained more "Science" facts than the first map. Anne's map contained noticeable detail and shared evidence of a new understanding of the content: "**telescopes** – *help you see the* – **constellations** – *are made from* – **stars** – *die out over hundreds of years it creates* – **supernovas**" (Anne, Astronomy, map 2). Ingrid and Carl's

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[3] These categories correspond to the grade scale used at Sunshine Academy. Failing achievement refers to a grade of F, low-average achievement corresponds to C range marks, high-average achievement is equivalent to B/B+, and high achievement is approximately equivalent to a letter grade of A. At my school, a student passes an assignment if they obtain a grade of 60% or higher.

maps showed attempts to unite the key concepts in terms of Science. Ingrid wrote: "*On the* – **universe** – *you can see a lot of* – **stars** – *threw (sic) a big huge* – **telescope** – *that sits on a* – ***galaxy***" (Ingrid, Astronomy, map 2). Carl wrote: "*In our* – **universe** – *we have many different kinds of* – **stars**" (Carl, Astronomy, map 2).

These students' final maps were varied and difficult to compare. Anne's map contained additional Science facts suggesting that she had continued to increase her knowledge of Astronomy. For example, she wrote: "**revolution** – *creates seasons* – **rotation** – *creates days*". Carl's map disclosed logical relationships between the terms but his links contained minimal scientific information: "*In* – **Astronomy** – *we talk about the* – **universe** – *that's what we learn about in* – **Astronomy**". Ingrid created another creative map that discussed "tasting" parts of the universe (Figure 15).

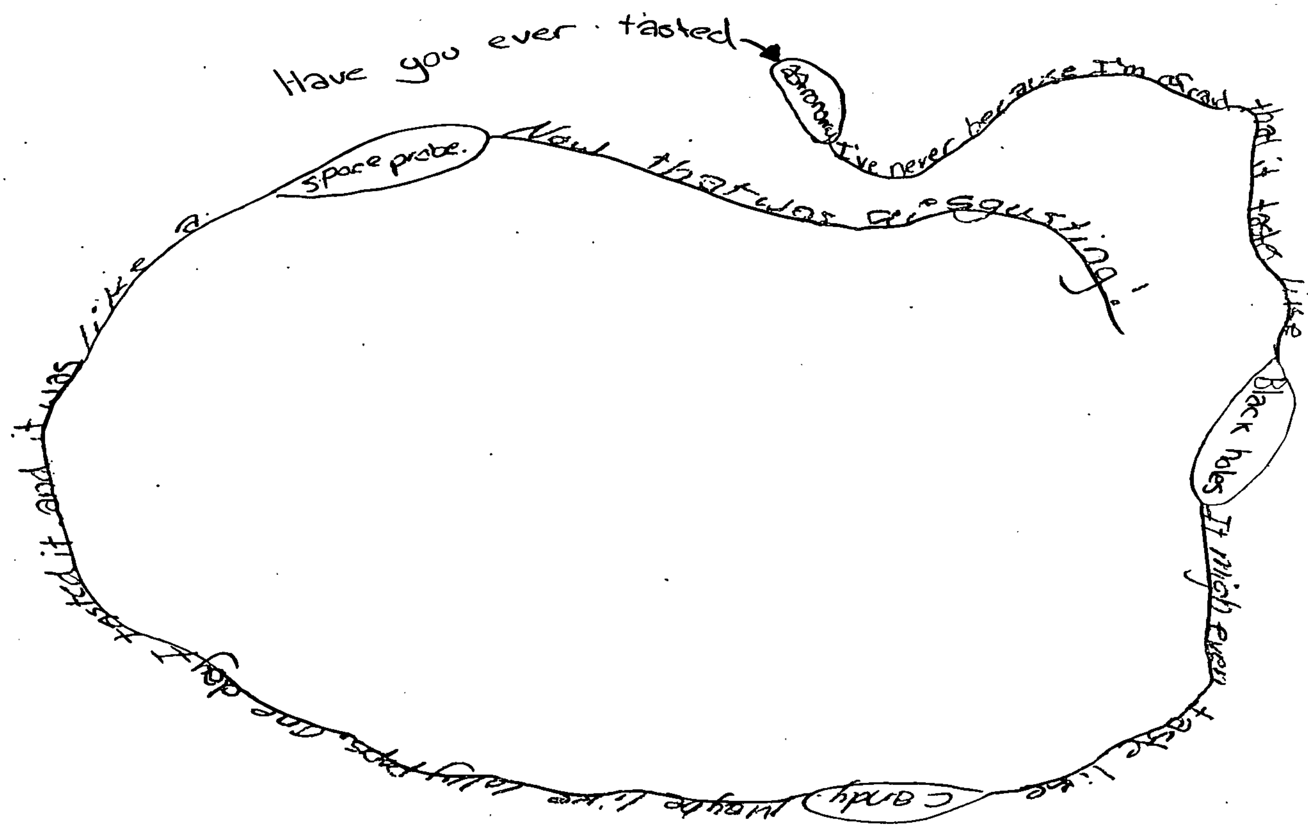

Figure 15. Ingrid's third Astronomy map.

Overall, the maps of students who received failing test scores can be described as displaying informal language, non-scientific use of the terms, few definitions, and creative responses. Anne's maps contained more scientific content than Ingrid or Carl's maps and did show growth in understanding of some concepts. Her test score was 12% higher than either classmate, reflecting a better understanding of the material.

Low-Average Achievement

Three students earned low-average scores on their unit test: Carly earned 74.3%, Gina 64.3%, and Farah 63.8%. None of their first maps contained scientific facts or definitions. Two students used all the list words to present their ideas about what they anticipated learning in the unit. Carly wrote: "**Astronomy** – *is cool but can it teach me about* – **nebulas** – *and* – **supernovas** – *and* – **black holes** – *what about* – **quasars**" (Carly, Astronomy, map 1). Gina's links were similar: "*we also learn about* – **quasars** – *and* – **nebulas** – *and* – **supernovas** – *and* – **big bang** – *and* – **astrolabe**" (Gina, Astronomy, map 1). Farah's first map was less logical in its organization and appeared to be a random association of the terms: "**Astronomy** – *is like a* – **star** – *in a* – **galaxy** – *with a* – **telescope** – *and a* – **big bang**" (Farah, Astronomy, map 1).

In the second maps, terms were linked more logically, but the maps were still focussed on what these students thought they were going to, or had learned, in Astronomy classes, as opposed to information about the discipline of Astronomy. Carly wrote: "*I like* – **stars** – *and* – **supernovas** – *better than* – **black holes**" (Carly, Astronomy, map 2). Gina wrote: "*we learned about our* – **universe** – *where we can see* – **stars** – *and* – **constellations** – *with a* – **telescope**" (Gina, Astronomy, map 2).

The third maps these three students produced contained some scientific terms and content. Definitions were included as linking statements. For example, Farah wrote: "**astrolabe** – *is a measuring tool*" (Farah, Astronomy, map 3). Information continued to be presented in a folksy and informal manner. This is evident in Carly's linking statement: "*did you know that a* – **quasar** – *is a high energy* – **galaxy**" (Carly, Astronomy, map 3). As in earlier maps, some links contained information about what they had learned and personal view and approaches to the subject matter. Carly wrote: "*I don't want to go near a* – **black hole** – *or a* – **supernova**" and "**Astronomy** – *I memorized words like* – **space probe** – *and* – **nebula**" (Carly, Astronomy, map 3).Gina wrote: "**nebulas** – *are a large cloud of gasses and* – **dust** – *are in* – **quasars**" (figure 16) (Gina, Astronomy, map 3).

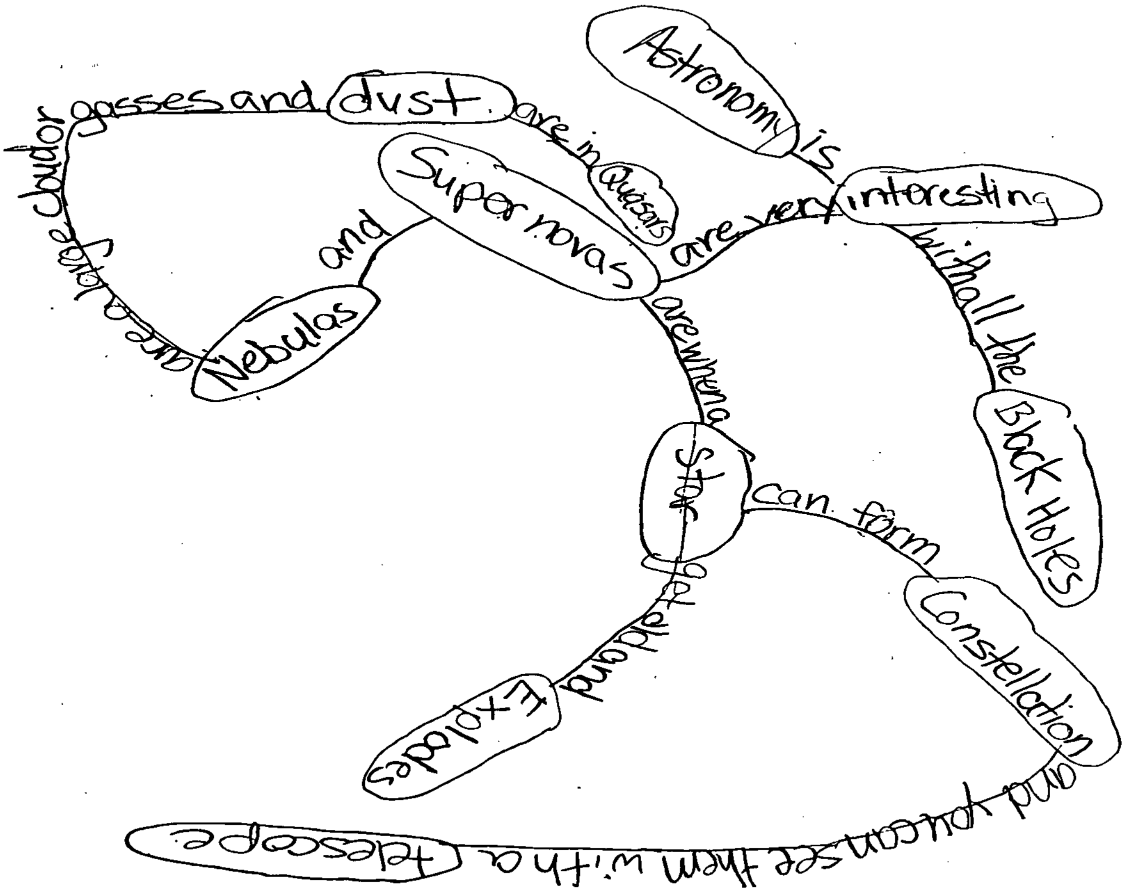

Figure 16. Gina's third Astronomy map.

Overall, the maps of students who received low-average marks on the final unit test contained simple scientific definitions, personal responses about what interested them, and reflective comments on what material they were going to or had learned in the unit.

High-Average Achievement

There were five students who earned scores classified as high-average on the unit test: Geoff 81.9%, Andy 81%, Betty 79%, and Elaine 78.1% and Frank 77.1 %. First maps showed evidence that these students began the unit with some basic scientific information about Astronomy. Andy wrote: "**stars** – *when stars spin on their axis it's called* – **rotation**" (Andy, Astronomy, map 1). Betty wrote "**stars** – *are in* – **constellations** ← *is a* – **big dipper**" (Betty, Astronomy, map 1). These maps were large and linked most of the list words. Elaine's map was unique, consisting of three small maps and linking statements that included her opinion of the subject matter: "**astronomy** – *is* – **cool** – *but* – **hard**" (Elaine, Astronomy, map 1).

The students' second maps generally contained fewer list words than the first map but included a greater quantity of scientific fact in linking statements. For example, Elaine wrote: "*The* – **black hole** – *is actually pretty small but it is so powerful that nothing, not even light can escape it*" (Elaine, Astronomy, map 2). Frank wrote: "**super nova** – *a huge explosion that occurs when a stars life has ended* – **star** – *are seen by telescopes*" (Frank, Astronomy, map 2). Geoff's map was the most densely detailed and contained the greatest number of linking statements, including scientific information (Figure 17).

The third maps were not as organised or as neatly presented as the second maps. Many of the maps used fewer list words than the second concept maps and linking statements contained fewer words. Some students used lists to group terms. Andy wrote: "*in the* –

universe – *there are* – **quasars** – *and* – **nebulas** – *and* – **black holes** – *and* – **supernovas**" (Andy, Astronomy, map 3). Andy framed some linking statements in question format: "*did you now (sic) the* – **Earth** – **rotates** – *every 24 hours and it does an* – **revolution** – *of the* – **sun** – *every 365 days*?" (Andy, Astronomy, map 3). Scientific content also appeared to have diminished. Elaine wrote: "**nebulas** – *come off of* – **supernovas** – *so do* – **black holes**" (Elaine, Astronomy, map 3).

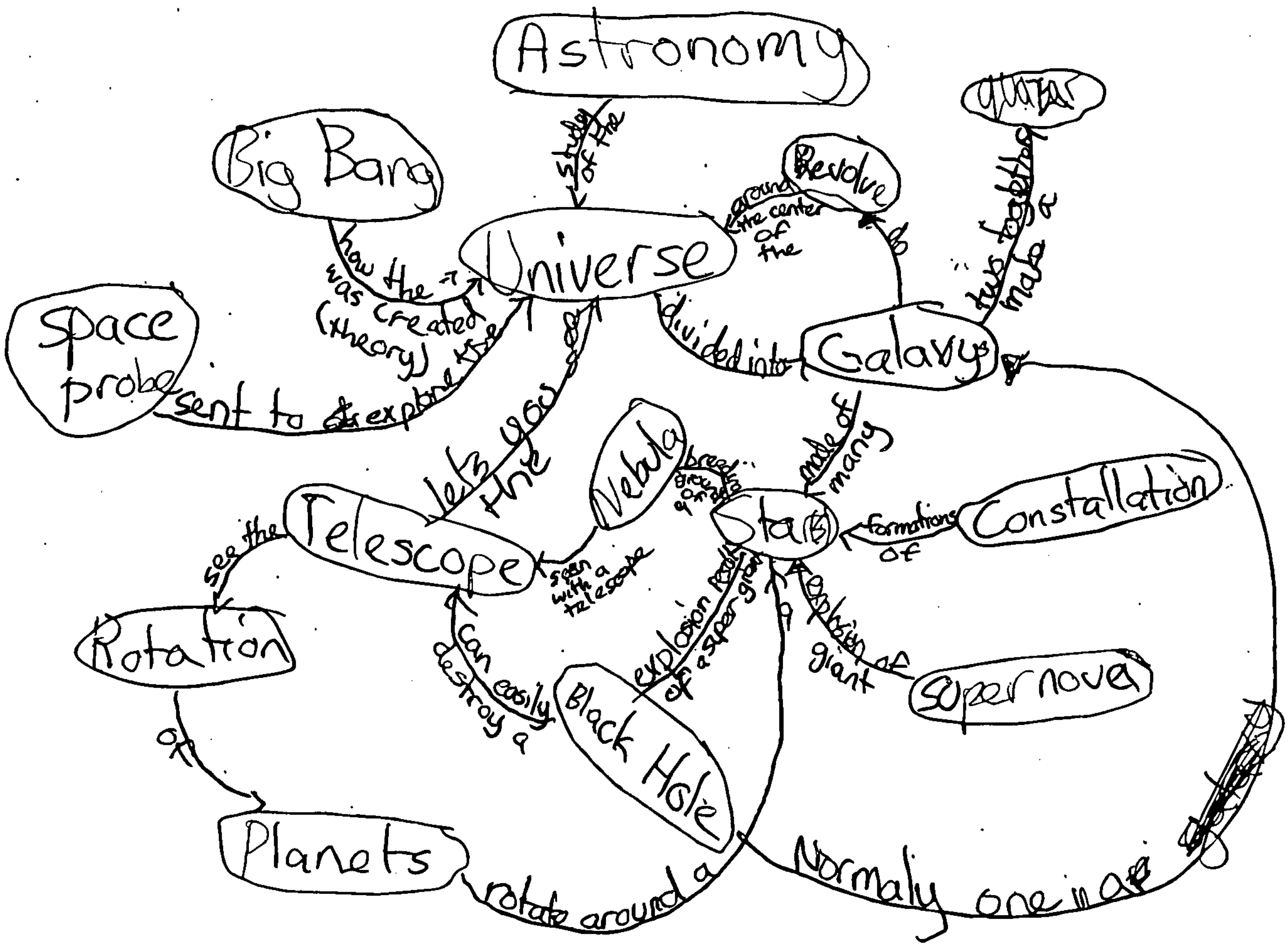

Figure 17. Geoff's second Astronomy concept map.

In summary, the maps generated by students in this category showed more consistent use of the list words in their scientific sense. The linking statements typically contained some simple scientific information or textbook definitions. Compared to the low-achievement group, there was a higher quantity of basic scientific knowledge and evidence of more detailed information. Linking statements often included phrases from the textbook and were written using formal language.

High Achievement

Five students were classified as high achievers: Bob 94.6%, Dave 89.5%, Hanna 85.7%, Evan 85.2%, and Diana 84.8%. For their first maps, each of the students used a different format. Bob's map was a spider's web of intersecting lines, Dave create a couple small maps, Hanna wrote in a spiral, Evan produced a star-like structure that used few interlinks, and Diana wrote her links in a chain. Bob's map was the only one of these that contained noteworthy scientific content (Figure 18). The other maps discussed Astronomy in general terms, or expressed students' opinions about Astronomy. Dave wrote: "**TLC TV** – *see a lot of programs on the* – **universe** – *and* – **big bang**" (Dave, Astronomy, map 1). Diana wrote: "**Astronomy** – *has to do with the* – **universe** – *there is a great big* – **star** – *if it explodes there will be a* – **big bang**." (Diana, Astronomy, map 1). These students tended to adopt informal language and used the list words in a creative but non-scientific sense. For example, Hanna wrote: "**Astronomy** – *is not my best subject. Often instead of paying attention to constellations my thoughts get stuck in the usual big* – **black hole**" (Hanna, Astronomy, map 1).

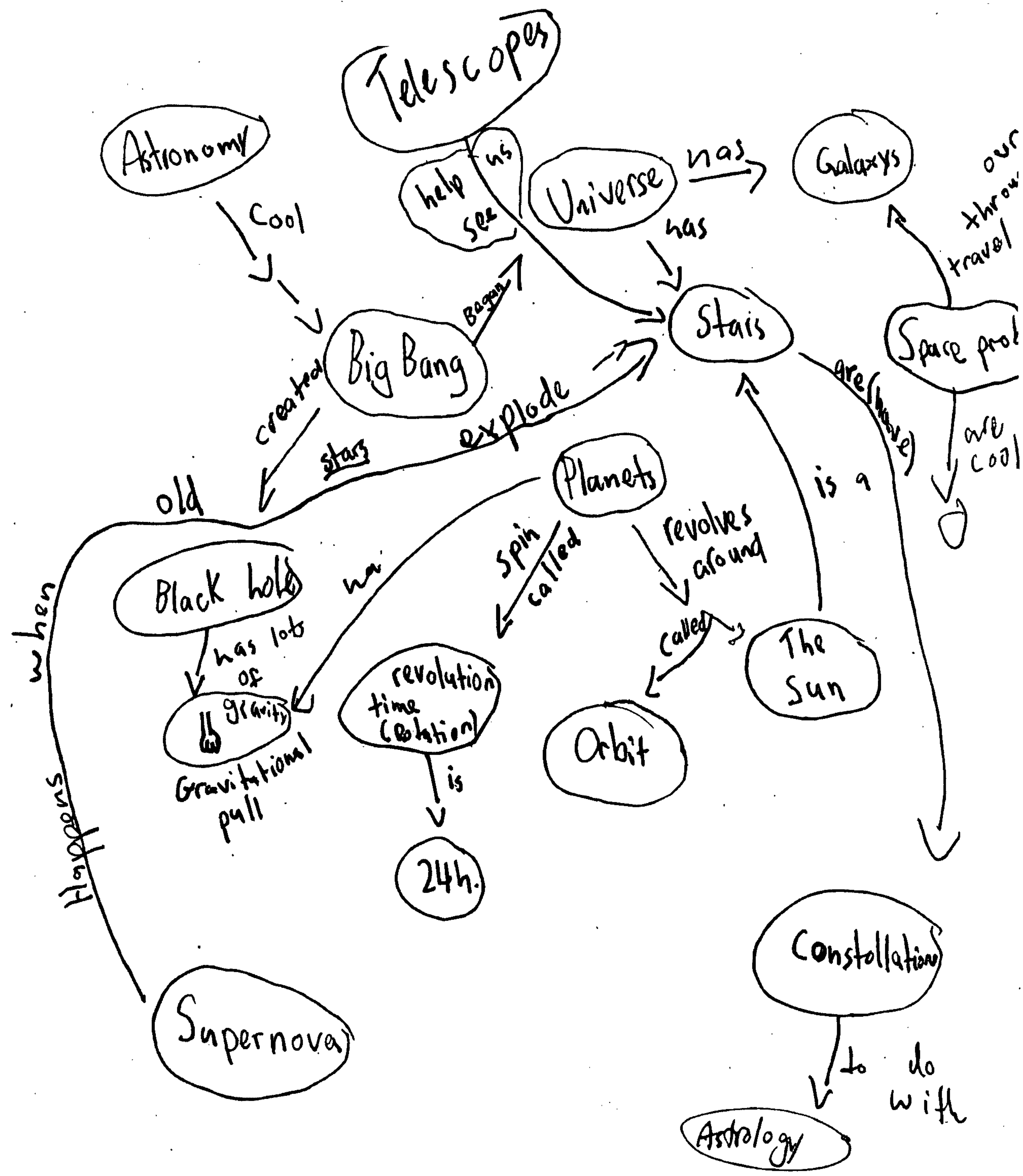

Figure 18. Bob's first Astronomy map.

The students' second maps were almost as individual as the first maps. These contained more scientific content and terms were used more consistently in their scientific sense. Bob's links were very detailed and specific: "**quasar** – *distant galaxy that collided with another galaxy in the* – **universe**" (Bob, Astronomy, map 2). Dave's map contained Science content that included simple definitions: "**Earth** – *does a* – **rotation** – *which is night and day*" (Dave, Astronomy, map 2). Evan's map included comments about the material. He wrote: "**Astronomy** – *is the study of* – **galaxies** – *and the* – **stars** – *and lots of other cool stuff like* – **quasars**" (Evan, Astronomy, map 2). Hanna's second map was another spiral with content that offered her philosophical reflections about our place in the universe (Figure 19).

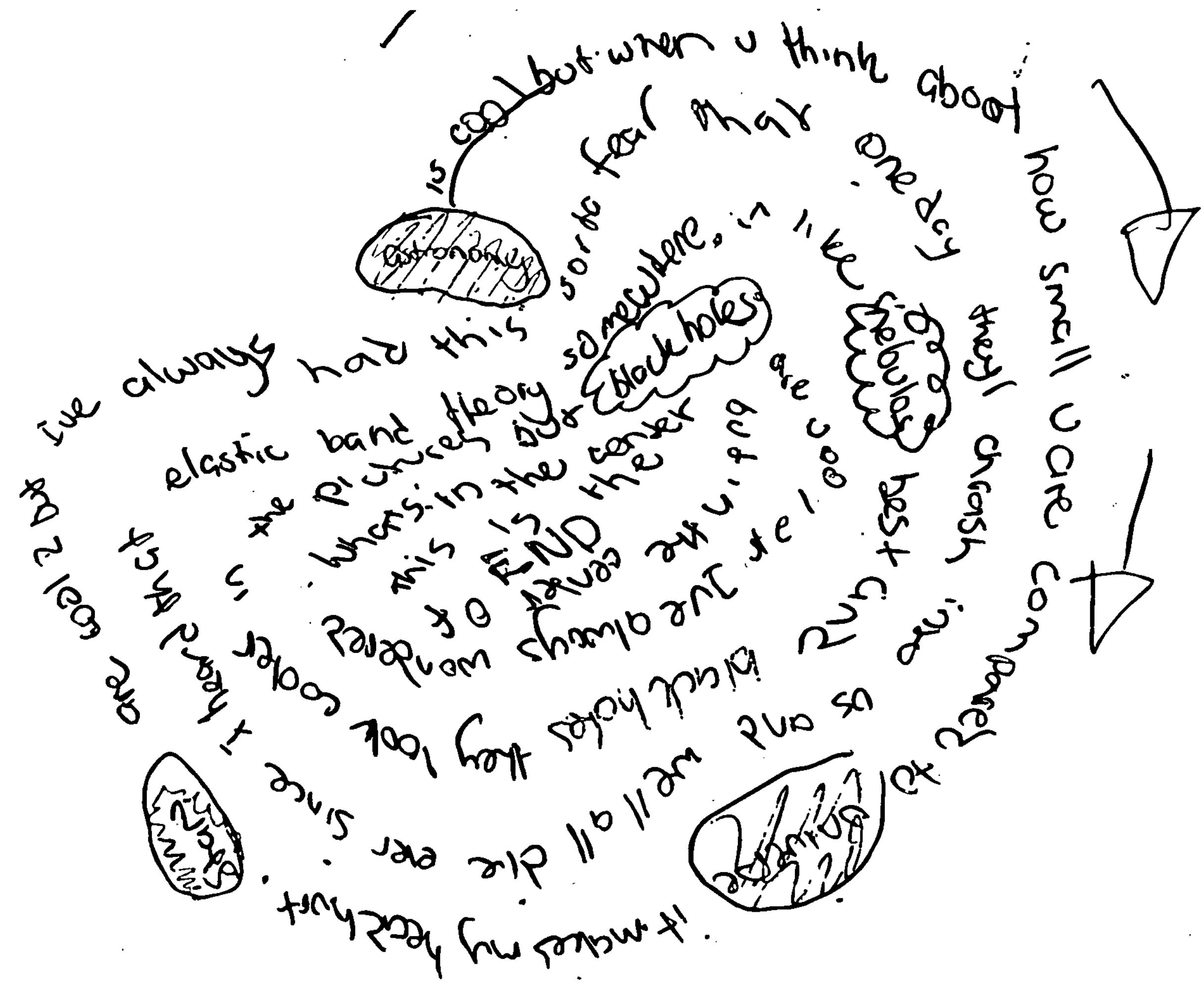

Figure 19. Hanna's second Astronomy map.

The high achievers' third concept maps did not contain either the quantity or quality of information present in the second concept maps. Generally, the maps were less complex in organization, contained fewer linking statements, used fewer list words and contained less scientific information. Bob's map had multiple short links and contained a note stating that he had run out of time. Dave's map contained only three linking statements. Hanna's map commented on the creativity of ancient astronomers in being able to see patterns and shapes in the sky. Evan's map contained a long list of what topics had been studied. Diana's map contained a short, densely-worded chain about the creation of the universe: "**universe** – *started out as a ball and then there was a* – **big bang** – *10 billion years later our own* – **galaxy** – *was created and the big* – **star** – *the sun*" (Diana, Astronomy, map 3).

Generally, the maps created by this group of students were more diverse than those in the average achievement groups. There wasn't a standard format to the maps or any similarities in approach to the content. The content in the linking statements ranged from simple to complex scientific facts, philosophical reflections, comments about what parts of Astronomy were interesting, and lists of the topics studied in this unit. Given the high level of achievement of these students, I admit that I was disappointed to find that, with the exception of Bob's maps, these students' maps contained rudimentary scientific information. I had expected more sophisticated and content laden maps.

Summary of Using Concept Mapping for Assessment

My analysis suggests there was some relationship between content expression in the concept maps and academic performance on the unit test. Students with low or failing performance on the unit test produced maps that were less detailed, contained simple ideas, and minimal information. Thus, their maps were reflective of their test scores. However, "stronger students" did not necessarily produce maps with a corresponding degree of increased depth and clarity. Some did, as in the case of Bob. However, for others, the maps became a creative outlet for reflective thoughts and contained little evidence of scientific knowledge. Thus, while simple concept maps seemed to be a reasonable indicator of limited content understanding and corresponded well with low academic achievement on a traditional test, above average academic performance on standard tests was not always reflected in concept maps. Hanna's work is a perfect example. If I had evaluated Hanna purely on the quantity and quality of scientific knowledge presented in her concept maps, she would have failed her assessment. Yet her test mark of 85.7% suggests this student had a solid grasp of the fundamental concepts of the unit as measured by traditional forms of assessment.

From this study, I realise that if I wished to use concept maps to assess students for factual content, I would need to change the instructions I provide. The students would need to know that I was going to be using the maps to evaluate their vocabulary knowledge, that each well-worded link would be worth a mark, and that the maps would be scored for the greatest number of "scientific" links. These were not messages I included in my concept mapping instructions. I believe that if I had informed my students, such as Hanna, that maps were going to be scored for the quantity of scientific content in the linking statements, I would have received more traditional maps and probably more Science content in the links. The problem I see with doing this is that the concept maps might not be a reflection of the students' thought, but rather a demonstration of how much information they could memorize.

Some Final Thoughts on Assessment

The concept maps produced in my classes were very different from "traditional" tests because they allowed my students to express what they found interesting and/or important, whereas "traditional" tests focus on what the teacher sees as the key points. Although the free-form maps generated in this study would not fairly assess the quantity of scientific facts students learned during the course of the unit, I believe the maps are valuable in other ways. The greatest value for students is the variability in form and content permitted by free-form concept mapping activities. Students traditionally have little control over how they are going to present their understanding of a topic or what information they are going to include in assignments. The open-ended nature of free-form concept maps allows students to determine the presentation of their ideas and information. For teachers, the maps provide some insight into what concepts the students understand, what student misconceptions and misunderstandings are prevalent, and which topics the students find relevant, interesting, or intriguing. This would allow teachers to review topics that have been misunderstood before administering end of unit assessment. Additionally, using concept maps in this way helps teachers decide which topics are viewed as exciting and motivational. I found examining the maps generated by my students informative and enlightening. It enabled me to be better tuned in to their interests and challenges, and has given me ideas on how I should address Astronomy content in the future.

CHAPTER EIGHT

CONCLUSIONS

At the outset of this study, I wanted to investigate student understanding of Science so that I could become a better teacher. I felt that concept maps offered a tool that would allow me to examine my students' thoughts and understandings about course content. At that time, I believed that free-form concept maps were a pedagogical structure that would augment my students' learning approaches, helping them to understand the material at a deeper level and improve their academic achievement. Additionally, I wanted to explore the effects of different teaching approaches on students' learning to allow me to evaluate which approach I should adopt as my dominant pedagogical strategy; Concept maps seemed ideally suited for this task. As a result of class observations when conducting pilot work with concept mapping, I was curious about apparent gender differences that I was observing during concept mapping activities; I wanted to determine if my observations were significant.

To answer my general question "What do concept maps tell us about grade seven students' understanding of Science concepts", I looked at each map individually, as a distinct entity. I coded the maps for the number of key words used from the list. I then recorded the number of non-worded links, links of minimal science content, and links of detailed science understanding. Additionally, I examined the maps as a whole for the number of maps a given student generated on the worksheet page (one, two, etc) as well as the relative size of the concept map (small with only a few links or large with multiple links) and concept map form (one long chain, short fragments, dense interconnection, or random symbols). The collection of these analyses provided information on the student's knowledge on a particular topic. All the data collected from each map were recorded and displayed in tables (Appendix F). The data were then examined through three lenses – gender, academic achievement, and instructional approach – to answer the additional research questions.

Summary of Results

In general terms, the maps showed that each student in my class approached learning differently. Maps showed the range of breadth and depth of understanding among students but every map was as unique as a fingerprint. Some maps showed a scientific understanding while others showed a creative response to the material. Each student engaged in concept mapping slightly differently from other students. There was evidence that the students learned new material over the course of each unit and that they could use key terms in a more "scientific" way by the end of the third concept map. While some maps provided evidence of misconceptions or incomplete understanding of concepts, a large number indicated that, by the time students had been through the course content, they were capable of using definitions from the textbook and were able to show how the major concepts of the unit were linked. I was surprised by how little information the students often put down on their maps and was worried about how limited their actual scientific knowledge was. Additionally, I did not expect to see such a variety of alternative formats for the maps, nor the creative responses, particularly in the Astronomy unit.

Gender differences were apparent in all aspects of concept map production. The boys' maps were generally similar in form and language. The boys used the mapping guidelines consistently throughout both units. Linking statements generally contained phrases from the textbook and indicated a basic scientific understanding of the material. The maps were, for the most part, well organized and easy to read. The girls' maps were diverse in form, language and content. Most girls developed their own mapping form including spirals, paragraphs, chains, and lists. The language in the linking phrases was often informal. Some linking statements showed basic scientific comprehension of the key terms, but many links expressed opinions and experiences and lacked any reference to Science.

The instructional approach used in the unit was found to have no significant affect on the quantity of scientific linking statements in the maps. In terms of quality of scientific linking statements, students showed a greater understanding of the key terms in the Chemistry unit than the Astronomy unit. Maps in the Astronomy unit were often more creative in their content whereas maps in the Chemistry unit showed evidence of students having recognized environment and Chemistry concepts. When the maps were re-examined along gender lines, it was clear that the boys and girls provided different information in the two units. The boys found it easier to link the concepts together in the Astronomy unit than the Chemistry unit, but their linking statements contained greater scientific detail in the Chemistry maps than the Astronomy maps. In maps produced for the Astronomy unit, the girls did not offer scientific definitions. Instead they wrote their opinions about what they were going to, or had learned. In the Chemistry unit, the girls' linking statements showed connections between the material and their lives and experiences.

Concept maps did not seem to be representative of the quantity and quality of knowledge that the students were able to demonstrate on their unit tests. The students were able to answer questions on their unit test that required a far greater breadth of knowledge than was indicated by the linking statements on the concept maps. Students who failed their test generally had concept maps that displayed little or no scientific understanding of the key terms, used informal language, and formed creative responses. Students who earned low-average achievement scores drew concept maps that showed some basic scientific understanding of the terms, used informal language, and included comments about what they found interesting. The high-average achievement group consistently used the list words in their scientific sense, frequently copied the language and the phrasing of the textbook, and had many linking statements showing basic scientific knowledge, as well as a few indicating more in depth understanding. The high achieving group's maps contained information range from scientific propositions to philosophical reflections upon the course content and areas of personal interest in the unit. The maps produced by students in this group were more diverse in form than those for other achievement groups, but they didn't show the depth or quantity of information that I was expecting, given their test scores.

Limitations of the study

The major limitations in this study were sample size and nature of the teaching intervention limited the potential number of students who could participate in the study. The school I teach in is small, with only 40 students per grade level. This number was further limited as there were students who could not be included in the study as they had not completed all the concept maps that were going to be analysed. Thus, while my study of sixteen students provides some insight into how and what students are learning, its generalizability is restricted.

My teaching intervention involved only two units. These were selected because they were viewed as the most gender neutral content among the curriculum topics. For each unit, I implemented what I believed was a distinctive teaching approach, and the units were comparable in terms of quantity of learning outcomes and teaching time. Extending this study to examine additional STS and transmissive units would have provided a bigger data set for comparison and possibly have enabled stronger conclusions to be made about the differences between teaching approaches. However, given the structure of my school year and other units I was responsible for teaching, this would not have been possible.

Issues and Implications

There are some issues involved in the concept mapping implementation process that need to be addressed. Many students made comments to me about the process of concept mapping during the course of the year. By the time we had gone through a few units, many of the students didn't want to do the maps, in their words "over and over again". They felt that if they did it once, that should be enough. When we would talk as a class, the students could understand that doing them multiple times helped to show the new links they had made and showed their progress. At the same time, they didn't want to do "the same work over again".

Other students made the request that they wished that they could do the new maps on top of their previous maps so that they could simply add on the new things that they had learned without having to go to the effort of writing it all out again. Some of the students commented to me that they were assuming that I had seen the previous map and, as they could remember what they had put down last time, were simply going to add from memory to what was previously done. This does put the data into a new context, as I don't know who did this or who didn't. Other students were frustrated as they felt that they spent the time on the later maps putting down previous information and never really got a chance to put down that much of the new material that was there.

Organizationally, some of the students found it hard to make sure that their concept maps were centred on the page, were neatly presented, or had sufficient space to write linking statements between nodes. I think that had it been an option to do it on a computer with a software program that would allow them to manipulate their concept map so that the key words were more centred on the page and the links weren't overlapping as much, they would have had a much easier time creating their map. On the other hand, mapping on the computer might disadvantage some students who had fewer technology skills.

A different problem was one of mental exhaustion and attention span. Many of the students really focussed on the first map of each unit and seemed to find working with new ideas and content stimulating. They appeared to be excited by having a chance to show me how much they knew beforehand. The final map, in contrast, was usually an agonized affair. The students were often tired and unable "to think anymore" having written a test. Considering that they had just been tested on the material and had spent a couple of nights reviewing all the material, it was safe to assume that their maps showed all that they knew. However, many commented that having just put all their knowledge down on the test, it was simply "gone" (not to be "found" again until we reviewed for the exam). In my experience, this phenomenon frequently occurs in younger students. However, this could be an interesting area for further investigation. Taken together, these issues suggest that I need to rethink aspects of my concept mapping procedure when I engage my students in this activity in future classes.

In my study, I found that boys and girls seem to generate different types of concept maps and the content included in the maps suggests that by grade 7, boys and girls find different types of information interesting and relevant. The boys tended to represent their thoughts and ideas using objective facts and the girls offered personal responses. This highlights the need for Science educators to consider gender difference at the upper elementary grade levels. As this is when girls traditionally begin to lose interest in Science, relating Science to students' experiences may well aid both the girls and boys in applying their understanding and maintaining girls' interest in Science.

The Chemistry concept maps revealed a better understanding of the material than the Astronomy unit. This was true for the boys and the girls. This supports my personal experience that the students tend to learn more and show greater academic success when taught in an STS manner. Although I am fully aware that it is difficult to implement this teaching approach in some units, I feel that the rewards for maintaining interest in the students are well worth the efforts.

This study shows that free-form concept maps can reveal what and how much students understand about a topic. Additionally, they were a good tool for showing student growth over the course of the unit. However, I would not recommend using free-form concept maps as a form of mark-based assessment, but I would strongly recommend them to be used as a part of regular classroom teaching. The students can clearly see their own growth, and the teacher can identify some of the topics the students are having difficulty in grasping or have misunderstood. I would recommend using them twice during a given unit so that the students do not get bored with the repetition.

Recommendations for Further Research

There are numerous areas for further research arising from this study. Two are discussed here. It would be useful to extend this study to see if the gender differences that I observed in maps of girls and boys are present in maps generated by older and younger students. It would be interesting to conduct a study with students in Grade 5 to see if gender differences emerge during mapping activities. Then a study with Grade 9 students might provide information on how those gender differences change as students mature. Ideally, if time and resources were available, a longitudinal study could be designed to study the same group of students over a five year period in order to track their development and changes over that time period.

Additionally, research should be conducted to examine if the concept mapping differences are related to instructional approach or to students' response to the content itself. This would be a valuable and exciting topic for future investigation. Given that this would require teaching units using different instructional approaches and examining a range of disciplinary knowledge, the study design would be challenging. Maintaining controls on this would be problematic but still I believe such a study could be revealing as to what has the greatest impact on student learning and make an important contribution to Science education and practitioner knowledge.

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Study Procedures:

We are seeking your permission to include your child in a study of the value of concept mapping being conducted at your child's school. Concept mapping activities regularly take place during school hours in your child's classroom.

If you provide written consent for your child's participation by signing this form, your child will take part in the *data collection* portions of this study. Specifically, we seek permission to collect photocopies of your child's concept maps. The classroom activities and data collection will fit within the time frame of regular school instruction. The total time expected will be approximately 90 minutes over a two month period. Your child's participation in this project's data collection procedures is entirely voluntary and will not affect their participation in the regular classroom activities in any way.

Confidentiality:

By agreeing to participate, please be assured that:

- All data collected will be confidential with the researchers listed at the beginning of this form and through the following procedures.
    - Your child's name will not appear in any written documents of the project. In addition, your child's name will remain strictly anonymous.
    - For any work that is collected, your child's name and identifying features will be removed prior to data analysis and reporting.
    - All data will be kept in a locked space accessible only to the researchers.
- You may refuse to allow your child to participate in or withdraw your child from the data collection procedure at any time, without prejudice, even if you sign this consent letter.
- At any stage in this project you may ask clarification on any issue regarding this study. This project will NOT involve risk of any kind.

If you choose not to allow your child to participate in this study, your child will continue to participate in regular classroom activities but their concept maps will not be included in the data to be analyzed. Your child's grades, his/her relationship with the teacher, and his/her relationship with the school will not be affected in any way if you choose not to allow his/her participation in the study. To ensure this, the researchers will not know the identity of which students are/are not participating in the study until after the completion of the school year.

TO PARTICIPATE IN THE RESEARCH PROJECT: Exploring the Value of Using Concept Mapping to Analyze Student's Understanding of Grade Seven Science Concepts, PLEASE RETURN THIS COPY OF THE CONSENT FORM

Please check the box indicating your decision:

- ❑ I CONSENT to my child's participation in the above stated project and agree to the photocopying of my child's concept maps. I have read the attached form and understand the nature of my child's participation in this project. With my consent, I acknowledge receiving a copy of this project information.

- ❑ I DO NOT CONSENT to my child's participation in the project activities described in the attached form.

Child's Name (please print):____

Parent/ Guardian Name (please print):____

Signature: ____ Date:________________

(Please return this consent form to Andrew Wallace, headmaster, in a sealed envelope.)

TO PARTICIPATE IN THE RESEARCH PROJECT: Exploring the Value of Using Concept Mapping to Analyze Student's Understanding of Grade Seven Science Concepts, PLEASE RETURN THIS COPY OF THE CONSENT FORM

Please check the box indicating your decision:

- ☐ I CONSENT to my participation in the above stated project and agree to the photocopying of my concept maps. I have been informed about the study by Miss Kathryn Murray, my teacher, and understand the nature of my participation in this project.

- ☐ I DO NOT CONSENT to my participation in the project activities described by Miss Kathryn Murray in the attached form. I understand that my decision to not take part in the study will not affect my grades in any way.

Your Name (please print):____________________________________

Signature: ____ Date:_________________

(Please return this consent form to Andrew Wallace, headmaster, in a sealed envelope.)

Appendix B

Institution Request Letter

THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Education
Department of Curriculum Studies
2125 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-5422 Fax: (604) 822-4714

March 18th, 2004

Mr. Andrew Wallace
Headmaster
Southpointe Academy
1741 West Fifty-Sixth Street
Delta, BC V4L 2B2

Dear Mr. Wallace:

We are requesting your permission to contact students at Southpointe Academy to invite them to participate in the research project entitled: *Exploring the Value of Using Concept Mapping to Analyse Students' Understanding of Grade Seven Science Concepts*. A copy of the parent and student information letter/consent form has been attached for your information.

The request for ethics review is currently being made. Thank you for considering this request, and we look forward to hearing from you.

Yours truly,

Jolie Mayer-Smith
Associate Professor

Kathryn Murray
Masters Student

THE UNIVERSITY OF BRITISH COLUMBIA

Faculty of Education
Department of Curriculum Studies
2125 Main Mall
Vancouver, B.C. Canada V6T 1Z4
Tel: (604) 822-5422 Fax: (604) 822-4714

TO PARTICIPATE IN THE RESEARCH PROJECT: Exploring the Value of Using Concept Mapping to Analyse Student's Understanding of Grade Seven Science Concepts, PLEASE RETURN THIS COPY OF THE CONSENT FORM

Please check the box indicating your decision:

- ☐ I CONSENT to the students in my school being contacted and invited to participate in this research project. I have read the attached form and understand the nature of the students' participation in the project. With my consent, I acknowledge receiving a copy of the project information. I also acknowledge my willing to store the data in a secure, locked cabinet and not to disclose the data to anyone. At the end of five years, I also agree to have the material shredded to protect students' identities. Additionally, I agree to remove from the data set any student's data where the student and/or parent requests that the student's data is not included in the data set.

- ☐ I DO NOT CONSENT to the students in my school being contacted and invited to participate in this research project.

Your Name (please print):______________________________

Signature: ______________________________ Date:____________

(Please return this consent form to Kathryn Murray who will forward the form to the principal investigator, Dr. Jolie Mayer-Smith.)

Appendix C

Grade Seven Science Prescribed Learning Outcomes 1999

Table C1

Intended learning outcomes for Chemistry, (Physical Science 7)

	It is expected that students will:
1.	Use the pH scale to classify a variety of substances
2.	Identify chemical reactions that are important in the environment
3.	Assess the impact of chemical pollution on a local environment
4.	Collect, analyze, and interpret data on environmental quality
5.	Propose and compare options when making decisions or taking action
6.	Analyze costs and benefits of alternative scientific choices related to a community problem

Table C2

Intended learning outcomes for Astronomy (Earth and Space Science 7)

	It is expected that students will:
1.	Identify characteristics of known objects outside the solar system
2.	Outline the changes in human understanding of the universe from early times to the present
3.	Illustrate the seasonal position of various constellations
4.	Identify factors that have made possible or limited the work of particular scientists
5.	Describe how technology and science are related

Appendix D

Blank Concept Mapping Task Sheets

Chapter 1 Concept Map

Name:____________________ Date:______________

Use the following words to make a concept map. You do not need to use all the words listed below, but please try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what is the connection. You may have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting word list

science	classify	theory
technology	predict	variable
measure	communicate	model
observe	experiment	process
estimate	interpret	sample

Chapter 8-10 Concept Map

Name:____________________

Use the following words to make a concept map. You do not need to use all the words listed below, but try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what is the connection. You might have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting Word List

Solution	Chemical change	Pollutant
Neutralization	Respiration	Environmental quality
Acid rain	Product	Particles
Water cycle	Biodegradable	Ozone
Change of State	Organic	Sewage

Chapter 14-16 Concept Map

Name:____________________

Use the following words to make a concept map. You do not need to use all the words listed below, but try to use as many as you can. You may add any additional words that you wish. You need to show how the words are connected. Use arrows to show the direction of the connection and write on the arrow line what is the connection. You might have more than one arrow between two words. What is important is that this shows how these words are linked or important to YOU. There is no wrong way.

Starting Word List

Astronomy	Universe	Quasar
Galaxy	Star	Constellation
Telescope	Nebula	Astrolabe
Space probe	Supernova	Rotation
Big Bang	Black Hole	Revolution

Appendix E

Concept Map Coding Form

Student Number:______________________________

Chemistry Unit

Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
1							
2							
3							

Astronomy Unit

Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
1							
2							
3							

Appendix F

Coding Form for the Scientific Content of the Linking Statements

0 = no words
1 = few words with no/little meaning to the nodes
2 = basic science definitions or understanding between nodes
3 = in depth science content

Student Number:______________________________

Astronomy Unit

Student Number	Map	0 links	1 links	2 links	3 links
	Astronomy Map 1				
	Astronomy Map 2				
	Astronomy Map 3				

Chemistry Unit

Student Number	Map	0 links	1 links	2 links	3 links
	Chemistry Map 1				
	Chemistry Map 2				
	Chemistry Map 3				

Appendix G

General Data Tables

Table G1

Data on the Mechanics of the Maps Constructed by the Boys in the Astronomy Unit

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Andy	Map 1	9	0	0	3	7	1	L
	Map 2	9	0	0	4	5	1	L
	Map 3	14	3	0	7	8	4	M
Bob	Map 1	11	6	0	9	6	2	S, L
	Map 2	15	2	0	4	12	2	S, L
	Map 3	10	0	0	0	8	1	L
Carl	Map 1	8	0	0	0	8	1	L
	Map 2	5	0	0	2	3	1	M
	Map 3	9	0	0	8	6	1	L

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Dave	Map 1	9	3	1	2	7	2	M, L
	Map 2	12	1	5	4	4	2	S, L
	Map 3	11	2	9	1	3	2	S, L
Evan	Map 1	7	3	0	4	8	1	L
	Map 2	9	1	1	8	6	1	L
	Map 3	12	0	0	6	8	1	L
Frank	Map 1	8	0	0	0	7	1	L
	Map 2	7	1	0	0	7	1	L
	Map 3	6	0	0	0	5	1	M
Geoff	Map 1	10	3	0	8	7	1	L
	Map 2	13	0	0	4	13	1	L
	Map 3	12	0	0	3	13	1	L

Table G2

Data on the Scientific Nature of the Links in the Boys' Maps in the Astronomy Unit

0 = no words

1 = few words with no/little meaning to the nodes

2 = basic science definitions or understanding between nodes

3 = in depth science content

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Andy	Map 1	0	10	0	0
	Map 2	0	4	5	0
	Map 3	0	10	5	0
Bob	Map 1	0	14	1	0
	Map 2	0	7	9	1
	Map 3	0	2	6	0
Carl	Map 1	0	7	1	0
	Map 2	0	1	4	0
	Map 3	0	14	0	0
Dave	Map 1	1	8	1	0
	Map 2	5	4	4	0
	Map 3	9	2	2	0

Student Code Name	Map #	0 links	1 links	2 links	3 links
Evan	Map 1	0	11	1	0
	Map 2	1	13	1	0
	Map 3	0	12	2	0
Frank	Map 1	0	1	6	0
	Map 2	0	0	7	0
	Map 3	0	0	4	1
Geoff	Map 1	0	11	4	0
	Map 2	0	6	11	0
	Map 3	0	7	9	0

Student Code Name	Map #	0 links	1 links	2 links	3 links
Evan	Map 1	0	11	1	0
	Map 2	1	13	1	0
	Map 3	0	12	2	0
Frank	Map 1	0	1	6	0
	Map 2	0	0	7	0
	Map 3	0	0	4	1
Geoff	Map 1	0	11	4	0
	Map 2	0	6	11	0
	Map 3	0	7	9	0

Table G3

Data on the Mechanics of the Maps Constructed by the Boys in the Chemistry Unit

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Andy	Map 1	5	0	0	2	5	5	S
	Map 2	6	1	0	2	6	5	S
	Map 3	8	3	0	4	5	5	S
Bob	Map 1	6	4	0	3	4	3	2S, M
	Map 2	8	10	4	6	5	5	3S, 2M
	Map 3	14	9	6	7	8	5	3S, 2L
Carl	Map 1	15	0	13	0	0	1	L
	Map 2	9	0	0	5	9	1	L
	Map 3	16	1	1	10	6	1	L

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Dave	Map 1	4	9	16	0	0	3	2S, L
	Map 2	11	0	0	8	0	3	2S, L
	Map 3	6	12	11	3	3	3	S, M, L
Evan	Map 1	1	5	0	2	4	1	L
	Map 2	6	8	0	10	3	2	M, L
	Map 3	2	5	0	11	3	2	S, M
Frank	Map 1	4	0	0	0	4	1	M
	Map 2	7	0	0	0	6	2	S, M
	Map 3	9	0	0	2	5	2	S, M
Geoff	Map 1	4	3	0	9	0	2	S
	Map 2	11	7	0	16	4	4	3S, L
	Map 3	13	4	0	11	7	2	S, L

Table G4

Data on the Scientific Nature of the Links in the Boys' Maps in the Chemistry Unit

0 = no words

1 = few words with no/little meaning to the nodes

2 = basic science definitions or understanding between nodes

3 = in depth science content

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Andy	Map 1	0	0	7	0
	Map 2	0	0	7	1
	Map 3	0	0	8	1
Bob	Map 1	0	5	2	0
	Map 2	4	6	5	0
	Map 3	6	8	4	3
Carl	Map 1	13	0	0	0
	Map 2	0	14	0	0
	Map 3	1	13	3	0
Dave	Map 1	16	0	0	0
	Map 2	0	8	0	0
	Map 3	11	2	4	0
Evan	Map 1	0	4	2	0
	Map 2	2	7	4	0
	Map 3	0	13	1	0

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Frank	Map 1	0	1	3	0
	Map 2	0	0	6	0
	Map 3	0	0	7	0
Geoff	Map 1	0	0	9	0
	Map 2	0	7	13	0
	Map 3	0	7	11	0

Table G5

Data on the Mechanics of the Maps Constructed by the Girls in the Astronomy Unit

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Anne	Map 1	9	0	0	8	3	1	L
	Map 2	9	0	0	0	8	1	L
	Map 3	10	0	0	4	5	2	S, L
Betty	Map 1	12	3	1	7	6	2	S, L
	Map 2	12	2	0	9	6	2	S, L
	Map 3	10	1	0	10	1	1	L
Carly	Map 1	15	0	0	12	2	1	L
	Map 2	15	0	0	9	6	1	L
	Map 3	15	0	1	7	9	1	L

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Diana	Map 1	10	0	0	1	8	1	L
	Map 2	15	1	0	8	5	1	L
	Map 3	8	0	0	2	9	1	L
Elaine	Map 1	10	3	0	5	5	3	2S, 1L
	Map 2	10	0	1	6	5	4	3S, 1L
	Map 3	7	4	1	4	6	4	3S, 1M
Farah	Map 1	15	0	0	14	1	1	L
	Map 2	15	0	2	5	7	1	L
	Map 3	15	2	7	7	5	1	L
Gina	Map 1	15	0	1	8	6	1	L
	Map 2	11	0	0	4	6	1	L
	Map 3	8	3	0	5	4	1	L

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Hanna	Map 1	9	1	0	0	6	1	L
	Map 2	5	0	0	0	5	1	L
	Map 3	8	0	1	1	4	1	L
Ingrid	Map 1	8	0	0	3	5	1	L
	Map 2	6	2	0	3	6	1	L
	Map 3	3	1	0	0	4	1	M

Table G6

Data on the Scientific Nature of the Links in the Girls' Maps in the Astronomy Unit

0 = no words

1 = few words with no/little meaning to the nodes

2 = basic science definitions or understanding between nodes

3 = in depth science content

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Anne	Map 1	0	11	0	0
	Map 2	0	0	5	3
	Map 3	0	0	7	2
Betty	Map 1	1	13	0	0
	Map 2	0	12	3	0
	Map 3	0	11	0	0
Carly	Map 1	0	14	0	0
	Map 2	0	11	5	0
	Map 3	1	15	1	0
Diana	Map 1	0	6	3	0
	Map 2	0	9	4	0
	Map 3	0	3	8	0
Elaine	Map 1	0	7	3	0
	Map 2	1	9	1	1
	Map 3	2	7	2	0

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Farah	Map 1	0	15	0	0
	Map 2	2	10	2	0
	Map 3	7	9	3	0
Gina	Map 1	0	12	3	0
	Map 2	0	7	3	0
	Map 3	0	6	3	0
Hanna	Map 1	0	6	0	0
	Map 2	0	3	2	0
	Map 3	1	1	3	1
Ingrid	Map 1	0	7	1	0
	Map 2	0	5	4	0
	Map 3	0	5	0	0

Table G7

Data on the Mechanics of the Maps Constructed by the Girls in the Chemistry Unit

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Anne	Map 1	4	1	0	4	1	1	M
	Map 2	8	1	0	4	4	4	3s, 1m
	Map 3	9	1	0	0	8	6	S
Betty	Map 1	5	6	8	1	0	4	3s, 1m
	Map 2	7	6	0	8	2	5	4s, 1m
	Map 3	10	7	0	10	2	6	4s, M, L
Carly	Map 1	15	1	2	12	1	2	S, L
	Map 2	15	1	4	8	2	2	S, L
	Map 3	15	2	5	8	1	2	S, L

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Diana	Map 1	10	1	0	3	8	1	L
	Map 2	14	1	0	4	12	1	L
	Map 3	15	2	0	4	12	1	L
Elaine	Map 1	4	0	0	0	4	4	S
	Map 2	6	0	0	4	4	3	S
	Map 3	5	4	1	3	5	3	S
Farah	Map 1	15	0	1	8	5	1	L
	Map 2	14	0	2	4	7	1	L
	Map 3	12	3	1	7	7	1	L
Gina	Map 1	5	2	0	3	4	4	S
	Map 2	7	2	0	3	7	6	S
	Map 3	6	6	0	5	9	7	5S, 2M

Student Code Name	Map Number	Number of list words	Number of new words	Number of non-word links	Number of 1-2 word links	Number of multiple word links	Number of maps generated	Relative size of maps
Hanna	Map 1	5	0	0	0	4	0	NA
	Map 2	4	1	0	0	6	1	L
	Map 3	13	6	0	0	19	0	NA
Ingrid	Map 1	5	3	0	1	7	1	L
	Map 2	6	3	0	3	6	1	L
	Map 3	4	0	0	0	4	1	M

Table G8

Data on the Scientific Nature of the Links in the Girls' Maps in the Chemistry Unit

0 = no words

1 = few words with no/little meaning to the nodes

2 = basic science definitions or understanding between nodes

3 = in depth science content

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Anne	Map 1	0	0	5	0
	Map 2	0	0	8	0
	Map 3	0	0	4	4
Betty	Map 1	8	1	0	0
	Map 2	0	8	1	1
	Map 3	0	11	1	0
Carly	Map 1	2	13	1	0
	Map 2	3	11	0	0
	Map 3	6	8	0	0
Diana	Map 1	0	7	4	0
	Map 2	0	5	11	0
	Map 3	0	9	7	0

Student Code Name	Map Number	0 links	1 links	2 links	3 links
Elaine	Map 1	0	0	3	1
	Map 2	0	4	2	2
	Map 3	0	3	3	3
Farah	Map 1	2	12	0	0
	Map 2	2	11	0	0
	Map 3	1	9	5	0
Gina	Map 1	0	4	3	0
	Map 2	0	6	4	0
	Map 3	0	8	6	0
Hanna	Map 1	0	2	2	0
	Map 2	0	5	1	0
	Map 3	0	14	5	0
Ingrid	Map 1	0	4	4	0
	Map 2	0	2	7	0
	Map 3	0	0	4	0

Appendix H

Unit Comparison Data Tables

Table H1

Average Number of list Words used in the Astronomy Unit

Student Name	Map 1	Map 2	Map 3
Andy	9	9	14
Bob	11	15	10
Carl	8	5	9
Dave	9	12	11
Evan	7	9	12
Frank	8	7	6
Geoff	10	13	12
Anne	9	9	10
Betty	12	12	10
Carly	15	15	15
Diana	10	15	8
Elaine	10	10	7
Farah	15	15	15
Gina	15	11	8
Hanna	9	5	8
Ingrid	8	6	3
TOTAL	165	168	158
AVERAGE	10.3	10.5	9.9

Table H2

Average Number of Level 2 Link Statements Used in the Astronomy Unit

Student Name	Map 1	Map 2	Map 3
Andy	0	5	5
Bob	1	9	6
Carl	1	4	0
Dave	1	4	2
Evan	1	1	2
Frank	6	7	4
Geoff	4	11	9
Anne	0	5	7
Betty	0	3	0
Carly	0	5	1
Diana	3	4	8
Elaine	3	1	2
Farah	0	2	3
Gina	3	3	3
Hanna	0	2	3
Ingrid	1	4	0
TOTAL	24	70	55
AVERAGE	1.5	4.4	3.4

Table H3

Average Number of list Words used in the Chemistry Unit

Student Name	Map 1	Map 2	Map 3
Andy	5	6	8
Bob	6	8	14
Carl	15	9	16
Dave	4	11	6
Evan	1	6	2
Frank	4	7	9
Geoff	4	11	13
Anne	4	8	9
Betty	5	7	10
Carly	15	15	15
Diana	10	14	15
Elaine	4	6	5
Farah	15	14	12
Gina	5	7	6
Hanna	5	4	13
Ingrid	5	6	4
TOTAL	107	139	157
AVERAGE	6.7	8.7	9.8

Table H4

Average Number of Level 2 Linking Statements Used in the Astronomy Unit

Student Name	Map 1	Map 2	Map 3
Andy	7	7	8
Bob	2	5	4
Carl	0	0	3
Dave	0	0	4
Evan	2	4	1
Frank	3	6	7
Geoff	9	13	11
Anne	5	8	4
Betty	0	1	1
Carly	1	0	0
Diana	4	11	7
Elaine	3	2	3
Farah	0	0	5
Gina	3	4	6
Hanna	2	1	5
Ingrid	4	7	4
TOTAL	45	69	73
AVERAGE	2.8	4.3	4.6

Appendix I

Gender Comparison Data Tables

Table I1

Average Number of List Words Used in the Astronomy Unit by Boys

Student Name	Map 1	Map 2	Map 3
Andy	9	9	14
Bob	11	15	10
Carl	8	5	9
Dave	9	12	11
Evan	7	9	12
Frank	8	7	6
Geoff	10	13	12
TOTAL	62	70	74
AVERAGE	8.86	10	10.57

Table I2

Average Number of Level 2 Linking Statements Used in the Astronomy Unit by Boys

Student Name	Map 1	Map 2	Map 3
Andy	0	5	5
Bob	1	9	6
Carl	1	4	0
Dave	1	4	2
Evan	1	1	2
Frank	6	7	4
Geoff	4	11	9
TOTAL	14	41	28
AVERAGE	2	5.86	4

Table I3

Average Number of List Words Used in the Chemistry Unit by Boys

Student Name	Map 1	Map 2	Map 3
Andy	5	6	8
Bob	6	8	14
Carl	15	9	16
Dave	4	11	6
Evan	1	6	2
Frank	4	7	9
Geoff	4	11	13
TOTAL	39	58	68
AVERAGE	5.57	8.23	9.71

Table I4

Average Number of Level 2 Linking Statements Used in the Chemistry Unit by Boys

Student Name	Map 1	Map 2	Map 3
Andy	7	7	8
Bob	2	5	4
Carl	0	0	3
Dave	0	0	4
Evan	2	4	1
Frank	3	6	7
Geoff	9	13	11
TOTAL	23	35	38
AVERAGE	3.29	5	5.43

Table I5

Average Number of List Words Used in the Astronomy Unit by Girls

Student Name	Map 1	Map 2	Map 3
Anne	9	9	10
Betty	12	12	10
Carly	15	15	15
Diana	10	15	8
Elaine	10	10	7
Farah	15	15	15
Gina	15	11	8
Hanna	9	5	8
Ingrid	8	6	3
TOTAL	103	98	84
AVERAGE	11.44	10.89	9.33

Table I6

Average Number of Level 2 Linking Statements Used in the Astronomy Unit by Girls

Student Name	Map 1	Map 2	Map 3
Anne	0	5	7
Betty	0	3	0
Carly	0	5	1
Diana	3	4	8
Elaine	3	1	2
Farah	0	2	3
Gina	3	3	3
Hanna	0	2	3
Ingrid	1	4	0
TOTAL	10	29	27
AVERAGE	1.11	3.22	3

Table I7

Average Number of List Words Used in the Chemistry Unit by Girls

Student Name	Map 1	Map 2	Map 3
Anne	4	8	9
Betty	5	7	10
Carly	15	15	15
Diana	10	14	15
Elaine	4	6	5
Farah	15	14	12
Gina	5	7	6
Hanna	5	4	13
Ingrid	5	6	4
TOTAL	68	81	89
AVERAGE	7.56	9	9.89

Table I8

Average Number of Level 2 Linking Statements Used in the Chemistry Unit by Girls

Student Name	Map 1	Map 2	Map 3
Anne	5	8	4
Betty	0	1	1
Carly	1	0	0
Diana	4	11	7
Elaine	3	2	3
Farah	0	0	5
Gina	3	4	6
Hanna	2	1	5
Ingrid	4	7	4
TOTAL	22	34	35
AVERAGE	2.44	3.78	3.86

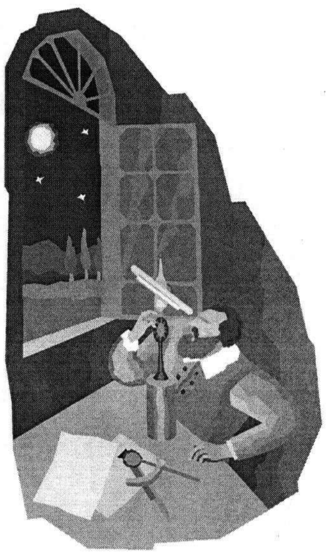
Appendix J

Astronomy Unit Test

Science 7
Chapters 14, 15, 16 Test

Name:____________________ Date:___________

Be sure to read through ALL the questions in the entire exam before beginning.



1. What was the first theory about the organization of the solar system? Explain the details.

____

____

____

2. What was different about the new or current order of the solar system?

____

____

____

3. What happened that caused people to change from their first understanding of the solar system to the second understanding?

____

____

4. Describe one theory about what caused a solar eclipse.

____

____

____

5. How did early people use knowledge from astronomy in their lives?

____

____

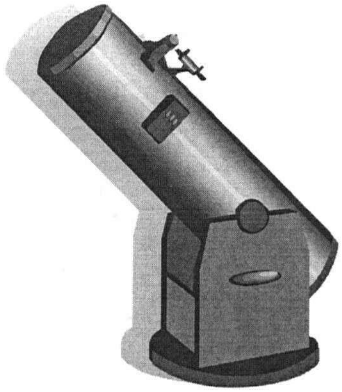
6. Why was astronomy so important in the lives of early people?

____

____

7. Name the five original 'wandering stars'.
   a) ____________________
   b) ____________________
   c) ____________________
   d) ____________________
   e) ____________________

8. What type of telescope is this? Describe 1 advantage and one disadvantage of this type of telescope.



Type: ________________________________

Advantage: ____________________________

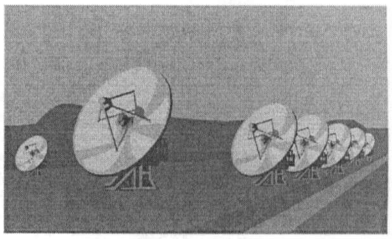
Disadvantage: __________________________

9. What type of telescope is this? Describe 1 advantage and one disadvantage of this type of telescope.

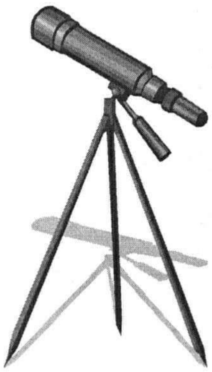
Type: ______________________________

Advantage: ______________________________

Disadvantage: ______________________________



10. What type of telescope is this? Describe 1 advantage and one disadvantage of this type of telescope.



Type: ______________________________

Advantage: ______________________________

Disadvantage: ______________________________

11. Which one would be the best for an amateur astronomer to use? Why?

____

____

12. Which one would be the best for an amateur astronomer to use? Why?

____

____

13. In 1781, the planet Uranus was discovered. Which planet was discovered in:

a) 1845 ____________________

b) 1930 ____________________

14. Why do you think that Planet X or Quaoar (the 10th planet) was discovered last?

____

____

15. What is the name of the HUGE telescope in Space?

____

16. Explain three major steps of the Big Bang theory.

a) ____

____

b) ____

____

c) ____

____

17. List 4 major characteristics of the sun

- ____
- ____
- ____
- ____

18. Rank the following sizes of stars from **biggest** to smallest.

- __________Giant
- __________Dwarf
- __________Super giant
- __________Midsize

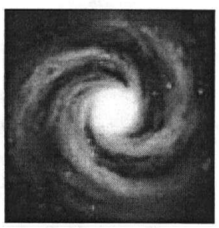
19. If the speed of light is 300, 000 km/second, how far would you travel in 3 light years? Think about the time VERY carefully and SHOW your work!

20. Name the two different types of NEBULAS and give and example of each.

a) Type: ____________ Name: ____________

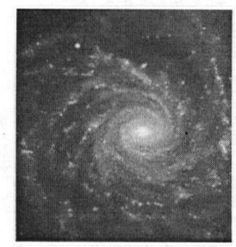
b) Type: ____________ Name: ____________

21. Name the shape of the following galaxies. Include the direction if appropriate.



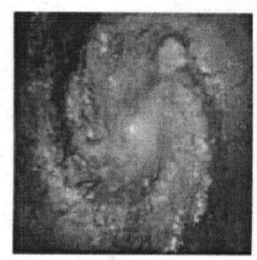
a) ________________

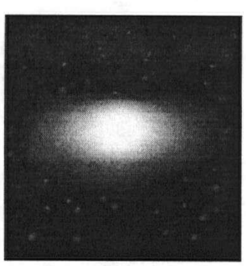
d) ________________



b) ________________

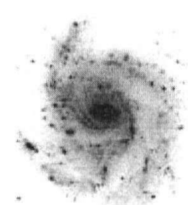
e) ________________



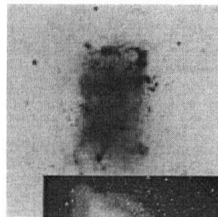


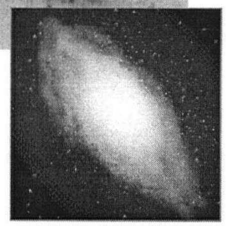
c) ________________

f) ________________



g) ______________





h) ______________

22. How does the following cartoon relate to black holes? Explain, in your answer, what is a black hole and how is this shown in the cartoon?

____

____

____

____

____

____

____

23. What happens during a supernova? Why our sun won't ever go through this process?

____

____

____

____

____

____

24. What is a quasar? How do they form?

____

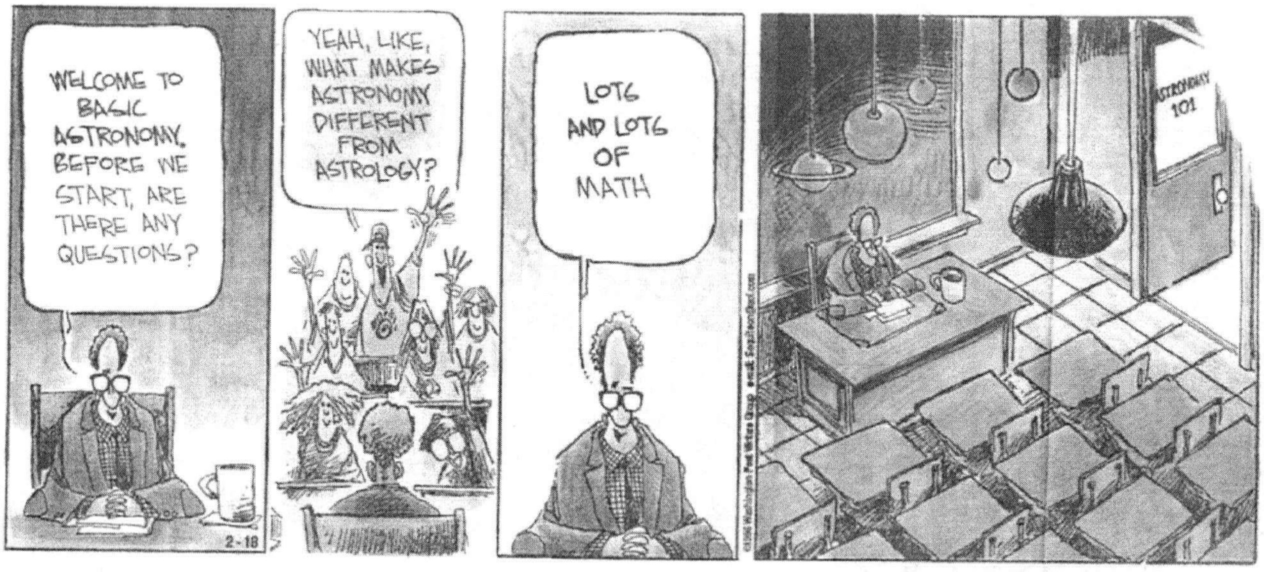
____

____

____

25. What two facts have scientists realized about the universe? (Hint: look at the comic for one clue!)

- ______________________________
- ______________________________



26. What is the other major difference between astronomy and astrology?

____

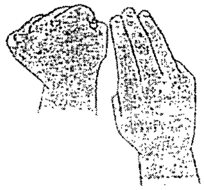
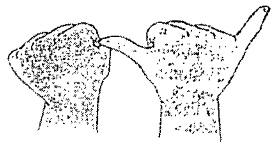
____

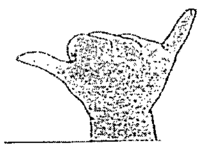
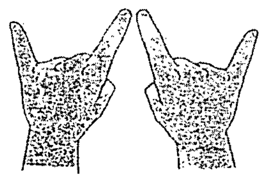
____

____

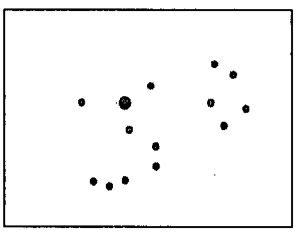
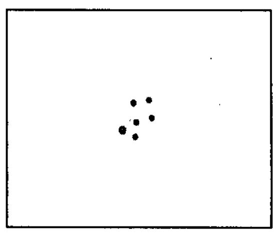
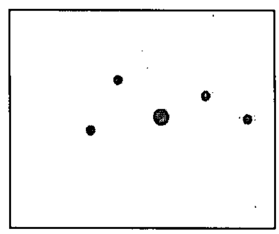
____

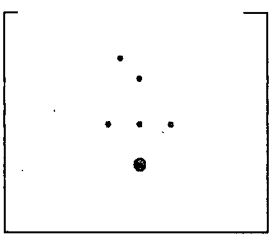
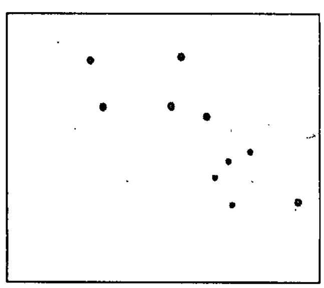
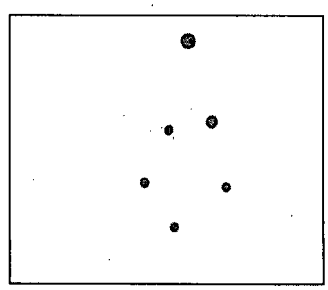
27. What would be the measurements of the following angles:

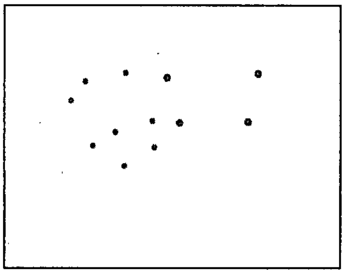



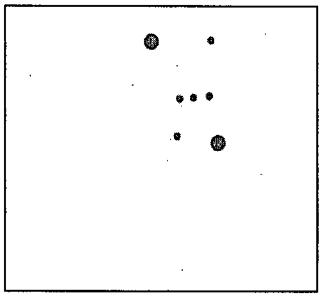




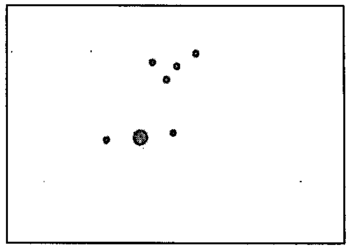
28. Name the following constellations. Write the answers ABOVE the box.

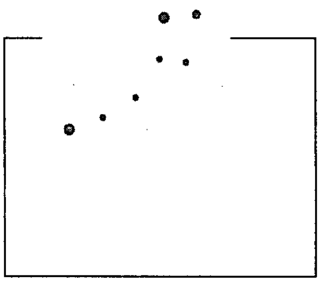




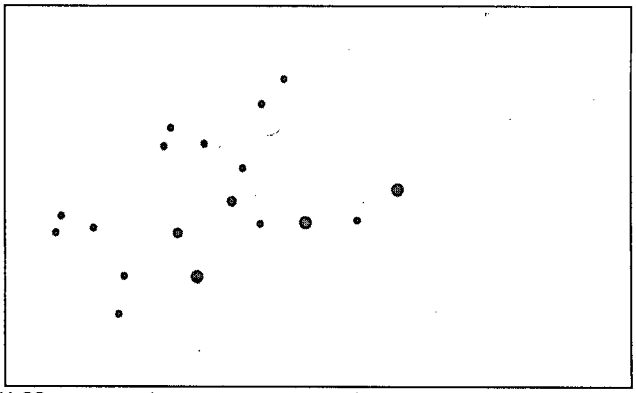














29. Define and explain the difference between rotation and revolution.

____

____

____

30. Name 2 constellations that can always been seen in the northern hemisphere.

- ______________________
- ______________________

31. Orion can only be seen in the winter. What type of constellation is it?

____

32. Describe one of the tools that astronomers use to help them study the stars OTHER THAN telescopes (think about the Planetarium show).

____

Bonus question: Write down and answer a question that has not been asked about astronomy on this test. It must be based on information from the text book.

Question:____

____

____

Answer:____

____

____

____

MAKE SURE THAT YOU GO AND DOUBLE CHECK YOUR TEST!!!!