

CONCEPT MAPPING: DOES IT PROMOTE MEANINGFUL LEARNING IN SCIENCE?

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## Abstract

Concept mapping is a learning strategy based on constructivist theory that students learn by incorporating new knowledge into pre-existing frameworks, or constructs. This study attempts to determine whether on-going use of concept mapping by Biology 11 students facilitates meaningful learning.

The study utilizes both qualitative (student interviews) and quantitative (statistical analysis of unit test scores) methodologies. For the quantitative analysis, the control and experimental groups consist of four classes of Biology 11 students where two blocks were exposed to concept mapping, while two were not ( $n=67$ ; 33 concept mappers, 34 non-concept mappers).

The findings are that although no statistically significant difference is found between the experimental and control groups, the statistical analysis suggests a trend of increasing test performance by concept mappers over non-concept mappers. The degree of difference increases the longer students have been exposed to concept mapping. Additionally, students provide insights into how concept mapping should be introduced, and shed light on common problems encountered while they learn the technique. Overall, students find concept mapping to be a valuable learning tool that most feel they will continue to utilize. Implications for teaching strategies are examined in light of students' experiences. A further study over a longer time frame could confirm the suggestion that with a longer exposure to concept mapping, a significant difference could be found between the experimental and control groups.

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## Chapter 1 – Introduction

My interest in concept mapping began in 1996 when I was an undergraduate student in the Faculty of Education at the University of British Columbia. One of the newer themes in Science Education at that time was the idea of promoting meaningful learning through constructivist teaching practices, a teaching strategy that immediately sparked my interest. As pre-service science teachers originating from Bachelor degrees in a variety of science disciplines, we all had the common goal of making learning *meaningful* for our students. Several strategies for doing so were presented in our classes, and the one that I found the most interesting of those was concept mapping.

My first experience with concept mapping in the classroom was with two classes of Science 9 students on my extended teaching practicum at Argyle Secondary in North Vancouver. According to a primitive set of rules that I designed more or less myself, the students used concept mapping to graphically depict the relationships between terms relating to the various body systems covered in the Biology unit of Science 9. I had mixed results from the process. Most students enjoyed it, as it was something most had not tried before, but what really caught my interest was the way that some students seemed to improve their understanding of the course material so rapidly after using the technique. Seeing success with junior level students in Biology, the experience pushed me to ask two questions of myself relating to the potential use of the learning strategy with senior level Biology students. Could concept mapping be successful in the promotion of meaningful learning in Biology students, and if so, what is the best way to go about utilizing the technique? This

was the beginning of my journey to answer these questions, and this masters thesis is the first of what I hope will be many conclusions.

As a senior secondary science educator, I am constantly torn between two educational ideologies regarding the effectiveness of teaching styles. In order to cover my prescribed course curriculum in the allowed amount of time, practicality tells me to type out my notes, run them off on transparencies, and put them on the overhead projector for the students to copy. When that is finished, I should give them an assignment about what they have copied in order to assess their understanding of the new scientific concept. Once completed, we move on to the next topic. On the flip-side of the educational coin, however, the practitioners of *meaningful* learning tell me something different – that my teaching should be done in a dialogue with my students. They are *not* empty vessels waiting to be filled to the brim with waters from my fountain of knowledge. Bonnie Shapiro explains this idea well in her writings about constructivist teaching in science, when she claims that “we must understand learning not only as a cognitive experience but also as an emotional, personal, social, and cultural one” (Shapiro, 1994, p. xiv).

A statement such as this can bring about deep frustrations from many teachers, the very people who are expected to implement these idealistic expectations. Am I really expected to have time in Biology 12, under the constraints imposed by the Provincial Government (both curricular and temporal) to worry about the emotional, personal, social, and cultural impacts of my teaching? How do I incorporate these aspects when it is all I can do to get across the basic fundamentals of *transport across cell membranes* or the mechanism through which the sun’s energy is converted to chemical bonds between the atoms of glucose molecules in a process known as *photosynthesis*? Throughout my teacher training, it was

explained to me time and again that the most important aspect of teaching a curriculum, regardless of subject, is to be certain to cover the Prescribed Learning Outcomes (PLOs) as outlined in the provincial Integrated Resource Package (IRP) for the course. The panic for each of us, brand-new to teaching at the time, was to first be sure we understood in-depth the PLOs and the topics they covered, and then to decide how much time we could afford to spend on each topic without falling short at the end of the year. Not surprisingly, many experienced teachers continue to concentrate on the *what* and the *for how long*, rather than the *how* of teaching. My inspiration to study the effectiveness of concept mapping with senior biology students was the desire to address this dilemma. It is a constructivist teaching strategy that has as its goal more meaningful learning by students who practise it.

Constructivism is a theory that describes the learning process. When students learn a concept, they do not merely assimilate the facts and order them in their minds exactly the way in which they were taught. This is of particular importance in a field of study such as science, where so much of the course content deals with explanations for why things behave the way they do in the world in which we live. New concepts are built, almost like the physical structures we use as metaphors to describe them, atop the foundation of pre-existing knowledge each student already knows, deep inside, to be true. How do students *know* their ideas are correct? Life experience is one of the most effective teachers. Unfortunately, *Mother Nature* doesn't always give a rationale to the student at the beginning of each lesson. Instead, *she* teaches by trial and error, and allows the students to draw their own conclusions. Many come to conclusions resembling those accepted by the scientific community; many do not.

Watson and Konicek (1990) describe a situation in which a fourth grade teacher sets out to teach the properties of heat. Because the students resided in Massachusetts where the winters are quite long, each had learned repeatedly that if you bundle yourself up in clothing or material of some kind, you will eventually warm up. Their experience had been that when they put clothes on they became hot, and this experience dominated their thinking on the subject. Students from the class were quoted as saying things such as “Sweaters are hot,” and “If you put a thermometer inside a hat, would it ever get hot! Ninety degrees, maybe” (Watson & Konicek, 1990, p. 680).

Although this fourth grade example is relatively easy to understand, situations such as this are not confined to elementary teaching situations. There are several examples of similar preconception problems at the high school level and on into university level studies. Several of these are outlined by Wandersee, Mintzes, and Novak in their research on alternative conceptions in Science.

When 50 undergraduate students at Johns Hopkins University were asked to sketch the trajectory of a moving ball emerging from a spiral tube, fully 36 percent of the drawings were of a curvilinear path. A similar set of predictions emerged when students were asked to describe the path of a pendulum bob cut from its string at the bottom of its arc (Wandersee, Mintzes & Novak, 1992, p. 181).

It is somewhat surprising to find that despite the fact that these students had completed high school successfully enough to be admitted a university science faculty, they still had inaccurate conceptions about certain scientific principles. As an educator, there is an important question that must be asked with respect to the origin of such misconceptions. Do all of our students have these skewed ideas to a certain extent? How is it that such inaccurate ideas about the world can come to be accepted as *true* by our students? The answer to this question lies in the life experiences that we all have through the process of growing up. Does

it not make sense that if an object is moving around in a curvilinear (spiralling circular) path, that once released it would continue to do so? Haven't we been taught that once something is moving in a certain direction, it will resist changes to that trajectory? This is in fact Newton's second law of motion, the law of inertia. Although it is being incorrectly applied in this example, it is understandable how students come up with their erroneous ideas. Unfortunately it is not as easy to understand how to deal with many of them.

The velocity of falling bodies under the influence of gravity and the relationship of position to relative weight of objects pose additional difficulties for many students. Gunstone and White (1981) confronted a group of first-year physics students at Monash University in Australia with a problem involving metal and plastic spheres of comparable size and asked them to predict the time each would take to fall to the floor when dropped from a given height. Nearly 25 percent of them believed the metal ball would fall faster (Wandersee et al., 1992, p. 181).

This example illustrates the concept that all bodies fall with a constant acceleration regardless of mass. It is first taught in B.C. schools in Science 10, and then again in Physics 11 and 12. How is it, then, that a quarter of first year university students still don't understand? Perhaps the experience of watching heavy objects fall and do more damage than lighter objects has confused them into thinking they must fall faster. There is also the problem that on our planet, some objects *do* fall faster than others due to air resistance. The law of constant acceleration assumes vacuum conditions, yet few of our students have ever lived in a vacuum! Regardless of the particular reasoning behind the misconception, it is obviously something that needs to be addressed in science education at the secondary level. As Watson & Konicek describe it, "when it comes to confronting the errors in one's thinking, scientists of all ages seem equally susceptible to certain barriers" (Watson & Konicek, 1990, p. 682). The question for educators is how exactly to overcome them with students.

It could be argued that a science teacher could avoid these barriers of maintaining students' false preconceptions by using a 'transactive' or 'transformative' style of teaching, rather than the traditional style of 'transmission' for which so many science teachers are famous. But those of us who teach with a more transmissive style do not do so without justification. The transmission orientation can provide serious time savings, a feature very important at the senior level when teachers are under constant pressure to cover a certain amount of material before the looming provincial exam strikes at the end of the year.

Still, there are issues that arise when students' prior understanding is not deconstructed before new material is covered. If students' previous conceptions are not challenged during the learning process, students will use *both* schemes of understanding to simultaneously explain a concept or principle. "If alternative views of scientific principles are not addressed, they can coexist with 'what the teacher told us' and create a mish-mash of fact and fiction" (Watson & Konicek, 1990, p. 681).

Perhaps some light can be shed on this issue if the ideologies of educational theorists are considered. Paulo Freire, in his article, *Pedagogy of the Oppressed*, discusses transmissive and transactive teaching styles from the perspective of *oppression* and *liberation*. Freire would describe the transmissive style of teaching science as oppressive in that it doesn't address students' individual needs to have their thoughts explored as they relate to scientific principles. He argues that "authentic thinking, thinking that is concerned about reality does not take place in ivory tower isolation, but only in communication" (Freire, 1993, p. 58). This communication of which Freire speaks is the dialogue between teacher and student about what the student thinks about the 'reality' that is science, and it is a

necessary process if the student is to come to terms with what they actually believe to be true *before* examining a new concept.

Freire would go on to say that his *banking* versus *problem-posing* metaphor fits well the situation in science education. He explains that problem-posing education “sets itself the task of demythologizing,” (Freire, 1993, p. 64) which is important if one is to address a student’s experiential knowledge, knowledge that they accept as truth although they might not understand why they do so.

Another opinion that might be sought on this issue is that of Joseph Schwab. Schwab (1969) explains that “ideas [are] formed by children out of received notions and experiences of things, and... these ideas [function] thereafter as discriminators and organizers of what [is] later learned” (Schwab, 1969, p. 492). He would argue that effective teaching addresses the preconceptions of students, what he terms *received notions*, and therefore a simple transmission of facts from student to teacher would not suffice.

Considering the ideas of these authors presents a problem to science teachers in classrooms today. Obviously, we cannot ask children what they think, nod our heads, and reply, ‘No, I’m sorry, that isn’t how it works – what you think is wrong.’ Exactly how do we teach, in a transactive way, such that we effectively address the pre-conceived notions of students without *oppressing* them with information as the scientific community sees it? In Freire’s eyes this would truly be oppressive, and regardless of whether it is oppressive or not, we likely all agree that it wouldn’t have a very good chance of being effective. Children can have a tremendous capacity for stubbornness, demonstrated by a refusal to admit that their own theory of how the world works could be inaccurate. “Children who are not often asked

their opinions are especially reluctant to admit the errors in their thinking and will find ways to adjust old ideas before assimilating new ones” (Watson & Konicek, 1990, p. 682).

Watson & Konicek use the terms *meaningful learning* and *teaching for conceptual change* to describe a learning situation in which students challenge their own ideas about how the world works, and in the process develop a deeper understanding of the concept being studied. Inquiry based learning, as first emphasized by John Dewey in the 1920s, is receiving more and more attention as educators realize its value in addressing student preconceptions. However, the texts currently in use in most classrooms merely “[pay] lip service to science as an inquiry-oriented discipline” (Watson & Konicek, 1990, p. 681). Individual teachers must therefore be the ones to do the right thing educationally in their classrooms. Students’ alternative conceptions “are tenacious and resistant to extinction by conventional teaching strategies” (Wandersee et al., p. 186). If they are to be replaced by accurate accounts of how the world works, specific steps must be taken with students. First, the student must challenge the old way of thinking through direct observation. This is most easily done as an experiment relating to some real-life situation. Next, a new explanation for the phenomenon being studied must present itself, and it must be both *understandable* and *plausible* for the student. The last step is to allow the explanation to lead to further testing, showing the student that all new explanations must stand up to the tests of scientific process. If a teacher can generate these conditions in the classroom, there is a good chance that conceptual change will happen for participating students (Watson & Konicek, 1990).

It seems that on the issue of transmission versus transaction (and/or transformation) orientations for teaching science, all the voices echo a similar opinion: transmission is out, transaction is in. We are still left, however, with somewhat of a dilemma with respect to the

practicality of actually doing what we say we should. As we all know, it is one thing to say that a particular theory is correct and another is not. As experience tells us, talk is cheap. Implementation is a whole other matter entirely. This issue is addressed by Bonnie L. Shapiro, in her book, *What Children Bring to Light*. Shapiro (1994) discusses the problem of valuing what she calls both objectivist and constructivist positions dealing specifically with science education, respectively:

At one moment, we know the scientist's perspective and want students to simply accept it as true. At another moment, we see that understanding the student's way of organizing thinking about ideas is vitally important in our work to help the learner consider new ways of looking at things like the scientific perspective (Shapiro, 1994, p. 8).

One excellent method for getting students to organize their own scientific knowledge, in a way that the teacher has access to for the purposes of addressing pre-existing knowledge, is the concept map. For meaningful learning to occur in students, new information needs to be attached to pre-existing knowledge within the semantic network of the learner (Ausubel, 1963; Fisher et al., 1990). With concept maps, we have the ability to prescribe the basic content that will go into the maps through the requirements of the assignment as we design it, while at the same time giving students complete discretion in the way that it is put together – according to their internal framework of understanding on the topic. But the two questions remain: Can concept mapping be successful in the promotion of meaningful learning in senior Biology students, and if so, what is the best way to go about utilizing the technique as a teacher?

## **Chapter 2 – Literature Review**

The majority of literature published on concept mapping is centred around six domains: (1) defining concept maps in terms of their component parts and how they are to be constructed, (2) the validity of using concept mapping as a research or educational tool to assess student understanding of particular bodies of knowledge, (3) how concept mapping should be introduced to students for the greatest long term benefit, (4) differences in the benefit of concept maps that are constructed individually as compared to those constructed collaboratively, (5) the use and benefits of computer-based concept mapping, and (6) whether there is a correlation between use of concept maps by students and subsequent achievement of learning outcomes. Literature in each of these domains will be reviewed in the sections that follow.

### **What is a Concept Map?**

A concept map is a two-dimensional node-link representation that depicts the most important concepts and relationships in a knowledge domain. As developed by Novak and Gowin, the technique produces a hierarchical schema that is particularly revealing and especially useful in diagnosing conceptual errors and faulty reasoning (Mintzes, Wandersee & Novak, 2001, p. 118).

Concept mapping has been used in varying forms by educators for the past 20 years, and was initiated by the work of Joseph Novak at Cornell University (Novak, 1990; Odom & Kelly, 1998). Novak based the development of the concept mapping strategy on Ausubel's (1968) assimilation theory that the most important factor that influences student learning is the knowledge already possessed by the student (Ausubel, 1968; Okebukola, 1992). Concept maps are diagrams constructed to represent understanding of a particular topic or idea. In

Novak and Gowin's (1984) classic concept map structure, the main ideas or phrases used in a lesson are ordered on a page working downward in a *hierarchical* manner. At the top of the page are found more general, inclusive and abstract terms, while specific and concrete terms are ordered beneath these. Although Novak feels that this hierarchy is an important aspect of concept mapping (Novak, 1999), it is one element that is not seen by all educational researchers as an absolute requirement. Current literature refers to hierarchically-arranged concept maps as adhering to "traditional concept map format" (Kinchin, 2000, p. 61), and research has been conducted using concept maps with and without this hierarchy (Williams, 1998).

Relationship linkages between terms are added in the form of lines or arrows, and phrases are finally placed on these lines explaining the relationship (Dorough & Rye, 1997; Okebukola, 1992; Smith & Dwyer, 1995). "The resultant is a concept map which is analogous to a road map. Every concept depends on the others for meaning" (Okebukola, 1992, p. 154). Although researchers differ in their explicit instructions to educators on how students should be taught to construct concept maps, they all adhere to a greater or lesser extent to these basic guidelines.

### **How Well Do Concept Maps Represent What Students Understand?**

Research suggests that concept mapping "offers a valid and useful mechanism for looking at [the] cognitive structure" (Wallace & Mintzes, 1990, p. 1045) of students in varying subject areas. It has been suggested, in the wake of the recent educational thrust toward authentic student assessment, that

all things considered, the concept map is perhaps the most powerful assessment strategy we have for exploring and documenting the structural complexity and

propositional validity of knowledge in scientific domains (Mintzes et al., 2001, p. 119).

Specifically, Wallace and Mintzes (1990) investigated the correlation between exposure to instruction in biology and the ability to build accurate concept maps on the subject, and found that "concept mapping offers a valid and potentially useful technique for documenting and exploring conceptual change in biology" (Wallace & Mintzes, 1990, p. 1033).

Markham, Mintzes and Jones (1994) conducted a similar study to examine the extent to which concept maps constructed by college level biology students differ from those constructed by beginning non-majors. Mammals was the topic used in the study. They found that "the concept map provides a theoretically powerful and psychometrically sound tool for assessing conceptual change in experimental and classroom settings" (Markham et al., 1994, p. 91). This literature indicates that research supports the use of concept maps in the classroom for assessing student understanding of course curriculum.

### **Introduction of Concept Mapping for the Greatest Long Term Benefit**

Although limited research has been conducted in this area, a recent study by Santhanam, Leach & Dawson (1998) investigated varied approaches to the introduction to concept mapping with first year genetics students at an Australian university. Their goal was to examine the frequency of student concept mapping, subsequent to the students being introduced to the learning strategy, to determine if the students would find it to be a worthwhile use of their time for self-guided study. They felt that

despite the apparent usefulness of concept mapping as a tool for improving understanding and the meaningfulness of learning, the real value of any learning strategy depends on it being utilised appropriately by those who have acquired the new skill . . . none of the [previous] studies . . . followed the participants to see if they

used concept mapping at times other than during the intervention period (Santhanam et al., 1998, p. 317).

Their project lasted for two years, and found that "although most students taking introductory subjects had taken part in the project, and many had realised the benefits of concept mapping, retrospective views of students indicated that almost none had adopted it as a regular part of study strategies" (Santhanam et al., 1988, p. 317). This result raises questions as to how concept mapping should be introduced to students with the goal of having them make it a part of their own long term learning. The researchers concluded that either their mode of introduction was inappropriate, or the timing was wrong, or some other factor was at work, such as students deciding that the payoff wasn't worth the time spent. Further research would be necessary to investigate this, and is recommended by the authors.

### **Benefits of Individual Versus Collaborative Concept Map Construction**

Conflicting results have been found in the comparison of the usefulness of individual versus collaborative concept mapping activities. Roth and Roychoudhury (1993) investigated concept mapping as a mechanism for meaningful learning with a group of high school physics students. The goals of the study were to attempt to "understand (a) how students construct knowledge during collaborative concept mapping and (b) the processes that allow students engaged in collaborative activity to decide on the next step in conflict situations" (Roth & Roychoudhury, 1993, p. 505). Both positive and negative results for the benefit of concept mapping in a collaborative setting were found. On the positive side, "concept mapping led to sustained discourse on the topic and improved the declarative knowledge of several students both in terms of the hierarchical organization and 'local' configuration of the concepts" (Roth & Roychoudhury, 1993, p. 503). Conversely, it was

noted that "[collaborative] concept mapping also let unintended and scientifically incorrect notions become ingrained and go unchallenged" (Roth & Roychoudhury, 1993, p. 503). It was consequently concluded that instruction on proper concept map construction should continue with students following the initial introduction to ensure that concept map quality remains high to promote "overall quality of the process of constructing the map and . . . the final product" (Roth & Roychoudhury, 1993, p. 503). It was found that without this teacher monitoring, students are more likely to stray from proper mapping techniques and are more likely to make errors that could reinforce alternative conceptions.

An additional benefit of using collaborative concept maps with students has been found by Roth (1994) to stem from their ability to engage both students and the teacher in scientific conversational exchanges, through what is described as knowledge that is *taken as shared*. Roth describes this sharing:

A concept map, as an emergent design and as a finished product, enlists student and teacher participation in its construction. It also provides a problem of which each participant in the conversation assumes that she or he has the "same" understanding of the problem at what it takes to resolve it. This assumption has thus the character of being *taken as shared*. Concept labels, propositions, and the emerging concept map design can be referred to in part and in total during the discourse because there is little disagreement about the ontological status of these taken-as-shared objects. This provides an ideal context in which meaning of the concepts and propositions referred to by the labels can be negotiated through engagement in discourse (Roth, 1994, p. 3).

Roth uses a *social constructivist view* to describe the concept map collaboration, whereby the interactions among students and between students and their teacher enhance learning, with the concept map serving as the catalyst for the interaction. Roth concluded that "students who collaboratively constructed concept maps showed more meaningful learning than those who engaged in this activity on their own" (Roth, 1994, p. 3).

A more recent study conducted with 80 sixth-grade science students (Ritchie & Volkl, 2000) compared the effectiveness of individual versus group concept mapping at achieving meaningful learning. They found no statistically significant difference between the two groups as measured by post-test achievement. These results were similar to those found earlier by Okebukola (1992) involving individual versus group mapping and the subsequent ability to answer biological test questions.

### **Computer-Based Concept Mapping**

Within the scope of the literature on computer-based concept mapping, several benefits specifically applicable to computer-based mapping, but equally applicable to concept mapping in general, have formed a consistent theme.

The first of these benefits is known as *depth of processing* (Ausubel, 1963; Fisher et al., 1990). When compared with other study techniques, concept mapping encourages students to analyze the relationships between ideas, and subsequently engage in a "deeper level of information processing than when they are transcribing, memorizing, or recalling information" (Fisher et al., 1990). This is due to the fact that a concept map deals primarily with the interrelationships between ideas, not just the ideas and their definitions exclusively.

The second benefit has been described as *chunking* by Fisher (Miller, 1956, as cited in Fisher et al., 1990) in her description of her concept mapping software known as SemNet® (Fisher et al., 1990; Fisher, Wandersee & Moody, 2000). *Chunking* is the feature of concept maps that enables the user to view only one piece of a concept map at a time, a technique accomplished on paper by physically covering up all but those parts of a map upon which a students wish to focus their attention. The same feat can be accomplished using

software with the click of a button, instantly hiding details outside of a learner's current focus. Due to the vast amount of information that can be contained in a concept map (either electronic or on paper), chunking is important so that students don't become overwhelmed by trying to direct their attention to all the information contained in a map simultaneously. The one frame, or chunk, that they do view can be "encoded by the student in long-term memory. If students store and recall information in long-term memory in a hierarchy of chunks . . . they may significantly improve their ability to recall and apply their knowledge as a result" (Fisher et al., 1990, p. 351).

*Conceptual proximity* is a benefit experienced by students who concept map two interrelated concepts that may be widely separated in either text or in a series of lectures (Fisher et al., 1990). For example, the Biology 12 topics of membrane transport and transmission of nerve impulses are separated by a distance of weeks, perhaps months in the B.C. curriculum, while they are in fact intimately related. This is just one example of many in the course, necessitated by the sheer volume of course content and the fact that most biological systems rely on multiple others to properly function. By building "semantic networks as [students] learn, concepts encountered later in the course are often brought into close juxtaposition with concepts encountered earlier, thus reducing the . . . conceptual distance . . . between them" (Fisher et al., 1990, p. 351).

*Spatial learning* is demonstrated by a learning situation where spatial or visual cues "can serve as memory aids" (Fisher et al., 1990, p. 351) to a learner. The graphical components of a concept map differ considerably from "the linear representations of texts and lectures . . . [and] have proven effective in promoting deep processing and increasing performance among . . . pre-college students," (Fisher et al., 1990; Novak & Gowin, 1984).

*Direction of Processing* is used to describe the way in which material is delivered to a student with respect to organization. Top-down processing is a learning strategy where the learner stores new information in an already established internal schema, or outline. Bottom-up processing is the opposite, where the learner must decide, based on the content of the information presented, how to structure its storage. According to Holley and Dansereau (1984, as cited in Fisher, 1990) "meaningful learning is promoted by strategies that alternate between top-down and bottom-up processing ... [and] this alternation seems to occur as one creates a computer-based semantic network" (Fisher et al., 1990, p. 352).

#### *Benefits of Computer-based Concept Mapping*

In addition to the general benefits of concept mapping as a teaching strategy, there are increased benefits to be had by students who do their mapping using computer software instead of using pencil and paper. The aspect of pencil and paper concept mapping, which is neglected in its title, is the *eraser*. This quickly becomes a requirement of the process in classrooms.

Electronic concept maps are *globally expansible*, which means that at any point in the mapping process, students can insert new information under any sub-topic of their map without disrupting that part of the map already completed (Anderson-Inman & Zeitz, 1994). As well, computer-based concept maps are *infinitely modifiable* (Anderson-Inman & Zeitz, 1994). Concept mapping "in an electronic environment makes the process more accessible to students in much the same way as word processing increases students' enthusiasm for writing" (Anderson-Inman & Zeitz, 1993, p. 7). Although changes can be made to pencil and paper maps, this cannot easily be accomplished "without creating a mess or engaging in time-

consuming recopying" (Anderson-Inman & Zeitz, 1994, p. 21). As classroom teachers, we have all had experiences where students spend too much of their time trying to make a project *pretty* rather than focus their attention to the *content* of the project. Using software to create maps helps tremendously in this respect in that the very structure of the software facilitates an attractive organization of ideas.

Another aspect of computer-based concept maps is that they are *focusable* by the learner (Anderson-Inman & Zeitz, 1994). This feature is similar to that of *chunks* already discussed, but differs in terms of its level of sophistication. With software, students can not only choose to focus the program on the area of the map they are currently studying, but they can also divide the map into a hierarchy of sub-maps, known as *child maps*, of the main map being stored on separate pages (Anderson-Inman & Zeitz, 1994).

Taking the ability to focus certain parts of a concept map one step further, software also allows for creation of concept maps that are rich in symbols, regardless of the artistic ability of the learner creating the map. Modern mapping software provides the ability to choose from hundreds (or thousands) of icons or symbols to enhance the appearance of concept maps. Anderson-Inman, Ditson & Ditson (1998) describe *symbol-rich* maps as those concept maps "in which at least 70% of the nodes are something other than text . . . for example, a graphic element that either stands for, or augments the text" (Anderson-Inman, Ditson, & Ditson, 1998, p. 5). They describe a situation in a middle school science classroom where the teacher required students to create outlines for oral reports using symbol-rich maps. The results of these presentations were that those students using the symbol-rich maps gave presentations that "were superior in five areas: volume, clarity, pace, eye contact and gestures" (Anderson-Inman et al., 1998, p. 6).

Computer-based concept mapping also allows for a *fluid environment* in which to organize ideas related to a particular domain. Once a map has been completed at one stage in a course to a high level of satisfaction by the student, it is of great value that the student be able to later make modifications to that map which incorporate new ideas and information that hadn't been previously included. By mapping in an electronic environment, students are provided with "a fluid medium for restructuring the information as patterns emerge and students' knowledge about a topic expands" (Anderson-Inman & Horney, 1997, p. 304).

A benefit for teachers, which results directly from students being able to restructure their concept maps, is the ability to monitor students' conceptual change over time in a particular course. Anderson-Inman (1998) calls this monitoring *concept-formation tracking*, and has students create concept maps at various stages in a learning process, "prior to instruction and after each significant instructional activity" (Anderson-Inman et al., 1998, p. 6). Due to its electronic nature, an electronic concept map can be "easily modified to reflect changes in the student's conceptual understanding over time, even when those changes require a total reworking of the map" (Anderson-Inman et al., 1998, p. 6). Although each subsequent map can (and usually does) differ greatly from the original, the teacher can track changes in student comprehension by comparing later maps with earlier versions that had been previously submitted.

Yet another benefit of computer-based concept mapping that should not be overlooked is the ease of use for students made possible with an electronic medium. While concept mapping is a teaching and learning tool with incredible potential, the theoretical benefits are unlikely to be realized if the process of drawing networks is excessively tedious, cumbersome, or time consuming for students attempting it. The computer-based mapping

environment "alleviates this constraint, permitting the user to concentrate almost entirely on the structure of knowledge rather than on the mechanics of representation (Fisher et al., 1990, p. 352). In addition, students working on projects as intricate as concept maps will tend to invest great pride in their finished product. If a concept map has been drawn by hand, even a slight change could require that most of the map be redrawn. "If the student who has created the concept map has put effort into communicating concepts and processes with images or other graphic features, then the task of modifying a map is even more daunting" (Anderson-Inman & Ditson, 1999, p. 7). For this reason, student satisfaction with the finished product is improved with computer-based concept mapping, while their level of frustration is simultaneously decreased.

The last benefit of computer-based concept maps to be discussed is perhaps one of the most important from the standpoint of an educator. One drawback of concept mapping with students is that, despite their obvious benefits for the students who create them, evaluating individual concept maps for each student can be an onerous task for the teacher. Fortunately, certain of the concept mapping software programs have companion programs available for teachers to use which interface with each student's saved concept map file. One such program is available for Inspiration®. Known as the *Assessment Companion*, it

provides a teacher with basic information describing a student's concept map, including the number of symbols and links on the map, how many of symbols and links are unlabeled, what kinds of hierarchical groupings exist in the map, and other related information. The report then lists each proposition and example as text (symbol-link-symbol) with a five-point scale on which the teacher can rate the relative validity of each proposition or example. A pilot study has shown that this report form gives teachers an effective method for evaluating concept maps ... [and] yields a high degree of reliability ... The printed report makes it possible to systematically account for and evaluate all parts of a map, making evaluation easier and more accurate (Anderson-Inman et al., 1998, p. 8).

With tools such as this available, an already strong case for using computer-based concept mapping is made even stronger in terms of the time savings possible for the teacher.

### *Currently Available Concept Mapping Software*

There are several software products available on the internet for use on personal computers that facilitate concept mapping. Some of the most prominent are listed in Table 1.

**Table 1.** Some concept mapping software described on the internet (Fisher et al., 2000; Mintzes et al., 2001)

Software Title	Internet Site
The Axion Idea Processor	<a href="http://web.signet.com.sg/~axon2000/article.htm">http://web.signet.com.sg/~axon2000/article.htm</a>
Banxia Software	<a href="http://www.banxia.co.uk/banxia/">http://www.banxia.co.uk/banxia/</a>
CoCo Systems Limited	<a href="http://www.coco.co.uk/">http://www.coco.co.uk/</a>
Inxight Hyperbolic Trees	<a href="http://www.inxight.com/Content/7.html">http://www.inxight.com/Content/7.html</a>
Inspiration Software	<a href="http://www.inspiration.com/">http://www.inspiration.com/</a>
Institute for Human and Machine Cognition (IHMC), University of West Florida	<a href="http://cmap.coginst.uwf.edu/">http://cmap.coginst.uwf.edu/</a>
LifeMap	<a href="http://www2.ucsc.edu/mlrg/lifemapusermanual375/lifemapusermanual375.html">http://www2.ucsc.edu/mlrg/lifemapusermanual375/lifemapusermanual375.html</a>
MindMan Software	<a href="http://www.mindman.com/">http://www.mindman.com/</a>
SemioMap Builder	<a href="http://www.semio.com/download/Download.cgi">http://www.semio.com/download/Download.cgi</a>
SemNet Software	<a href="http://trumpet.sdsu.edu/semnet.html">http://trumpet.sdsu.edu/semnet.html</a>
Smart Ideas	<a href="http://www.smarttech.com/smartideas.htm">http://www.smarttech.com/smartideas.htm</a>
VisiMap	<a href="http://www.coco.co.uk/prodvm.html">http://www.coco.co.uk/prodvm.html</a>

Inspiration® software was chosen for use in this study, but many of the applications listed in Table 1 could also have been used. One of the newer products listed is an online concept

mapping tool available from the Institute for Human and Machine Cognition at the University of West Florida, which allows users to create online concept maps individually, or through collaborative efforts with other users over the internet (Mintzes et al, 2001).

### **Correlation Between Concept Map Use and Achievement of Learning Outcomes**

Does concept mapping promote meaningful learning in science? This is a question that many researchers have already investigated using various methodologies. The research to date has yielded mixed results. In some cases, concept mapping has proven to be a successful strategy in science classrooms, and in others no significant difference has been found between experimental and control groups.

#### *Positive Results*

Willerman and Harg (1991) investigated the potential success of using concept maps as advance organizers to introduce lessons to eighth-grade physical science students. Their results indicate "that the use of concept mapping as an advance organizer produces a significant increment in academic gain for the students" (Willerman and Harg, 1991, p. 708).

Okebukola (1992) investigated the correlation between student exposure to concept mapping activities and their ability to solve biological problems given in test format. The results of this study are more significant due to the fact that the period of exposure to concept mapping for the experimental group was a full six months, a duration extensive enough to more closely mimic the situation in a teacher's classroom. The concept mapping group was found to be "significantly more successful in solving three biological problems than 20 subjects who served as control" (Okebukola, 1992, p. 153). Given the length of the study,

those results are encouraging for teachers who can commit to an activity for a duration long enough to elicit long term results from students.

A study of even longer duration was undertaken in Israel (Barenholz & Tamir, 1992) in which the achievement of mappers versus non-mappers in a grade 10 and 11 microbiology program were compared over a four-year period. Concept mapping assignments were completed on a regular basis by students, and data were collected in the form of student marks on post-tests as well as questionnaires regarding student attitudes toward concept mapping. The results were that the concept mapping students had an overall gain significantly greater than the non-concept mapping students. In addition, “students and teachers were found to have mostly favourable attitudes toward the cognitive benefits of concept mapping... however many students did not like certain aspects of concept mapping” (Barenholz & Tamir, 1992, p. 37).

In a recent study, Ritchie and Volkl (2000) compared the relative success of learners who used concept mapping as compared to those taught using manipulatives in an intermediate science class. Although no significant difference was found on the immediate post-test between the two groups, the delayed-post test result indicated a significant difference in the long-term retention in favour of the concept mappers.

### *Negative Results*

Smith and Dwyer (1995) conducted a shorter-duration study with 81 college level biology students to compare the results of a single assignment that differed among the three treatment groups. All three groups received a 90 minute instructional session on proper construction of concept maps prior to being given their assignments. Each group was then

given a different assignment to complete, and finally all participants wrote a comprehensive test which included drawing, identification, terminology, and comprehension components to assess their level of understanding of the subject matter.

The assignments differed in that the first group (control) was given instructions to simply read the instructional booklet without completing any concept mapping activity. The second group was given the same information booklet, and was instructed to construct a concept map on the information provided according to the instructions given previously to all participants. The third group was again given the same material, but instead of constructing their own maps, were provided with a teacher generated map to use as a study guide.

This study produced "contradictory findings compared to other studies where students were required to generate their own concept maps. In this study, students did not benefit from the concept map strategy" (Smith & Dwyer, 1995, p. 26).

### **Implications for Further Research**

In light of the broad scope of the research that has been conducted on concept mapping, and the potential value of its use in science classrooms as a mechanism to help facilitate meaningful learning, there are several areas where research still needs to be done. Much of the work done to date has either produced statistically insignificant results, or contradictory results when compared to similar studies.

In general, experimental results have conclusively found that concept mapping as a research tool to investigate student understanding of concepts is legitimate. However, one aspect of this research not mentioned in this review is the potential role that computers could play in the process of concept mapping. Research involving concept maps can be

problematic for two reasons. First, the length of time required to score concept maps can be onerous when dealing with large sample groups. Second, many students have trouble organizing their thoughts in the form of a graphical map, particularly when they are not diagrammatically or artistically inclined. Computers could be used to make both situations more manageable by serving as tools for both the construction of maps by students, and by assisting researchers with manual scoring by either eliminating the problem of hand-drawn, difficult-to-read maps, or by scoring the maps using complex, pre-programmed algorithms specifically designed for the task.

In the area of investigation dealing with how best to introduce concept mapping to students for long term benefit, Santhanam et al. (1998) suggest that further research would be necessary as their study showed that very few of their test students found that concept mapping was a valuable way to spend their time. Varied methods of introduction conducted with different experimental groups could be researched, in order to find which method provides students with the type of exposure most likely to elicit a positive response to using concept mapping by their own choice.

By the very nature of the activity of concept mapping, it is logical to assume that maps done in collaboration with other students would naturally, through the very nature of scientific discourse, generate a more meaningful learning situation for students. Results appear mostly one-sided in this aspect of concept mapping, showing that most collaborative mapping sessions are more successful than those carried out on an individual basis. However, a possibility for research in this domain is possible if ideal grouping size were to be examined. Would pairs of students be a more successful situation than groups of three, or perhaps even four? This has not yet been established.

The last area of possible research lies in the correlation of concept mapping by students to achievement of learning outcomes. While the results have been somewhat mixed, it appears that the trend is for a positive correlation when students have been given the required exposure to concept mapping before commencement of data collection. In addition, it would be valuable if more studies were conducted over extensive enough time frames to more closely resemble real classroom situations. As previously mentioned, when a task as complex as concept mapping is attempted even with senior secondary students, it takes time for many to become comfortable enough with the process to reach the peak of their potential achievement. As a classroom science teacher, I would like to see the effects of concept mapping with my own students for a duration of several units of instruction in order to evaluate the technique's usefulness.

The research in this study will address the question of whether concept mapping promotes meaningful learning in senior high school biology students. The primary focus will be to determine whether regular use of concept mapping by senior high school biology students has a positive correlation with achievement of learning outcomes, as measured by standardized teacher testing methods and student views of their own learning. A secondary focus will be how to best introduce and utilize concept mapping as a learning strategy with senior biology in light of student feedback and a teacher's experiences in classes new to the activity.

## **Chapter 3 – Research Methodology**

### **Purpose and Objectives of Project**

The purpose of this research project is to determine whether concept mapping promotes meaningful learning in senior high school biology students. Additionally, the research will determine the most effective teaching methodology to be used when introducing concept mapping to students exposed to it for the first time.

The research methodology incorporates two distinct components. The qualitative aspect involves interviewing students about their experiences with concept mapping. They are asked specific questions to do with how and why they think it works, or doesn't work, to help them achieve meaningful learning. The quantitative aspect involves a statistical comparison of the achievement of Biology 11 students who regularly concept map compared to those who are taught using alternative learning techniques (not concept mapping).

### **Research Participants**

The research participants are students enrolled in Biology 11 at John Peterson Secondary School, a public school in School District No. 73 (Kamloops/Thompson). The school has a population of 650 students, and is located just outside the downtown area of Kamloops, British Columbia. John Peterson Secondary is somewhat of a unique school in Kamloops due to the fact that it contains the only French Immersion program at the secondary level in the city. Approximately 45% of the school population is enrolled in the immersion program, while the remaining 55% are non-immersion students. Biology classes are made up of a mix of these two groups, and are taught only in English (immersion students

take their science courses in French up to the end of grade 10, after which all science courses are taught in English).

The four classes of Biology 11 involved in the study enrol a total of 109 students. Two of these classes are treated as experimental, while the remaining two serve as control. However, data for only 67 of the 109 students is included in the study, as only these students returned the required consent forms. While there is no risk of harm to participants, proper ethics requires that students are given the option of participating or not and that release forms are signed by a parent or guardian of each student participating. Of these 67 students, 33 are contained in the experimental group (concept mappers) while the remainder comprise the control group (non-concept mappers). Of the 33 concept mappers, ten have volunteered to be interviewed at the conclusion of the study (late June, 2000).

### **Data Collection**

The experimental group is introduced to concept mapping as a learning tool through a variety of assignments, all related to the B.C. Biology 11 Curriculum. While concept mapping is not the only strategy used with the students, they all have significant exposure to it as a tool for learning the course material.

The control group is taught the same curriculum, however they are not taught using concept mapping techniques. Instead, they do other learning and reviewing activities (each of which is, of course, educationally sound) in their classes much the same as what they have done previously this year. Concept mapping has not been done prior to the commencement of this study with any of the students in Biology 11 at John Peterson.

The two groups are evaluated in the same way, with test layout, content and difficulty being almost identical (the slight variations between blocks exist only to discourage sharing of test information between sections). No test questions require the use of concept mapping skills (a sample test is included in Appendix A). Students from the experimental group who volunteer to be interviewed are asked questions to describe their experiences with concept mapping. The interviews take place after the students' course marks have been finalized, in order to ensure that students feel comfortable answering questions with the knowledge that what they say cannot have an impact, either positive or negative, on their grade in the course.

Until the completion of the study, the researcher, the other Biology 11 teacher at John Peterson Secondary, and the student teacher responsible for all four blocks of the course at the time, do not know which students have agreed to participate in the study and which have declined. Only once the course marks had been finalized is it known which students gave their consent.

The sources of data include student test results, submitted concept maps, audio-taped student interviews, and my field notes. All students participated in the classes. However, only data sources from those students who formally agree to be part of the study (and for whom proper documentation of consent is collected) are used. The names of students in this thesis have been changed to assure their anonymity.

### **Data Analysis**

The qualitative analysis is based on data collected during student interviews in terms of how students feel about concept mapping and whether they think it is useful to them as a learning tool. Throughout the interviews, the students are not led to particular answers.

They are probed when it appears that they are not expressing in words what they really mean to say. The questions are:

1. What did you like about the concept mapping you have done as part of Biology 11?
2. What did you *not* like?
3. How has concept mapping helped you learn the material in this course?
4. What was difficult about learning to make a concept map when you were first taught?
5.
  - a. Did you get better at concept mapping as you did more maps?
  - b. If so, what became easier about the mapping process?
  - c. Why do you think it got easier?
6. What was the most difficult part of Biology 11 for you?
7.
  - a. In what ways did concept mapping help you with your difficulties in this course?
  - b. Did you spend more time *making* the map or studying *with* the map?
8. Now that you've done concept mapping, *how* and in *which cases* do you think you would use it as a study tool on your own if it wasn't part of an assignment?
9. What was your preferred method of study prior to using concept mapping for Biology 11?
10. If not concept mapping, what would you rather do to study for Biology 11?
11. Did you prefer mapping on paper or on the computer? Why did you prefer that method?

The student responses to these questions provide a fantastic amount of data for a qualitative analysis. While the quantitative data merely provides an answer to the question of

whether students score better on tests as a result of concept mapping, the interviews give me, the students' teacher, insight into what the learning experience has been like for individual students. To this end, it provides practical information on how best to introduce concept mapping to students who are new to the activity. It undoubtedly sheds light on which aspects of concept mapping students new to the activity are likely to find difficult, and leads to the development of specific teaching strategies designed to alleviate student difficulty, and anxiety, related to the concept mapping process. The analysis of the student interviews is based on emerging themes in the transcribed student responses to questions about their concept mapping experiences.

The quantitative analysis involves two-group comparisons between the experimental (concept mapping) group and the control (non-concept mapping) group. The test scores of the two groups prior to concept mapping being done is first compared to determine if there is a significant difference between the two groups at the outset of the study. The test scores for units in which concept mapping is used (with one group and not the other) are then compared to determine if there is a significant difference between the groups that can be attributed to the use of concept mapping.

### **Teaching Methodology - Introducing the Concept Mapping Activity**

When I first introduced my Biology 11 students to concept mapping, the majority of students had never done it before. Many were familiar with mind mapping or webbing in various forms, as well as diagram-based brainstorming, but the idea of connecting terms together graphically with explanations relating the connected terms was brand new for

virtually all of them. For this reason it made sense to first show students examples of concept maps so they could get an idea of the product they were working toward.

For this purpose I made overheads of five different concept maps based on scientific content to be used in the first lesson introducing concept mapping. The first (Figure 1) was a simple map on the human circulatory system, with a total of six terms and eight links to give students a basic idea of what a concept map looked like. The other maps ranged from slightly more complex to quite complex, covering topics such as cell division, friction, and basic chemical reactions. The students saw that each map was organized differently in addition to seeing the type of information that could be placed on arrows to describe the relationship between terms.

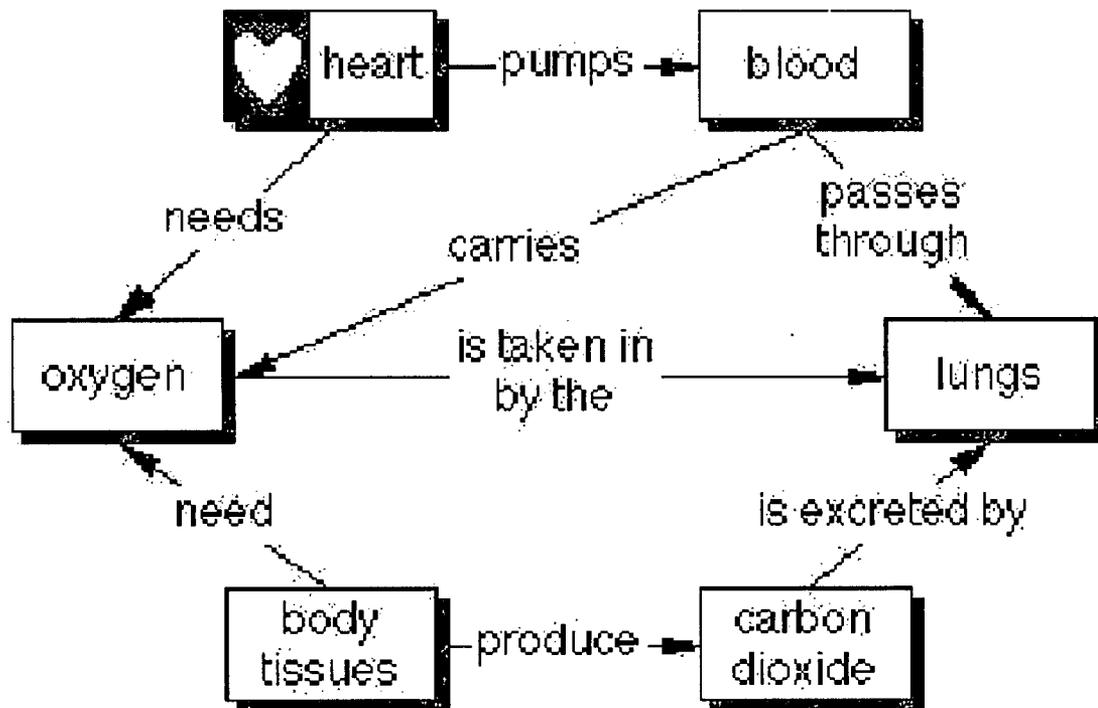


Figure 1. Simple concept map of the circulatory system used in introducing students to concept mapping.

The next step was getting students to actually try mapping on their own. Throughout their concept mapping exercises, the vocabulary words to be used were provided for the students. I had initially planned on only handing out lists of terms for the first few maps, but the lists I provided seemed to really motivate the students to get started on their maps. Many saw the lists as a challenge, to see if they could incorporate every single term on their map. Therefore, I continued to provide students with lists of terms. I have also found that showing students examples of concept maps prior to their first mapping exercise is a valuable process, and I continue to follow that routine with first time mappers.

At this point in the introductory mapping lesson, I gave students a handout that included the terms they were to use, as well as a set of directions that reiterated what had been explained to them about the basic rules of mapping (Figure 2).

## **Biology 11 Concept Map Guidelines**

Work in groups of two (with your lab partner). Using the poster paper and felt pens provided, make a concept map linking the following terms:

**Primary growth, secondary growth, meristem, apical meristem, lateral meristem, seed, vascular, vascular cambium, xylem, phloem, transpiration, Cohesion-Tension Theory, translocation, pressure-flow hypothesis, tropism, hormone, photosynthesis, source, sink.**

### ***Directions:***

- ① Write out the terms in a logical pattern on the page. Do a rough copy on scrap paper first! Use a pencil - you may want to move terms later.
- ② Make links between terms by connecting the terms with lines. Write out the ideas which connect the terms above the connecting lines.
- ③ All lines must have written explanations with them, and enough information should be given so that the reader can understand what is meant.
- ④ Avoid negative explanations (i.e. "Term X is NOT part of term Y).
- ⑤ Avoid repetitive explanations if possible.

### ***Criteria:***

- ① Catchy title.
- ② Poster is neat and legible.
- ③ Map displays an understanding of all terms and the connections between them.

Figure 2. First concept mapping assignment handout given to students as review activity in preparation for Plant Structure and Function test.

Along with their handout of instructions, students were provided with 11 x 17 inch sheets of paper on which to create their maps. I emphasized to students that it was more important that the connections be meaningful and accurate than for them to have a large

number of connections. *Quality before quantity* was the catchphrase I used with them, although I did suggest that once they got the hang of making quality links to try to use as many of the terms as possible. They were then given the remainder of the period (approximately one hour) to work on their maps with a partner, with the understanding that their maps were to be submitted at the beginning of the next class prior to writing their unit test.

Up to this point, my first class had gone very well. However, that was all about to change. Despite the fact that the students had been shown several examples of what a concept map was, and had directions in front of them about what to do to complete their first concept map, most of them had incredible difficulty getting started. They didn't understand what a *logical pattern* on the page meant. They didn't understand which terms to link together first once they had their terms distributed on the page. The students did eventually figure out what to do, but they went through several sheets of paper and many required one on one coaching to form their first few links before being able to design a layout for their maps that was workable. There were so many hands raised with questions in the first 15 minutes of the activity that I was literally running around the room answering questions and explaining what the students needed to do to form those first links that would lay the foundation for the rest of the map. "Mr. Hembling, I don't get how to start" was the most common question, and when I would arrive to help there would be a blank sheet of paper in front of the student and a blank stare on the student's face. After walking through the first couple of links, the confused students eventually got a feel for what they were doing and proceeded on their own.

As a result of the difficulties students had starting their first map, they were given a modified set of instructions for their second mapping exercise. Subsequent mapping sessions continued to evolve as I gained wisdom about how to get students started.

The first of two main changes was that students were no longer instructed to first write all of their terms out on the page. Instead they were asked to pick two related terms to start with, and put only those on the page with a link between them. Then they would add new terms from the list one at a time as they discovered relationships to terms already on the page.

The second modification was that instead of setting the students loose to start their maps on their own right after having received their list of terms, we started the maps as a class to let off some of the pressure and walk them through the beginnings of the process. I started by asking students to look at their terms and decide which ones suggested a framework that would help organize the rest of the map. These terms were the most general in nature, and could be linked to the greatest number of other terms. For example, it would make more sense to place the more general terms *photosynthesis* and *vascular* near the middle of the Plant Structure and Function concept map than more specific terms such as *source* and *apical meristem*. As we made the first few links on the white board as a class, students copied the terms and links onto their own sheets of paper as a starting point from which to continue on their own. After the students had worked through the formation of the first few links together, it was amazing to see the difference in their ability to get to work on their own. They seemed to understand what they needed to do after the *group map* activity. With the incorporation of these two modifications to the introduction process, I found this to be a solid framework for use with students in their first few concept mapping experiences.

After they did three or four maps on their own, most students did not feel the need to be walked through the beginnings of the map as a group, although some students still appreciated pointers from the teacher for their first few links on an ongoing basis.

## Chapter 4 – Qualitative Analysis

The ten students who volunteered to be interviewed as part of this concept mapping research had a lot to say about concept mapping, their own learning styles and strategies, and the Biology 11 course material itself. The excerpts quoted in this chapter are presented as evidence of how students used concept mapping in their own learning, as well as what they thought about the process. More important, however, are the conclusions that can be drawn about what effective learning is, and how best to achieve it as an educator in light of the candid student comments analyzed in this study.

The student interview data has been examined for insights into the role that concept mapping plays in student learning. In the analysis of the student interviews four categories of data emerged. It is from within each of these categories that the data will be presented.

First we will examine the main learning difficulties experienced by students in Biology, in order to identify those areas where a teaching or learning strategy could be most useful to students. Second, we will look at how concept mapping serves to engage students in a meaningful way with the curriculum. This will be examined from the perspective of students first, and then from the perspective of their teacher. Third, we will investigate what students said are the most important elements of successful concept maps from their own experiences as they used concept maps in their studies. This will lead to the related topic of how students in the study learned the difference between *good* and *bad* maps as they gained experience with the concept mapping process.

## Student Difficulties in Biology 11

The first question that needs to be examined, if our goal is to determine whether concept mapping promotes meaningful learning, is which aspects of Biology students found the most challenging. To find out which sections of the course these might be, the students were asked, “What was the most difficult part of Biology 11 for you?” Students responded to this question with surprising consistency, and each of their explanations revolved around a central focus: there is a large volume of information to be learned in Biology 11, and memorization of the individual facts associated with each concept, or in many cases with each organism being studied, is no easy task.

Jessica had this to say about what was difficult about the course. “The memorizing. All the different words. All the different terms... and everything. It was just, we covered a *lot*. Yeah, just trying to make sure that everything kind of fit together” (interview June 26, 2000)<sup>1</sup>. Similarly, Ross thought that the most difficult aspect was “memorizing, figuring it out, and just remembering all those names” (interview June 26, 2000), referring to the volume of scientific vocabulary required in Biology 11. Many of the terms students must learn have either Latin or Greek roots, so as a teacher I try to point out the meanings of word roots in an effort to help the students decipher meanings rather than rely only on memory skills. But despite this strategy, time and again students find all the minute details about each concept or sub-topic quite overwhelming. This is evident in their test results, where most students end up confusing terms and mixing up definitions.

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<sup>1</sup> Quotes from student interviews, as well as student concept maps appearing as figures, are included unedited by the author to assure authenticity. For this reason, grammatical or typographical errors may be present in such inclusions.

When Ethan was asked about his difficulties he focused on the challenge of visualizing the numerous organisms covered in the course, and the specific detail about each that he was expected to remember. “The [microbiology section] was tough because they’re just... they’re really small, and there’s lots of parts to memorize and... they’re not really, you don’t think of them as animals, or living things, or anything. It’s really tough to think about them” (interview June 28, 2000).

Monique explained it well when she described her difficulties not only with the memorization of individual details, but also with the task of making connections between related ideas. It is this kind of understanding that is important for answering the more difficult test questions that not only require an understanding of individual terms, but their relationship to each other. She explained that for her, the most difficult part of Biology was “probably all the memorization. Not just words, but you also have to know what they mean and how they apply to other things. Also, applying... some of your questions on your tests it would be, something we learned, but you had to apply it to something different, and I have trouble with that.” Monique refers to what many students find difficult: applying knowledge previously learned to a new situation that they might not have previously considered. As teachers we know that these application questions are often poorly answered on tests, in addition to those questions requiring even higher level thinking skills such as analysis and synthesis. While questions which test simple recall of facts, such as definition type questions, can be answered even by students with a fairly shallow understanding of the topic, the higher order questions require that students understand the connections and relationships among aspects of a unit. Bloom (1956) describes six levels within what he describes as the “cognitive domain” (Bloom, 1956, as cited in Cruickshank, Bainer, & Metcalf, 1995, p. 135)

that define the degree of difficulty of a particular learning outcome. Application type questions are ranked third of the six levels, while analysis and synthesis are found at levels four and five (Bloom, 1956, as cited in Cruickshank et al, 1995). It is these upper levels of understanding that concept mapping is particularly useful for enabling student learners to achieve.

### **Engaging Students in Meaningful Learning**

Students often have trouble with the amount of information they are required to both understand and retain for success in Biology. In addition to the factual aspects of the course, connecting each piece of information to other concepts within the course is a constant challenge. As a teacher I see that one of the most important things I do is organize learning activities that actively engage students with the material. By this I mean that students in my class are forced to make connections not only between what they already believe to be true and what they are learning, but also among the various concepts within the course material itself. This is why I believe concept mapping is such a valuable tool for teachers and their students. In the process of making a concept map, students must uncover their own ideas about a topic to make the first few basic links. These ideas are apparent in their work, as will be shown shortly by an example. Next, students add to that scaffold of knowledge the more difficult concepts of each unit, again making their ideas clearly visible not only to themselves but also to their teacher. Figure 3 shows a concept map created by a Biology student that demonstrates two key points.

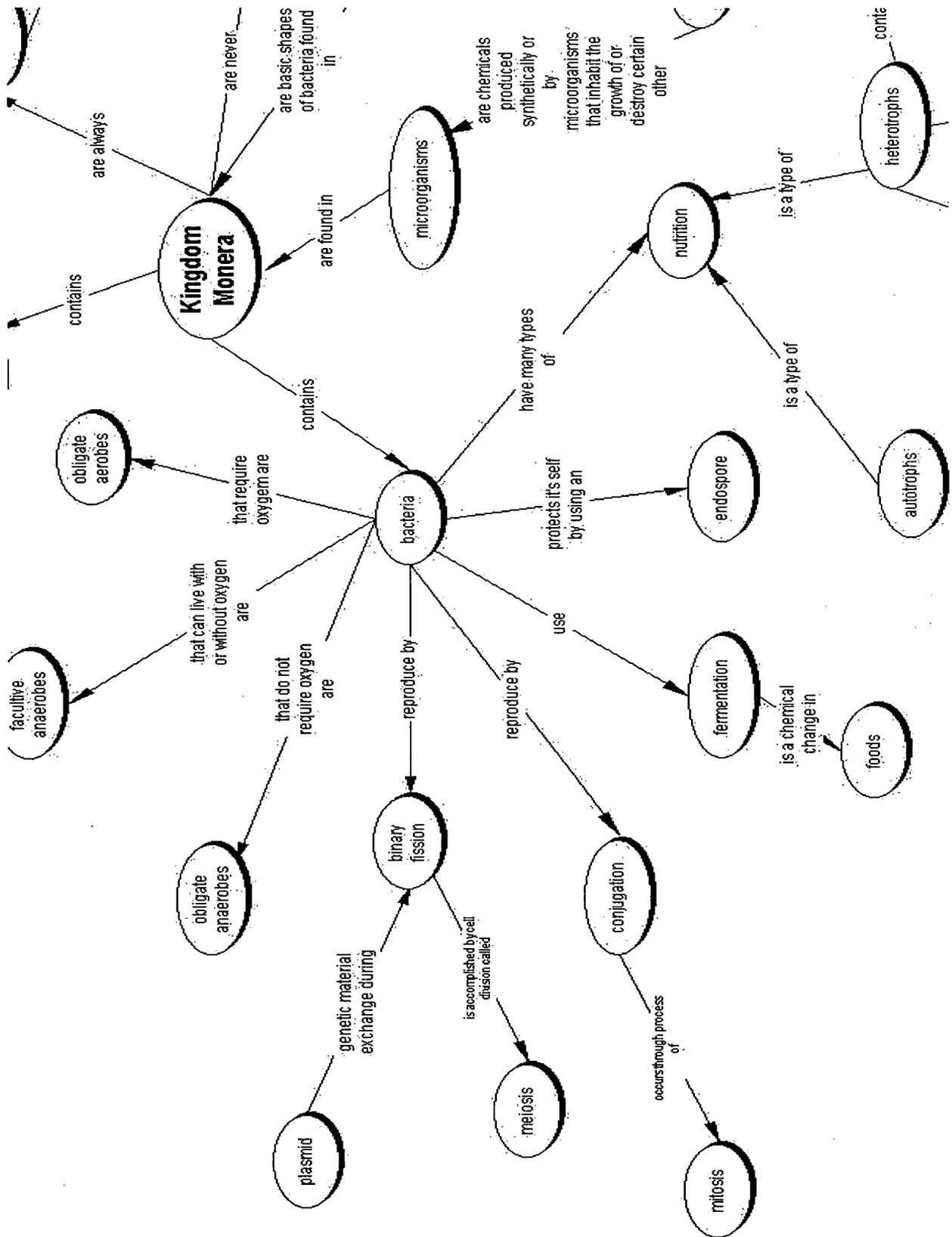


Figure 3. Concept map showing confused understanding of mitosis and meiosis.

At first glance, the student has demonstrated a good understanding of several key concepts in the bacteria section of the Monera unit. The three types of oxygen requirements are explained, as well as binary fission and conjugation, the two types of reproduction possible in bacteria. However, the map does uncover the student's misunderstanding with respect to the roles of meiosis and mitosis in bacterial reproduction. Binary fission and meiosis are linked in the concept map, inferring that binary fission is accomplished through meiosis. In fact, these two processes have nothing to do with each other and are not related in this way. In addition, conjugation and mitosis are unrelated processes, contrary to the link shown on this concept map. As a teacher it is very interesting to discover that the mitosis and meiosis concepts are not well understood by this student. These topics are covered in the Science 10 curriculum, a pre-requisite for Biology 11. While the processes are reviewed to a certain extent in Biology 11 to bring students back up to speed after their summer away from science, the fundamentals of these processes are concepts that Biology 11 teachers assume students already understand. It is important in this case for the student to re-examine these misunderstood concepts in order to understand related topics that build upon the basics later in the course. Without the concept map exercise, this misunderstanding may have been overlooked until it was too late.

Although this particular student didn't realize in the process of mapping that this problem existed, many would have realized it as they created their maps, double-checking their information as they worked. This is a powerful feature of concept mapping as a learning tool. However, if left to devise their own learning activities, most students do not normally choose the type of activity that actively engages them. There are many reasons for this, several of which were exposed in the interview process.

### *A Survey of Student Study Habits*

“What was your preferred method of studying prior to using concept mapping for Biology 11” was a question that yielded interesting results. Although each of the ten students interviewed had a different approach to studying, there were some definite commonalities among their responses. Two strategies showed up more consistently than any others, and won't come as a surprise to most teachers. The first of these is re-reading the notes given in class, and the second is re-reading a section, or sections of the textbook.

Prior to asking the students about their study habits, my own prediction was that the more academic students would employ a more active method of study. This did not, however, appear to be the case. Jason, a fairly academic student, describes his strategy for test preparation. “I would just usually review my notes. I would go through them once, and just look them over” (interview June 26, 2000). Tracy, a highly academic student, had a similar strategy. “I'd probably read over everything... everything I have as far as notes go. And then I'd find what I thought was most important and I'd just look that over and remember it. Just sort of memorize it” (interview, June 26, 2000).

There were a few students who described a more active type of studying. Monique is one of them, and is a proponent of self-quizzing. “I go over [my notes], and then try to ask myself questions, and I just take a big pile of notes from whatever section and stick them right in front of me,” (interview, June 27, 2000) she explained. Stephanie had a different approach, although hers was also active in nature. She is a self-proclaimed cue-card enthusiast, and had a lot to say about her cue-card studying process:

Cue cards. I've spent hours and hours making cue cards. I would just take lined paper, and cut it up into little squares, and first of all I would go through the study guides and the notes that we took, and if it was a study guide, I'd write down the question on the front, and then have the answer on the back. And then with the notes,

I would just make up my own questions, and then have my answer on the back. And then I would go through the textbook, and you know how they had like the highlighted words in the text, and they would have the definitions of those words on the sides, and then I'd write down the word on the front and then the definition on the back, and that's about it (interview June 28, 2000).

Of the ten students interviewed, only these two gave significant descriptions of more active forms of studying, listing these particular techniques as their main activities. Most students described less active review methods, such as reading through their notes or the textbook. From our own experience as students we know that these types of activities are not as useful as those which force us to process information rather than simply repeat or review it. Concept mapping is an activity that requires extensive processing, as evidenced by the descriptions of students who used it.

#### *How Concept Maps Work: According to Students*

How, then, does concept mapping facilitate students making connections? Students gave a great deal of detail about this in their interviews. The type of comment most often made was that concept mapping served to link concepts together in the course. It was described as "connecting things," "showing relationships," and "making connections." Jessica described her thoughts when she said, "It was... easy to just stick everything together. It helped me piece things together as far as biology is concerned, because everything kind of went off on different tracks very easily... it just helped bring everything together" (interview, June 26, 2000). Monique compared it to other learning activities she has tried, and said that "there's never [been] a way that I studied that fit everything together so easily" (interview, June 27, 2000). Ethan, a student who admittedly avoids homework of any kind, said that he "liked the ability to make connections between terms" (interview, June 28, 2000)

when he concept mapped, and it was clear by the maps he submitted that he enjoyed the activity more than other assignments I've given him. He was also more successful on unit tests when he concept mapped, a clear indication of the success of the technique in his particular case. Jason described his own connection successes when he said, "Well, you were able to look at the whole picture of the chapter I guess, instead of just studying individual parts of it. You could relate to how they went together" (interview, June 26, 2000).

Stephanie is a student who particularly enjoyed the way concept mapping enabled her to learn. She compared her experience using concept mapping to her previous study methods when she said, "Before when I studied it was pretty much memorizing, but when we did concept mapping it was kind of going in depth with the material and making the connections and actually *learning it*" (interview June 28, 2000).

When asked specifically about how concept mapping helped them learn the material in Biology 11, the students described a variety of useful aspects. By far the most common reason given had to do with the way that concept mapping enabled students to organize and connect their ideas. Students said that it "pieced things together" for them while preparing for tests, and enabled them to visually organize all the information on one topic in the same place. Paige described this process when she said, "it broke the information down into smaller pieces that I could understand more... and the relationship between them, to fit into the big picture of the whole... topic that we were looking at. It was *so* much easier for me to learn" (interview June 29, 2000).

Ross described the extent to which he became involved with the material in the process of preparing his map. "I kind of had to read about it, if I wanted to connect them, so

I had to go back a few times and do... research, to complete the map, instead of just reading it once and answering some questions... I kind of researched and really concentrated on my words.” Chris would have agreed with this statement. He found that preparing a concept map got him to dig deeper into the subject material, and he thought it made him actually learn more.

When we were doing a concept map we had to learn a lot more, we had to go *in depth* about the subjects, right, so once we got to the test we could answer all kinds of questions about it because we had a better understanding of how things worked. It’s not just reading out of a textbook, it’s how things work, and how they all go together. So it’s a lot easier to put things together on a test. The concept map gave me a better understanding, an in-depth understanding of things, and I brought that to the test with me and it helped me out a lot. I could answer a lot more questions on the tests from what I studied on my concept map. It just helped me understand things (interview June 28, 2000).

The level to which students were engaged with the course material while they generated their concept maps is further evidenced by how they used their maps once they were complete. Of the ten students interviewed, only one thought that she spent more time studying with the map (after she had completed it) than the time she initially spent putting the map together. All nine other students felt that they spent more time actually creating their maps. It is interesting to note the consistency with which students claimed that they didn’t study with the map after it was finished because the process of concept mapping was in itself enough of a study session that they didn’t require any further study to prepare for their tests.

Stephanie described her thoughts about the value of making concept maps as study time. “I definitely spent more time making [the concept map], but making it *was* studying. I didn’t really study with it afterwards... making it was enough for me, because you just had to spend so much time with it...” (interview June 28, 2000). Ethan described the same idea when he said,

I think [I spent more time] making the map [than studying with it]. You made the map, and as you went along you kind of studied it I guess. Because when you look up a word, you find out what it means, and then you have to link it to another one. So you're basically studying in a way I think, when you're making it. That's what I felt (interview June 28, 2000).

Ross summarized his concept map sessions as follows. "Well, honestly, I don't really study that much. So for me, it would be like I wouldn't have studied anyway, you know if it was concept mapping or not concept mapping, because I just don't. But I think that making the map is a kind of studying. It kind of forced me, well not really forced me, but subconsciously forced me to study because just going back all the time, *that* made me study. Just making the map was my study time" (interview June 26, 2000). It is interesting to note that Ross' test scores improved dramatically after the onset of concept mapping with the class. For those units where Ross didn't complete his review concept map, his unit test scores were consistently lower than for those units where he did complete his maps. It seems that concept mapping really did *force* him to study.

The impact that concept mapping had on students in enabling them to really learn the course material was further tested when students were asked if they thought they would use the technique again. Most thought it was highly likely that they would use concept maps in Biology in the future. They thought that it would be helpful for courses that require an in depth understanding of the subject matter, as well as those requiring students to make conceptual links between one aspect of the course and another. Chris describes his thoughts about future use of concept mapping. "I guess I'd use it on my own, outside of school, if I had something I had to really understand in depth, like science, I had to understand how it worked..." (interview June 28, 2000). Ross thought concept mapping worked best for subjects like Biology and Social Studies, where he has to make connections between

different pieces of information in order to understand something as a whole. "I think I would [use concept mapping as a study tool]. Because I like the concept. I really like that. I think that for Biology I probably would, because it helped a lot. Probably Socials, all those events in history, connecting with this and that. I think I would use it for that" (interview June 28, 2000). Clearly, students value concept mapping as a technique for their own learning where the issues are complex and inter-relationships must be understood. Equally powerful, however, are the insights gathered regarding refinements to the concept mapping process from a learner's perspective. The next section deals with what experienced concept-mappers see as vital aspects of successful maps.

### **Student-valued Concept Mapping Techniques**

This study was originally undertaken to determine whether concept mapping was an effective tool for students to generate meaningful learning of senior Biology. The experience for the students, however, was not just one of using concept maps to that end. As students began to concept map, they soon realized that there is more to concept mapping than originally meets the eye. It is a technique that they must learn in order to be successful, and like any skill that is learned the process takes time to perfect.

In their interviews, students provided a great deal of information about their own learning experiences, particularly through descriptions of the process they went through as they learned to concept map. As they became more experienced, they discovered which types of strategy work and which do not. This information was elicited when students were questioned about their mapping frustrations. Students commented primarily on two such frustrations. Many complained about the sheer length of time required to make a good map.

This was presented by students as an unfortunate but often unavoidable by-product of concept mapping in general, particularly in the early stages when students are new to the activity. However, a second issue was described as something that wasn't necessarily inevitable. This was the difficulty in making the first few links between terms in a way that was conducive to successful completion of the map. In fact, eight of the ten students focused on this as their main difficulty.

Stephanie described what she saw as the most important part of getting a map started. "Just making a first really good connection that could help make all the other connections. That you could relate to all the other words" (interview June 28, 2000). She described the impact of making poor first decisions when planning the structure of the map, and explained situations that could cause a map not to go well, "like using things that aren't really that important in the unit. Like using words that aren't that important in the unit that weren't really *that* big of a topic, and then you end up with about four connections" (interview June 28, 2000). Here she is referring to a poorly-planned map, where the first terms placed on the map are not central enough to the unit to allow for rapid incorporation of other sub-ordinate terms. Paige summarized similar frustrations when she described her first concept mapping experience.

We had a list of terms to choose from and I didn't know if we had to start from the easiest, like the least kind of specific one, or the most complex idea in there, or just... I was totally blown away what to start with and how to connect them all. And the list was not that long, but it looked really long at the beginning, and it just was like, oh my gosh, we have to fit all of these together? (interview June 29, 2000).

Paige also describes trouble organizing her terms in a hierarchical manner, despite the fact that students were shown how to do that and given specific examples prior to starting the activity (this introduction process will be detailed in Chapter 5). The very fact that she had to

make these decisions for herself before being able to move on was a major stumbling block for Paige and many others.

Ethan had the same problems, and emphasized specifically the importance of choosing that first, most central term when constructing a map.

I think it was starting it off, getting that first term. And then if you did get the first term, sometimes it wasn't the best term. You had to find that term, usually there was one term that had a lot of... that you could hook a lot of things to. And if you didn't get that one term you were in trouble (interview June 28, 2000).

Another key difficulty encountered by students was organizing their terms and links on the paper in a way that allowed them to complete their maps more easily. Jessica described her map organization troubles when she said that "everything had to be forced into one page, and it was a little hard because all of the words were really close together" (interview June 26, 2000). Ross believed that the answer to the problem could be found in the *planning* of the concept map, and he described one of his early attempts when his planning wasn't well thought out beforehand. "Ok, if I start with this... and I start with it, my map all sits like... then I have nothing else and it's all in the middle and all my important [terms] are all on the sides, like very far, and I realize I've got arrows winding all over the place... and I ended up connecting... six words to a word that's right in the corner" (interview June 26, 2000). This was not unusual for beginning mappers, who didn't yet have the experience to guide them through wise placement of main terms in the centre of the page, rather than on the edges where crowding would become a problem. This was usually overcome with experience, and was viewed by the interviewed students as one of the growing pains of learning the activity.

As they produced more maps, students tended to overcome this initial difficulty. In addition, as they became more experienced and skilled with concept mapping, students developed a strong sense of what differentiated a strong, high-scoring concept map from a weaker, low scoring concept map. This knowledge served to direct their future maps in the direction of what they, and their teacher, considered to be a high-quality product.

### **Toward Quality Concept Maps – The Student Learning Process**

The evaluation of student concept maps was achieved by a combination of two processes. First, students were required to evaluate their own maps prior to submitting them to the teacher. They were marked out of 15 total marks, broken down into three sub-categories. Five marks were allocated to each of three categories: quality of links, number of links, and effort. Students were required to record this mark breakdown on their maps, showing how many marks the map was *worth* in each category. After making this determination, students traded maps with a peer. Each then re-assessed the other's map, and they discussed any differences of opinion until agreement had been reached.

Only at this point was the map ready to be submitted for grading by the teacher. Often my evaluation of the map would be identical to what the student had already decided, and other times the marks would need to be adjusted. As time progressed, student self-evaluations more and more closely matched that of the teacher. Through this process, students quickly learned the requirements of a quality map, and most improved their work with practice to achieve this goal.

The most difficult of the three categories for students to improve upon as they completed more maps was quality of links. Effort was for the most part a function of how

much time students put into making their maps presentable and easy for the teacher to read. Numbers of links was primarily a function of the amount of time the student dedicated to working on the map prior to submitting it. Link quality, however, represented the essence of what concept mapping is about.

This essence was described by Jessica when she explained her problem of “trying to piece everything together... trying to make links between things” (interview June 26, 2000). When students make a concept map, they are forced to show what they know about the relationships between terms within a unit. If they have trouble making the links, it demonstrates that they don’t understand the necessary relationships. In order to continue with their map, they must do what it takes to dig up the necessary information. This often involves going back to their notes, re-reading the relevant section of the text, or asking for help from a peer or the teacher. This is what active studying is about, and it holds the real power of the learning strategy that is concept mapping. The most profound evidence of the active nature of concept mapping came when I had the class working on their maps, and I could see them digging for information with a focus unparalleled by other class activities. At times it was all I could do to keep up with the influx of questions, raised hands, and lively discussions between students about what something *really meant*.

Tracy had similar trouble forming links, but hers was more a difficulty with a specific quality of link for which students were encouraged to strive. The most useful links for a student are those that contain detailed information, and Tracy had trouble including enough of it. She thought that making basic connections was “easy,” but making connections with rich detail was “the hardest part” (interview June 26, 2000).

The figures below contain concept maps that are representative of the difference between these two qualities of links. Figure 4 is an example from early in the process of learning to concept map, with simple links between concepts. Figure 5 is another example, but this student was a well-seasoned mapper at the time that this map was created.

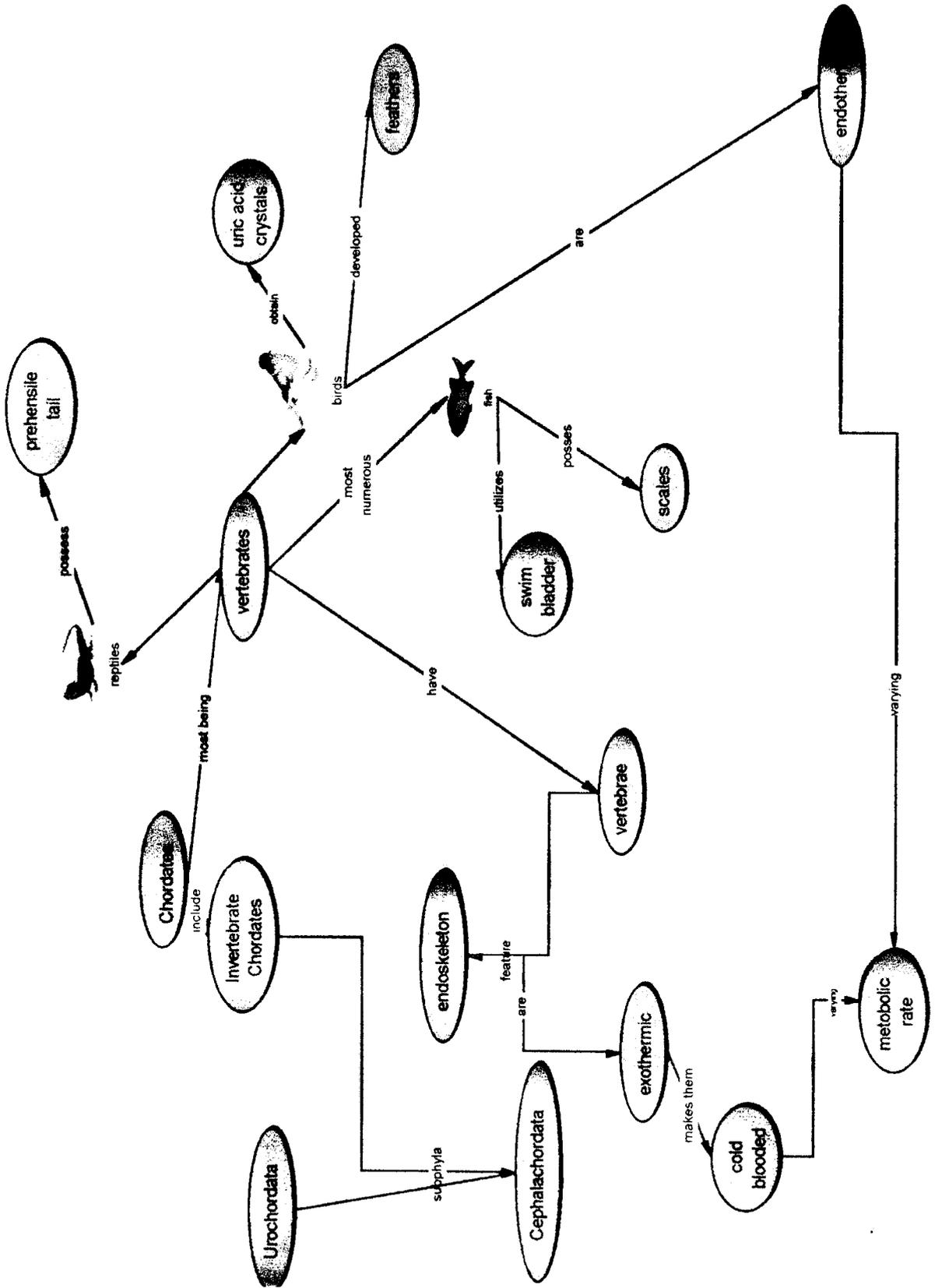


Figure 4. A concept map created by a student just learning the process, showing simple, low-information links.

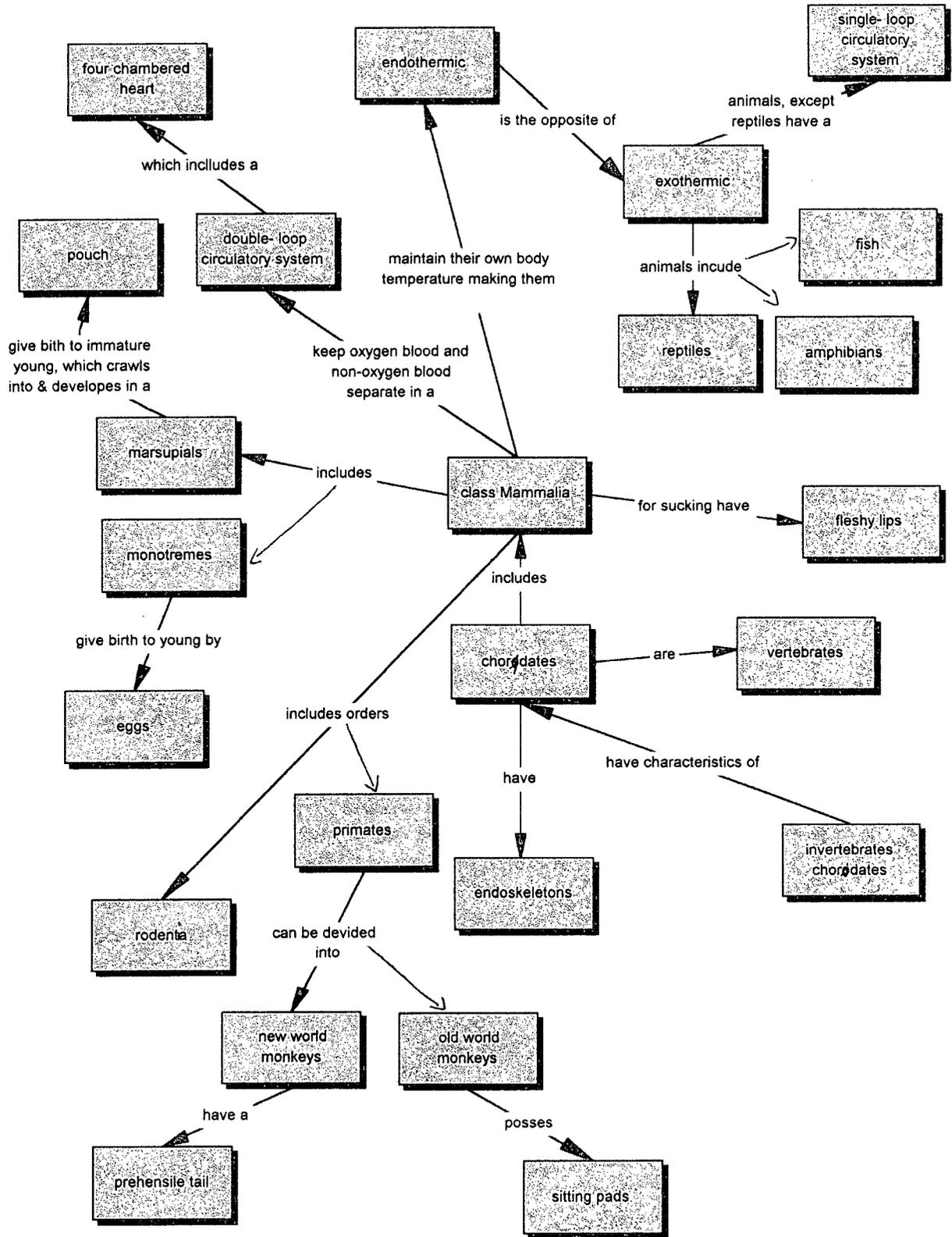


Figure 5. A concept map by a seasoned mapper showing informative links with detail

The detailed links found in the map in Figure 5 are representative of what Tracy had trouble with when she made her maps. While it is relatively easy to make simple links such as “vertebrates → have → vertebrae”, it is far more involved to produce a map that gives more detailed information of the relationships between the two terms, such as “Class Mammalia → maintain their own body temperature making them → endothermic”.

Despite the collectively rough start to mapping for most students, all ten students felt that with practice they became considerably more adept at mapping. Jason described his own experience. “I got better at it. I found it easier to find links, and start. It took me way less time.” (interview June 26, 2000). His opinion was echoed by the remaining students.

Monique described her improvements in great detail:

The links started to get better, but also the information on them; not just something *is* something, it kind of had a little bit of an explanation behind it, so it made sense. It's not just an arrow with one word. And I learned how to do more terms put together because it was just... everything was easier so it was quicker so I could do more (interview June 27, 2000).

What she is describing is her ability to see the relationships between terms on her page as she generates her map. “An arrow with one word” describes a weak, low information link, and “putting more terms together” is her description of the improved complexity of her maps. Students are encouraged to make as many links as possible on their concept maps, as it is rare for a term in biology to be conceptually related to only one or two others.

When students were asked directly what became easier about concept mapping as they completed more maps, they explained that their maps improved with practice. Specifically, several students felt that the reason for this improvement was better organization in how they planned the map in the early stages of putting it together. Ross thought that experience helped him by “just knowing where to start ... I kind of grouped

things together to help me” (interview June 26, 2000). Jason echoed his comment. “I think just getting started, which terms to start with, and how to organize it all.” (interview June 26, 2000).

Ethan had an interesting comment to make regarding his appreciation for the learning process as he got better at mapping. He had just finished explaining that he’d had growing pains while learning to map, and I asked him if he thought I should have walked him through the first map to make it easier. His response: “No, I think it was good to learn on your own. It was good too, because then you... if someone else does it for you, or gives you too much direction, you’re not really doing it, if someone else is helping you” (interview, June 28, 2000). He was quite pleased with having learned to do good maps under his own steam. The students certainly had the benefit of helpful hints and suggestions from the teacher, but because it is such a creative process it really is something that they had to learn to do through practice themselves. A teacher can give you strategies to use and basic steps to follow, but the maps students create must come from their own minds.

Chris was quite matter of fact about the improvements he made with practice. “You get a sense of what to do after a while, a sense of what wouldn’t work, and what would work, and how it should start off and all that” (interview, June 28, 2000). When he says “what wouldn’t work” he is referring to a map that ends up working itself into a corner of the paper, or one where information isn’t well organized on the page such that it facilitates links to other related terms. Students learned that pre-planned maps are more successful than unplanned maps. It’s important to have an idea, prior to laying the terms out on the page, of which sub-topics of the main topic are going to be placed close to one another on the map. Others can then be placed further away because they are less closely related and won’t

support as many links between them. The following figures demonstrate the differences between poorly- and well-planned concept maps.

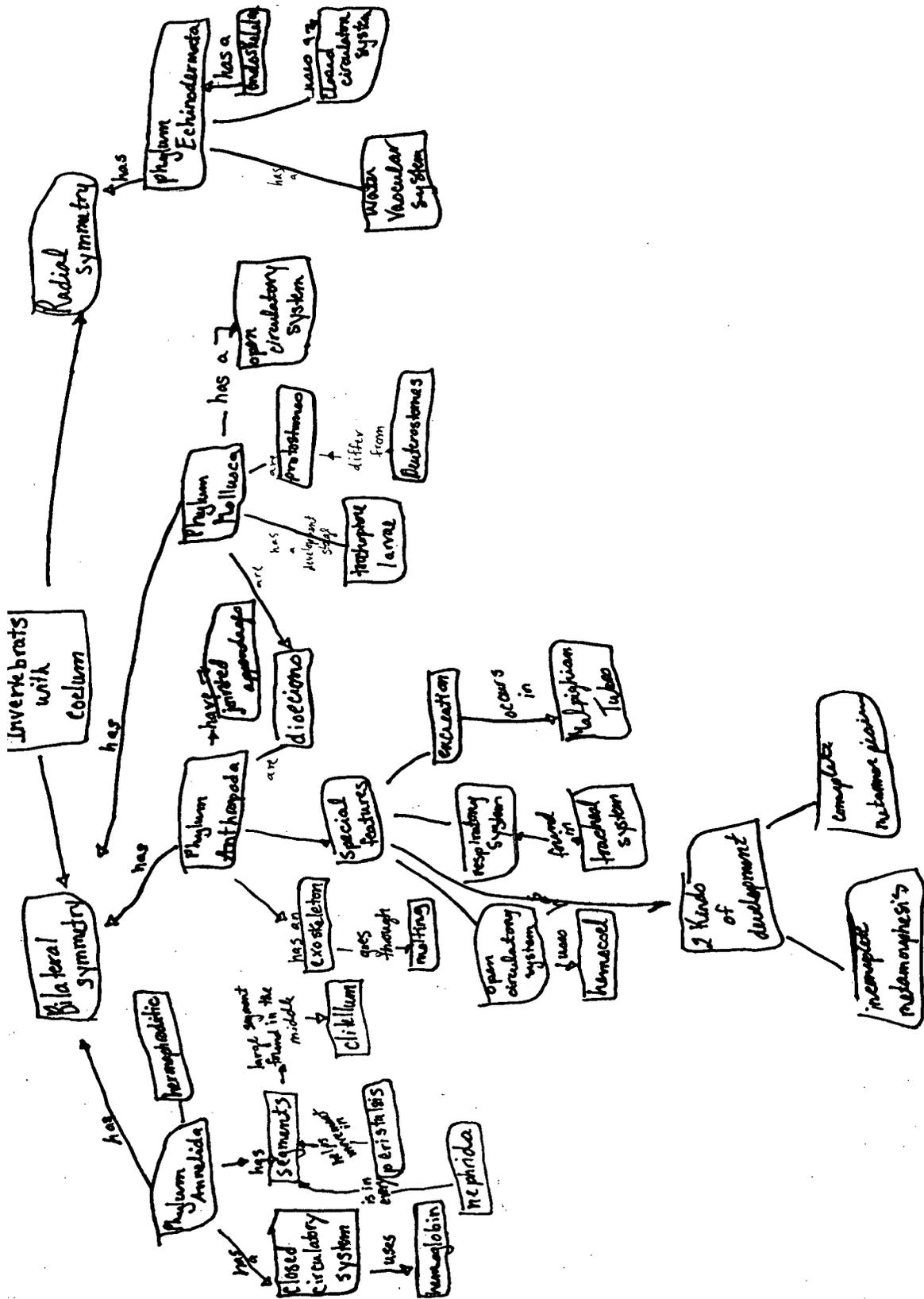


Figure 6. A poorly-organized student concept map on Invertebrates with Coeloms unit.

In Figure 6 the student chose symmetry type as the first link from Invertebrates with Coeloms. However, as can be seen in the map, most of the information under this topic is related to organisms possessing bilateral symmetry rather than radial. The map had ended up very one-sided with extra space on the right hand side and a crowding on the left, and links relating to features other than symmetry are difficult to make between groups.

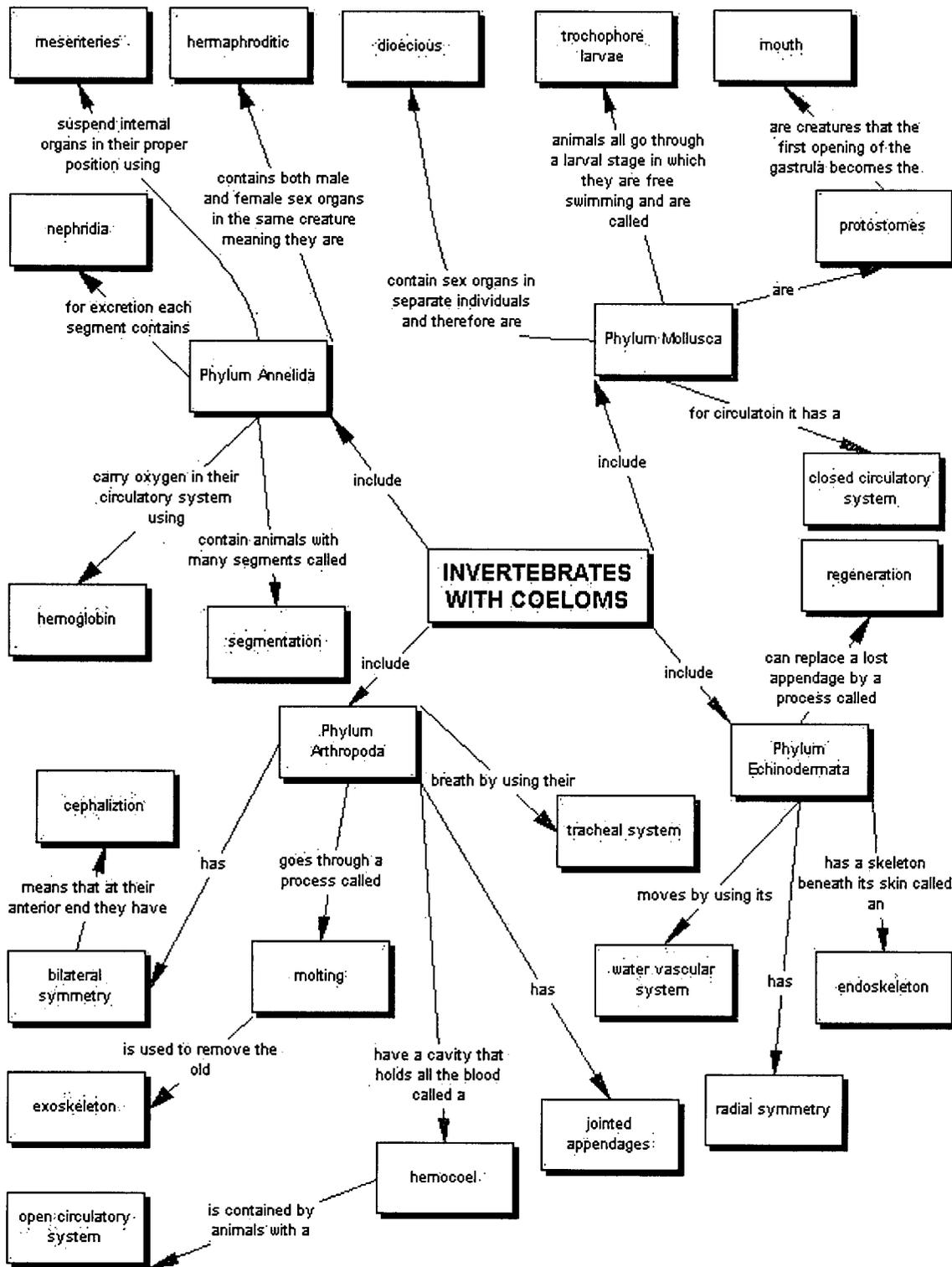


Figure 7. A well-organized student concept map on Invertebrates with Coeloms unit.

The concept map in Figure 7 shows much better organization and fore-thought. By placing the main term in the centre of the page, and the four main sub-terms (Mollusca, Annelida, Arthropoda and Echinodermata) radiating out from it, the student has made a better use of space. This has left the student more room for detailed links, and the map is easier to follow than the previous map in Figure 6. It is possible that this improved organization facilitated the creation of more meaningful links in Figure 7 as compared to Figure 6, as those are also evident.

One of the most interesting insights about the process of learning to map was from Paige, who divulged through her interview that a large part of her trouble in the early stages of concept mapping was anxiety - thinking the task was larger and more complex than it actually was. When asked why her mapping skills improved, she responded,

Well for one, I wasn't worrying what to start with anymore, because after you started with something you could also connect it back up, like back up to it with other information, and so it wasn't such a big deal what to start with that I made it out to be. And it just, it... I guess it just all came together in my mind, like, oh, well it's not that big a deal. Like when we first got the concept map, it was like a huge project, like Ahhhh! A big huge web of things. But after that it was not, it was just information like, being put together. It was... way easier (interview June 29, 2000).

She also shed light on one of the wonderful flexibilities of concept mapping: that you can shape the map as you create it, and that early errors can be easily corrected later on in the process. Exactly how this is accomplished depends on the medium in which students choose to generate their maps. Some argue that changes are more easily accomplished using computer software rather than a pencil and paper as changes can be applied without the need for erasing. Others would rather do a rough copy of a map on paper and then re-copy the final edit as a good copy to be submitted for grading, and quality maps have been produced using both methods. This issue will be further investigated later in this chapter.

## Evaluation of Concept Maps

How students are evaluated their concept maps has a direct effect on both their enthusiasm for the activity and the quality of maps they produce. The marking schemes I used to evaluate student maps changed as the students grew from beginning mappers who had little faith in their own abilities, to experienced mappers who were both proficient and confident in their work. In every case, the students were made aware of the criteria used to mark the maps at the time they were assigned.

### *Concept Map One: Plant Structure and Function*

For the first concept map assigned, I wanted to encourage students to give the activity a try regardless of what their final product looked like. It has been my experience that many students, when they feel threatened by an assignment, would rather do nothing and accept a zero than risk putting effort into something that could be given a poor grade by the teacher. For this reason, I made the first concept map worth only five marks, the same value normally allocated for a completed homework check. I told students that if they submitted a map, and it looked like they'd put in a reasonable amount of effort regardless of how *good* it was, they would get five marks out of five.

This approach worked well at getting students to at least attempt the first map in light of the fact it was a new experience for them. Out of the two classes who were given the assignment only three students failed to submit maps, a consistency much greater than that of assigned homework in the course.

### *Concept Map Two: Early Invertebrates*

The second concept map was marked according to criteria that had higher expectations than the first. Instead of being worth five completion marks, the second maps were marked out of 10, broken down into two categories worth five marks each. The first category was called *number of links* and was an indication of both the number of links made on the map as well as the number of terms used, as the latter has a direct impact on the former. Students were told that if they used roughly two thirds of the total number of terms given and had a reasonable number of links between them, they would get five marks out of five in this category.

The second category was called *quality of links* and was based on just that – the quality of the links between terms. Students were told that if they had only single-word descriptions on their links, they could expect a one or two out of five. If most of their links had phrases that related the terms in a descriptive, informative way, they could expect a five out of five in this category.

### *Concept Map Three: Invertebrates with Coeloms*

At this point, students had successfully completed two concept maps and were really starting to get the hang of it. Many of the maps submitted in the previous round (their second maps, on Early Invertebrates) were of such quality, and had demonstrated such effort by students, that I felt the need to up the ante once more and make them out of 15 marks. To do this, I added one final category to the evaluation scheme out of an additional five marks, and named it *effort* to reflect the amount of work put into the map. I explained to students that neatness, organization and the amount of effort the student put in would contribute to the

mark. As long as a student did a conscientious job of the map with a reasonable amount of effort they would be awarded four out of five. Five out of five in this category required outstanding effort.

This evaluation scheme, totalling 15 marks with three sub-categories of five marks each, is the final marking scheme by which all subsequent concept maps in the study were graded. The three-category system was not pre-planned, but rather evolved out of what I saw to be the three most important factors in a good concept map. By making the three categories explicit to students prior to evaluation, the importance of these three aspects was conveyed to them in order to give them a framework within which to work. When they received their graded maps back from the teacher, they could see in which areas they had excelled, and in which they still needed to improve. I have found this marking scheme to be very useful in teaching students to concept map. I continue to use it with my classes today, although I have subsequently modified it to include two additional components: self and peer evaluation.

### *Self and Peer Evaluation*

Although I didn't require students involved in the study to use self or peer evaluation techniques, I have since found them to be very effective in getting students to internalize what qualities are possessed by a *15 marks out of 15* concept map. Now when I assign students a concept map for homework, part of the assignment is to evaluate their own map right on the concept map paper itself. They are required to break it down into the three categories: number of links, quality of links, and effort, each worth five marks. Just before they submit them for marking on the day the maps are due, I have students take five minutes to swap papers and evaluates each other's maps. The students then discuss their grading

evaluation with each other until agreement is reached on marks for both maps, and this score is the one left on the map when it is submitted to the teacher.

Using this technique, I have found that over time students become quite reliable at grading their own maps fairly. The first few are often self-graded either too high or too low, but with practice, and after seeing the teacher's adjustments to their assigned grades when the maps are returned, students get to the point where rarely do I need to adjust the self / peer evaluation when I assign a final mark to their work.

The last modification I have made in the last year is to set up a format for the lists of terms that are handed out to students. The terms are listed in alphabetical order, so that students have to sort them according to relationships that they choose (rather than having all the related terms grouped together in the order in which they appear in their notes or the textbook). However, at the top of the list, not alphabetized with the others, are the most general, categorical terms that are suggested as the first to place on the map. An example of such a list is shown in Figure 8 which is my current list of terms for the Invertebrates with Coeloms concept map assignment.

### Invertebrates with Coeloms Vocabulary

- Kingdom Animalia
- Phylum Annelida
- Phylum Mollusca
- Phylum Arthropoda
- Phylum Echinodermata
- Abdomen
- Antennae
- Anus
- Book lungs
- Cephalization
- Cephalothorax
- Chitons
- Clams, mussels, oysters, scallops
- Class Cephalopoda
- Class Gastropoda
- Class Polyplacophora
- Clitellum
- Closed circulatory system
- Coelom
- Complete metamorphosis
- Compound eyes
- Convergent evolution
- Crop
- Deuterostomes
- Dioecious
- Dorsal anterior ganglion
- Earthworm
- Egg, larvae, pupa, adult
- Egg, nymph, adult
- Endoskeleton
- Esophagus
- Excretion
- Exoskeleton
- Foot
- Gastrula
- Gills
- Gills (it's here twice on purpose!)
- Gizzard
- Head
- Hermaphroditic
- Hirudin
- Hirudinea
- Incomplete metamorphosis
- Internal fertilization
- Intestines
- Leeches
- Malpighian tubules
- Mantle
- Molting
- Nephridia
- No parasitic species
- Oligochaeta
- Open circulatory system
- Parapodia
- Pentamerous radial symmetry
- Peritoneum
- Pit/projection
- Polychaeta
- Protostomes
- Radula
- Segmental ganglia
- Segmentation
- Septum
- Setae
- Shell
- Simple eyes
- Sinuses
- Snails & welks
- Spiracles
- Squids, octopods, nautilus
- Starfish, sea urchins, sand dollars
- Thorax
- Tracheal system
- Trochophore larva
- Tube feet
- Visceral mass
- Water vascular system

Figure 8. Student handout of terms for Invertebrates with Coeloms concept map.

In this list, the name of the kingdom and four phyla covered in the unit are listed at the top, and students are told that those are wise terms to start with when setting up the first few links from which the others will branch. After those first five terms, however, the others are listed

alphabetically and students must decide which are related to which and explain the relationships with the links they put on their maps.

### *Common Student Mistakes*

When working on their first few concept maps, most students needed coaching while they worked in order to help them refine their concept mapping techniques. In addition, while marking I noticed that many students shared the same problems with their maps. In order to address these common issues, for the second and third concept map assignments I started the class off with a tutorial on how to avoid the types of problems I had seen on the previous assignment. Students took to these sessions quite well, possibly because they saw value in finding out how to get a better grade for their efforts.

One of the most common mistakes by rookie concept mappers was misunderstanding the relative importance of quality versus quantity as far as links were concerned. I explained that it was far better to have a few informative, high quality links than many single-word, low information links.

Another common problem was in the format of the links themselves. Some students didn't realize in their early work that the links between terms on a concept map needed to read like phrases, and that proper grammar assisted in the reader's understanding the connection. Paramount to the formation of these phrases is the proper direction of the linking arrows. I was surprised by the number of students who had their arrows pointing in the opposite direction to how they intended the phrase to be read. Figures 9 and 10 show an example of an improperly formatted, non-descriptive link as compared to a properly formatted, descriptive link.

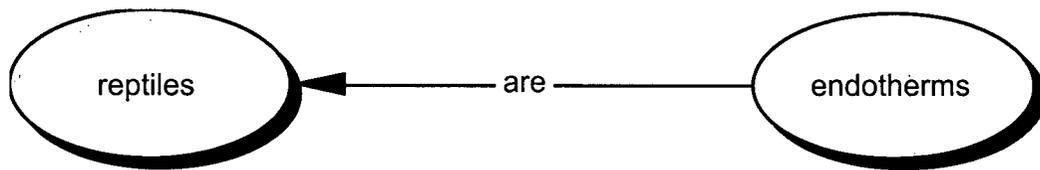


Figure 9. Improperly formatted link.

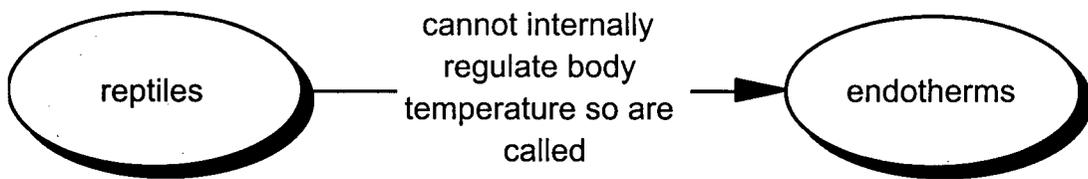


Figure 10. Properly formatted descriptive link.

In Figure 9, the student's map shows either carelessness on the part of the student, or a misunderstanding of what it means for an organism to be endothermic. In this particular case, the student claimed that he did understand the relationship, but simply made a mistake with the arrow direction. As far as the description was concerned, he claimed that he did understand the relationship in as much detail as is shown in Figure 10, but didn't realize that so much information was expected on the map.

### **The Concept Mapping Medium**

For their third concept mapping exercise, the students in the study were given a choice with respect to the medium through which they did their concept mapping. The first two maps were done with pencil or pen on paper by everyone so as not to further confuse an already complex learning activity that was new. By the third map, however, I wanted to give

interested students a chance to use computer software to create their maps. Instead of walking students through the first few links of the map on the whiteboard as had been done in the previous mapping session, I connected a laptop computer to a multimedia projector in my classroom and showed students not only how to organize the beginnings of the concept map, but also the basics of using the software<sup>2</sup>. Students were then given the choice to either continue mapping on paper, or make their concept map using the software in the computer lab.

While most students attempted at least one concept map on the computer, not all of them continued to do so. During the student interviews, it became clear that students who had tried both methods of mapping had a strong preference of one method over the other. Of the ten students interviewed, seven said they preferred mapping on the computer, while the other three preferred to map on paper. What follows are some of their reasons for preferring one method over the other.

There were two reasons given by the three students who preferred paper and pencil concept mapping to using software to accomplish the task. It should be noted that all three students did at some point attempt to complete a concept map on the computer, so their opinions are based on their actual experiences of both computer- and paper-based mapping.

Ethan's reason for preferring to map with a paper and pencil was that he felt it took too long to learn the computer software in the first place to make it practical.

Yeah, I tried it, and it... I think it took me like half an hour to get going when I could have done it on paper. I ended doing it on paper in half an hour when I didn't even get started on the computer in half an hour. I think the computer

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<sup>2</sup> Inspiration ® was generous enough to provide copies of its concept mapping software to the school for the purpose of this study. Information about the software can be found at [www.inspiration.com](http://www.inspiration.com).

would work, but you'd probably be investing more time in it. Because you'd have to learn how to use it, and then you'd have to get on the computer, boot it up, print it off, when on paper you can get down to it in 15 seconds. I think the computer is better, would be better, but paper is more efficient and convenient (interview June 28, 2000).

To further probe his thoughts on computer mapping, I asked him how he felt about making corrections or changes to his concept map on paper. While I expected that it might be difficult to justify using paper and pencil for that reason, he surprised me with his response. "No. I think on the computer it would be tough to do that. Like I remember I messed up once, on the last one I did, I totally messed up one section hugely, and so I basically went back and just re-did it... I don't think I could have done that on the computer. Or if I was going to do it on the computer it would be much longer. It would be... twice as long, I think" (interview June 28, 2000).

Beth and Chris expressed their preference for mapping on paper in terms of their feelings of comfort working with one medium over another. Beth simply preferred the feel of having a big piece of paper in front of her while she created her map. However, despite her overall preference for paper as a mapping medium, she did also express that computer generated maps had the advantage of built-in neatness. "I liked doing it on paper, because you could use up lots of space and just write information, but it was kind of messy, so the computer was much easier to organize" (interview June 27, 2000).

Chris described mapping on paper as

less complicated, and just it seemed that you were more in like... you had more control over what you were doing. It kind of seemed like... I don't like doing things like that on the computer, because you see it up there, but it's really not there. I don't know. I'd prefer to write it down myself, so I know what I'm doing, kind of more like that (interview June 28, 2000).

When asked about making mistakes, Chris admitted that mistakes would probably be easier to correct on the computer, but he thought an eraser worked just fine for him.

The students who preferred to map on the computer had four main reasons for their preference. The most popular reason was the ease of editing afforded by the computer interface. Jason described his preferred medium if given the choice. "I'd put it on the computer. Because it's easier because you can correct if you make mistakes... instead of having to, like, erase it and then you have to go over it in pen" (interview June 26, 2000).

The second most popular reason for using the computer software was that it allowed students to produce their maps in less time than with conventional methods. Stephanie said that she "definitely preferred the computer, because it was faster. And also because it would do the same job, like I would still understand the material as well" (interview June 26, 2000). When asked to back up her statement with actual times, she quickly produced numbers. "I'd say I'd probably spend somewhere from an hour to an hour and a half on the computer, whereas writing it all out took me closer to two hours" (interview June 26, 2000). Monique offered an explanation for why it took her less time to concept map on the computer. "When I did them on paper, I did a rough copy, and then a good copy, but on the computer I just went straight from my notes to the paper both times" (interview June 27, 2000). This sentiment was shared by several other students.

The third reason students reported that they preferred mapping on the computer was because of the built in neatness that comes from using an interface that avoids handwritten expression. Monique explained that if she made a mistake, "you didn't have to erase something, you could just move it with the arrow, and everything looked neater, and it was more organized" (interview June 27, 2000). Stephanie would have agreed with Monique

when she described her computer generated maps as being “all neat and tidy, and [they] would look more organized [than when done on paper]” (interview June 28, 2000).

The last, and perhaps most important reason, that students reported a preference for computer assisted concept mapping was very straight forward: put simply, it is more fun! Jessica sounded almost embarrassed when she described her experience in discovering you can use the software to create cartoon-like icons to represent nodes in the concept map. “I had a lot of fun switching all my words into animals... it was great <laughs>. I never handed it in like that, but...” (interview June 26, 2000). Ross also enjoyed the interface provided by the computer. He said that he enjoyed “just playing around, putting a monkey in there, behind there, just for fun before I’m done, and just playing with the clipart and stuff like that. It just made it more interesting” (interview June 26, 2000). Particularly with students such as Ross who have built-in negative associations with doing homework, it is refreshing to see them enjoying an assignment to the point where they will spend extra time *playing* with it just for fun. As teachers we know that providing students with activities they enjoy doing is one of the best ways to encourage meaningful learning. For this reason, it is important to consider how students feel about a learning strategy when investigating its value in the classroom.

### **Student Opinions of Concept Mapping**

When teachers plan meaningful learning activities for their students, they try to provide experiences that motivate students to interact with the course material in a way that improves their understanding. In order to facilitate this motivation, one of the most important factors to consider is student enjoyment of the activity. If they have fun doing the

assignment, it is reasonable to assume that they are more likely to complete it and put forth a solid effort. If not, students are less likely to put in the time and effort required to do a good job, and can even procrastinate the task to the point that it doesn't get done at all.

### *Positive Concept Mapping Experiences*

Students who had positive comments to make about concept mapping often said that they liked it because it was different, or more interesting, than other types of assignments they'd done. During Ethan's interview, he likened concept mapping to working on a puzzle. When I asked him if it was fun, he said, "I don't think it was fun, compared to, like, the fun things that I do, but it was easier, it was much more diverse than writing notes and reading" (interview June 28, 2000). Paige had other positive comments to make about the variety offered by concept mapping. "I thought it was ... really interesting to learn a new way of studying. All the other times before teachers just told us to write a new page out for notes, but concept mapping was really different and it was really neat after you learned how to do it. It made [studying] easier" (interview June 29, 2000).

Ross thought that concept mapping was more enjoyable than many of his other assignments in school, and he said this was one of the reasons he actually did them unlike much of the rest of his homework. "I liked this because it was different than just the usual, boring homework... the concept mapping part was kind of more of a challenge, it was more fun to do, and I liked matching words with other words" (interview June 26, 2000). His feelings are corroborated by his improved track record for completing concept mapping homework as compared to other assignments in the course.

Although Chris had positive things to say about concept mapping, he didn't like it strictly for reasons of personal enjoyment. Rather, his reasons were more strategic in nature, and this came through quite clearly in the descriptions of his studying. "Concept mapping definitely helped me with studying. It was a great studying tool" (interview June 28, 2000). He explained that he did find it quite difficult to do, but it was worth the reward. "It was hard, but in return it paid off on tests" (interview June 28, 2000). When asked how he knew, he said enthusiastically that doing it brought up his test averages to an extent that it became obvious to him that there had been a change. He had somewhat mixed feelings about the process, which became evident when he explained his actual feelings about doing it. "I didn't exactly *enjoy* it. It was a little frustrating to *do* it, and extremely time consuming but it paid off in the end, so... I can't say that I *liked* it, but it still paid off" (interview June 28, 2000). It is these frustrations and dislikes related to concept mapping that is the next topic to be examined.

### *Negative Concept Mapping Experiences*

We have already discussed the problems faced by students when first learning to concept map, and many of the frustrations caused by these problems. There were, however, students in the study who expressed dislikes of a different nature.

One of the more common comments was that concept mapping was a time consuming process. Monique described the time it took her to do her maps. "I didn't like how it took so much time... on the computer it took me... the first one took me an hour and a half because I did it with someone else, but the second one took me almost two hours, and... maybe because I was slow... it took quite a while (interview June 27, 2000).

Tracy didn't like concept mapping at all. She clearly described her feelings on the subject when she said,

I didn't like having to do it because I thought it was kind of a waste of time because it didn't really... like I don't know, it didn't really help me *do* anything. It didn't make me think of anything more than I already did. I thought there [were] better things I could have been doing, or ways to study that I could have been doing instead of that. For example... reading over my notes or something like that (interview June 26, 2000).

In her case, she seemed to dislike the learning style itself, particularly because of how much more time it took her than her traditional method of study. While most students who disliked mapping initially warmed up to it after they'd had some practice, Tracy disliked it from start to finish. Monique, on the other hand, had an amazing change in her feelings about concept mapping, and her story is particularly interesting.

When Monique first began to concept map, she felt such a strong dislike for it that as her teacher I would not have expected her to get over it. The emotion she expressed during the interview cannot be done justice by paraphrasing. In order for the flavour of the interview to come through in print, the teacher-student dialogue is being included here in its entirety:

**Hembling:** Okay. If you had a choice, would you start concept mapping earlier? We didn't do it until half-way through fourth term.

**Monique:** Yeah, I would have. I probably would have hated it at the beginning, just as much, but...

**Hembling:** Did you, did you hate it at the beginning?

**Monique:** Yeah, I did, I *hated* it.

**Hembling:** Really.

**Monique:** I did, I *HATED* it.

**Hembling:** *REALLY!*

**Monique:** Yeah.

**Hembling:** How come? Like, why?

**Monique:** Oh, it was just *so*... I thought, how the other class didn't have to do anything extra, and we did, I was so mad about that.

*[Here Monique is referring to the fact that the two control classes weren't doing concept mapping, but were doing other review activities, such as answering sets of*

*review questions from their textbook, putting together vocabulary lists with definitions, etc. that she was apparently unaware of.]*

**Hembling:** Were you really?

**Monique:** Yeah. It really frustrated me.

**Hembling:** How did you know that the other class wasn't doing them?

**Monique:** I just knew.

**Hembling:** Do you know people in the other class?

**Monique:** No, actually, I don't.

**Hembling:** You just assumed that they weren't.

**Monique:** Yeah.

**Hembling:** Did you know that they were doing other work that was different?

**Monique:** No! <Laughs>. But, but, umm, and just how it was so new to me, and I just, I didn't like how everything... it was too hard, and I just didn't like it, but after it got easier then I liked it more. But at first I hated it (interview June 27, 2000).

As can be seen from her comments, one of the greatest obstacles preventing Monique from enjoying concept mapping when she was first introduced to it was her feeling of being overwhelmed. This was actually a two-fold problem for her. At first she felt overwhelmed by the activity itself, a feeling that perhaps originated from the fact that she felt she didn't know how to do it properly. In addition to that, she felt that she was being treated unfairly because other Biology 11 students (in the control group class) *didn't* have to concept map as part of their assigned work.

Although Monique was unique in the degree of her dislike for concept mapping at the outset of the activity, she was not alone in her sense that she didn't know how to do it very well when she made her first attempt. What her story does demonstrate is the importance of introducing concept mapping to students in as non-threatening and easy to understand a way as possible. In addition, it is clear that at the outset of the study Monique neither shared her teacher's enthusiasm for concept mapping, nor understood why concept mapping was such a valuable learning tool. I now discuss with students why concept mapping is such an effective learning tool as part of the introductory class, and wonder if things would have been different for Monique if she had been introduced to concept mapping with the benefit of the

improvements that I've made since that first year. I suspect if she had, Monique wouldn't have experienced such frustration; I'm glad she did eventually get over it.

At this point it is clear that from the perspective of students, as well as from that of their teacher, that concept mapping is a useful tool for achieving meaningful student learning. In light of this, it will be interesting to examine statistically the effect that regular mapping has had on student achievement in the course. The next step is to determine if it can be reasonably concluded that student achievement can be improved in a statistically significant way by use of regular concept mapping in classrooms.

## Chapter 5 – Quantitative Analysis

The data for quantitative analysis has been gathered from individual student test results from each of the 13 unit tests written in Biology 11 from the beginning of the school year in September 1999 to the end of the school year in June 2000. Two of these tests (5 and 13, the mid-year and final exams, respectively) covered a large amount of material. The other 11 tests were given at the end of units throughout the year, and were composed of multiple choice, matching, diagram labelling, fill in the blanks, short answer and finally, long answer questions. The level of difficulty was designed to be identical between the four blocks of students for each unit test, although individual test questions did vary from class to class (the multiple choice sections of each test were identical). None of the test questions required students to produce a concept map, nor did they evaluate any knowledge that was specific to the concept mapping activity itself. The overall test length, number of questions and type of questions on each test were identical for all students. Examples of unit tests are included in Appendix A.

The quantitative analysis is based on a statistical comparison of the concept mapping group (CM) and the non-concept mapping group (NCM), to ascertain if there is a significant difference between the two groups. It should be noted that although statistical comparisons are being conducted on all 13 tests, concept mapping as a learning strategy was only undertaken with students starting with the 9<sup>th</sup> unit test (Plant Structure & Function). Prior to that point in the year (tests 1 through 8), neither the control group (NCM) nor the experimental group (CM) had been exposed to concept mapping in Biology 11. These data are being included for the purpose of determining if there was a significant difference

between the experimental and control groups prior to the start of concept mapping with the experimental group. Tests 9 through 12 represent units during which the experimental group students concept mapped as a review activity in preparation for writing their unit test, while the control group was continuing to review as they had done for previous units. Their review did not involve concept mapping. Test 13 was the students' final exam, which covered the material from the entire course. The final exam consisted primarily of multiple choice questions (70 percent of the test value) which were identical for all four blocks of students. The long answer section (30 percent of the test value) differed slightly between blocks, however the length and level of difficulty was designed to be the same across all blocks.

### Descriptive Statistics

The following is a summary of the test results for the two groups.

**Table 2.** Descriptive statistics comparing test results of concept mappers and non-concept mappers.

Test #	Test Name	Group	n	Mean (%)	Standard Deviation (%)
1	Biochemistry & Evolution	NCM	34	56.8735	17.1240
		CM	33	56.6303	16.4957
2	Taxonomy & 5 Kingdoms	NCM	34	68.7647	13.4473
		CM	33	70.0242	14.4696
3	Viruses & Immunity	NCM	34	72.9235	14.6782
		CM	33	66.9879	13.8490
4	Monerans	NCM	34	60.3265	20.7588
		CM	33	65.8364	16.1735
5	Mid-year Exam	NCM	34	63.1941	12.8677
		CM	33	63.6364	13.5139
6	Protists	NCM	34	58.8529	21.5385
		CM	33	71.3455	21.3659
7	Fungi & Aquatic Plants	NCM	34	60.9059	19.2574
		CM	33	66.3636	18.3641
8	Terrestrial Plants	NCM	34	61.9971	17.6097
		CM	33	69.4818	18.0311
9	Plant Structure & Function	NCM	34	54.6206	19.7084
		CM	33	58.2061	18.8836

Test #	Test Name	Group	n	Mean (%)	Standard Deviation (%)
10	Early Invertebrates	NCM	34	53.2353	20.2448
		CM	33	58.6848	21.1288
11	Invertebrates with Coeloms	NCM	34	61.3471	17.5093
		CM	33	63.0939	14.4244
12	Chordates	NCM	34	63.2676	20.6364
		CM	33	69.0394	18.9916
13	Final Exam	NCM	34	60.9059	13.3585
		CM	33	60.0758	15.9026

Before the data are examined using statistical tests, some interesting trends are apparent based solely on the average (mean) scores on each of the tests by the two groups of students.

Prior to the point in the year when one group started concept mapping while the other group did not (tests 1 through 8) there is no identifiable trend in the test averages between the two groups. On the first unit test, Biochemistry and Evolution, the two groups differed by only about 0.2%. On the next test, Taxonomy and the 5 Kingdoms of Life, the difference was only about 1.2%. On tests three and four, Viruses and Immunity and Kingdom Monera, first the non-concept mappers did better by about 6%, and then the concept mappers did better by about 5.5%. Based on these pre-concept mapping scores, the two groups of students appear to be evenly matched in terms of test achievement. It should be noted that although we are comparing the achievement of the two groups on a test by test basis, the students involved in the study were at no point provided with class versus class data. These comparisons have been made subsequent to student completion of the course

When the data are examined starting at the first test for which concept mapping was used by one of the groups, a different trend is evident. On every single test from the onset of concept mapping until the last unit test of the year (tests 9 through 12) the concept mapping group did better on average than the non-concept mapping group. In addition, it appears that

the margin by which the concept mappers out-performed the non-concept mappers generally increased with each test written. The respective differences between the groups starting with test 9 go as follows: 3.4%, 5.3%, 2.7%, and 5.8%. In only one instance (5.3% to 2.7%) did the difference decrease from one test to the next. In general, the descriptive statistics indicate that prior to concept mapping, the test achievements of the two groups are more similar than different, whereas after the concept mapping had been started with one group, the two groups are more different than similar.

Another interesting aspect of the descriptive statistics is that on the final exam, the non-concept mappers had a higher average than the concept mappers, despite the fact that on each of the previous 5 unit tests the concept mappers had outperformed them. This suggests that even though concept mapping appears to have helped the group using the strategy on their unit tests, for the final exam, a comprehensive test covering the entire year's course material, the non-concept mapping group still did better. Perhaps if concept mapping had been used for the entire year with the experimental group, the final exam results would indicate an overall higher level of understanding among students using the technique. This is supported by the data in that once we have a test that incorporates material for which there was no concept mapping, as evidenced by the final exam marks (most units in the course were done without concept mapping by any students), the concept mapping group loses their advantage.

Additional support for this possibility is evidenced by the tendency of students to have difficulty with the concept mapping activity while they are still learning how to do it. These early concept mapping sessions where the learning curve was steep, as described by students in their interviews, would have been less effective at facilitating meaningful learning

of the topics students were studying. If the students had started mapping at the beginning of the school year, however, they would have had more opportunities to apply concept maps to the curriculum and their final exam results would have been more likely to demonstrate this differential success over their non-concept mapping counterparts.

Now that the descriptive statistics have been examined and visible trends identified, it is time to conduct statistical tests on the data from the two groups to determine if the differences between them is statistically significant. *Statistical significance* is an assurance that the differences observed are highly unlikely to be the result of chance alone. In order to be considered statistically significant, there must be less than a 5% chance that the differences observed are due to chance, as indicated by the *p-values* of each test.

### Test Assumptions Required for Parametric Tests

Two assumptions must be examined to use parametric tests. Each sample must be normally distributed and the groups being compared must have roughly equal (i.e. homogeneous) variances. The validity of the tests depends on these assumptions being met.

First, the data were tested for normality. The results of the Shapiro-Wilk test are summarized in Table 3.

Table 3. Shapiro-Wilk test for normality.

Test #	Group	Test Statistic (W-value)	Significance (p-value)
1	NCM	.971	.556
	CM	.938	.080
2	NCM	.943	.105
	CM	.926	.040
3	NCM	.944	.114
	CM	.967	.484
4	NCM	.968	.489
	CM	.972	.594

Test #	Group	Test Statistic (W-value)	Significance (p-value)
5	NCM	.960	.356
	CM	.981	.857
6	NCM	.952	.246
	CM	.911	.014
7	NCM	.946	.149
	CM	.961	.399
8	NCM	.946	.150
	CM	.925	.038
9	NCM	.868	.010
	CM	.965	.452
10	NCM	.933	.051
	CM	.947	.173
11	NCM	.957	.318
	CM	.959	.369
12	NCM	.898	.045
	CM	.931	.010
13	NCM	.952	.246
	CM	.956	.315

Any sample which has a reported p-value of greater than 0.05 is considered to contain normal data. If the p-value is less than 0.05, the data is not normal. The results of this test show that the student scores for tests 1, 3, 4, 5, 7, 10, 11 and 13 are normally distributed, while those for tests 2, 6, 8, 9 and 12 are not.

The second test done was Levene's test for homogeneity of variance. This test was conducted only on the normally distributed data; the non-normally distributed data will later be run through tests that operate independent of either normality or variance. The results of this test are shown in Table 4.

Table 4. Results of Levene's test for homogeneity of variance.

Test #	Test Statistic (F-value)	Significance (p-value)
1	.000	.994
3	.006	.937
4	2.598	.112
5	.013	.911
7	.016	.900
10	.211	.648
11	2.066	.155
13	.367	.547

In this test, the assumption (null hypothesis) is that the samples have homogeneous variances. For each test, if the p-value for each test statistic is large (i.e. greater than .05 or even .10) then it is unlikely that the result has arisen by chance alone. This test shows that all 8 cases do in fact have homogeneous variances.

Now that these two assumptions have been tested, we can proceed to conduct the two-group comparison tests on each of the 13 data sets.

### **Two Group Comparison Tests**

In order to determine if there is a statistically significant difference between the unit test scores of the concept mapping versus non-concept mapping students, two group comparison tests must be performed. Because the data is divided into two different types, those with a normal data distribution and those without, different two group comparison tests were done on each type. The first is tailored for parametrically distributed (normal) data, and the other is for non-parametric (not normal) data. For a given test, if either of the samples being compared was not normally distributed, the non-parametric test was used.

### *Parametric Data – 2-Sample T-Test*

For the eight unit tests in which both groups have a normal distribution, a standard 2-Sample T-Test has been conducted to determine if there is a difference between the concept mapping and non-concept mapping groups. The results of this test are summarized in the Table 5.

Table 5. 2-Sample T-test for parametric data.

Test #	Test Statistic (t-value)	Significance (p-value)
1	.065	.949
3	1.725	.089
4	-1.306	.196
5	-.146	.884
7	-1.327	.189
10	-.694	.490
11	-.533	.596
13	-.221	.826

As can be seen by the p-values, none of these tests show a statistically significant ( $p < 0.05$ ) difference between the concept mapping and non-concept mapping groups.

### *Non-parametric Data – Mann-Whitney U-Test*

For the six tests in which one or both of the groups was not normally distributed, a Mann-Whitney U Test was performed to determine if a statistically significant difference exists between the two groups of students. Table 6 summarizes the results of this test.

Table 6. Mann-Whitney U-test for non-parametric data.

Test #	Test Statistic (U-value)	Significance (p-value)
2	557.500	.652
6	374.500	.013
8	440.500	.092
9	500.000	.339
12	511.000	.313

Again, the p-values indicate whether a statistically significant difference exists. In this case, only test 6 (the Protista unit test) indicates a statistically significant difference between the two groups of students. In this one case, the concept mapping students did significantly better than the non-concept mapping students. However, at this point in the research neither group had been exposed to concept mapping. Although we can assume that there must be a reason for the difference between the groups, as the test informs us that it is unlikely that it results from chance alone, we can say for certain that the difference cannot have anything to do with concept mapping. For the purposes of this study that one significant difference has little meaning, as spurious statistical significance occurs roughly 5% of the time as a function of probability.

### Statistical Test Implications

It is unfortunate that the student achievement trends visible in the data (see Table 2) are not supported by tests for statistical significance. However, this does not nullify their importance. Based on the trend in the differences between the concept mapping group and the non-concept mapping group upon commencement of concept mapping activities, and through to the end of the school year, I predict that the longer students are exposed to concept mapping and the more practice they get with it as a learning activity, the more effective it

will be at improving student achievement of learning outcomes. To test this prediction, a longer study would need to be carried out similar to this one, where students would be exposed to concept mapping from the beginning of the school year.

One statistical test option that was considered with the data in this study was a linear regression analysis of the concept mapping group's test scores. If the prediction is correct that concept mappers will improve their unit test scores with increased experience and expertise in concept mapping as a review activity, then the mean test scores should increase with time throughout the study. Unfortunately, in order for such a linear regression analysis to be valid, the level of difficulty on each unit test in the series would have to be equal. In this study, the tests written by each group of students were equal in difficulty for the same unit, but between units some tests were more difficult than others. Although this type of analysis would be very valuable in assessing the usefulness of concept mapping in the classroom, the difficulty associated with establishing a fixed difficulty level across a series of different unit tests is a daunting task for a classroom teacher.

## Chapter 6 – Conclusions

As modern science educators, our primary aim is for our teaching to facilitate meaningful learning in our students. While it is true that students can succeed to a limited extent on achievement tests using rote learning techniques alone, the long-term impact of such methods are insignificant when compared to what can be achieved using constructivist approaches such as concept mapping.

The new agenda in biological education is based on some 25 years of cognitive research showing, despite the best efforts of the most creative teachers and most thoughtful scholars and curriculum designers, that the majority of students leave secondary school with a distorted view of biological objects and events (Mintzes et al., 2001, p. 118).

We don't want our students to merely remember a list of biological facts about the amoeba, but rather to understand the functional relationships among the processes that allow it to live, and the importance of its role within its ecosystem and its many interrelated components.

Research has generally shown a positive correlation between the use of concept mapping and improved achievement of learning outcomes when compared to more traditional methods of instruction (Barenholz & Tamir, 1992; Okebukola, 1992; Ritchie & Volkl, 2000; Willerman & Harg, 1991). While the quantitative data in this study do not show a *statistically* significant correlation, there is an obvious trend that suggests that the concept mapping group made gains over the non-concept mappers. If students had concept mapped over a longer time frame, it is reasonable to predict that the differences between the experimental and control groups would have increased as concept mappers improved their proficiency with the learning strategy.

More important, the insights and opinions expressed by students in their interviews suggest strong support for concept mapping as a meaningful learning activity in the biology classroom. While students definitely did experience struggles and frustrations with their concept maps, particularly when they were new to the technique, most had more positive comments than negative to make about their experiences, and saw themselves using concept mapping in the future under their own initiative. In addition, their struggles with learning to concept map shed light on important aspects of how teachers should go about introducing concept mapping.

When teaching students to concept map for the first time at the inception of this study, my methods differed considerably from those I currently use. The changes I have made in the last year are the result of knowledge gained from several sources. These include student feedback, both in the classroom and as part of the interview process of this study, my own personal reflections on my teaching, and the wisdom that comes with teaching experience. This study has reaffirmed for me that when a teacher does something for the second and third time, the activity is much clearer for students as a result of the refinements that can be made through teacher reflection. There are several specific procedures that I have added to my concept mapping instructional methodology since the outset of this study.

First, I have changed the initial procedure for starting students off on their concept maps. Rather than have them make their first attempt in isolation, following a set of guidelines given as a handout, I now have students go through a process of *group mapping* with the entire class, teacher included. This procedure is followed for their first few concept mapping sessions, and serves to reduce stress levels in students. Additionally, it gives them

a live example of what a concept map looks like *in progress*, as well as the mental steps required in order to create it.

Second, I have adopted a system of moving the evaluation process of student concept maps through three phases, effectively *easing* students into an evaluation scheme that emphasizes the three most important areas for concept map evaluation. The first map is evaluated out of five marks, with the aim of producing a low-risk environment so students can try an activity that is new to them. This is followed by the second map which is evaluated out of 10 marks, an increase reflective of the increased expectations for students more familiar with the technique. The third map follows the standard marking scheme which is then used for all subsequent maps. It is scored out of 15 marks total, based on three five-mark categories: *quality of links*, *number of links*, and *effort*.

The third change to my teaching methods involves the way I provide the vocabulary words to be used in each student's concept map. Instead of giving them a list of terms and asking *them* to decide which ones to link first, for at least the first few maps I highlight for them the terms that should be used initially to organize the main structure of the map, until they've learned to do it for themselves. This way students get a good start to their map from the outset, regardless of how confident they feel about mapping, and their early successes translate into more enjoyable, and therefore more effective, learning experiences. Eventually with expert mappers there would be no need to do this, but with the students in this study it proved highly effective at motivating them to get started.

My concept mapping work with students has evolved a fourth component that involves the role that computers can play in the process. While not all students involved in the study saw value in it, more than half preferred computerized mapping to mapping on

paper. For these students the technology played an integral role in both their enjoyment of, and success with the activity, and for that reason I will continue to introduce students to this form of mapping. I'm sure that with further technological advances the computer medium will continue to improve. The next technological possibility I would like to explore with students is to have classes create collaborative concept maps using online software such as that offered free by the Institute for Human and Machine Cognition at the University of West Florida, as described by Novak (2001). This could be a means to raising group learning to an entirely new level.

I see the next step for concept mapping research as a study that is conducted over a full school year or longer with the same group of students. Such research is needed to verify my prediction that a longer exposure to concept mapping, resulting in increased student competence with the technique, *will* result in a statistically significant difference between experimental and control groups. My only reservation in conducting such a long term study is the requirement to deprive the control group students from using a learning strategy that holds such obvious potential benefits for the learner. The real question, which quickly becomes one of ethics, is whether a statistically significant research result is worth the sacrifice required by the students who by design cannot use the strategy. It is my belief that it is not.

Conducting research on concept mapping with my own students has been one of the most rewarding experiences of my teaching career. It has not only impressed upon me the incredible value of reflective practice, but also provided me with what I now consider to be one of the most valuable teaching implements in my educational tool chest. While I realize that my teaching practices with concept mapping will continue to evolve, I am certain that

the technique, in one form or another, will always be an integral component of my teaching practice.

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## Appendix A – Sample Unit Test

### Biology 11

Invertebrates with Coeloms Test

Maximum: 67

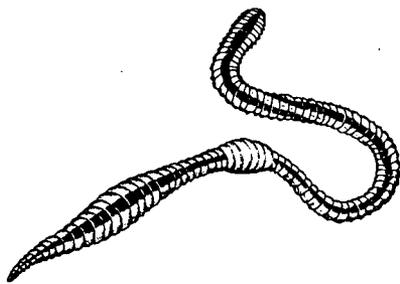
Name \_\_\_\_\_

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### Part A: Multiple Choice (32 marks)

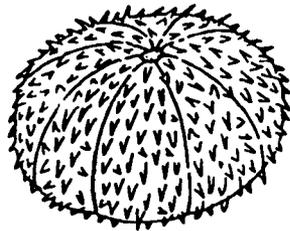
- An important behavioural difference between radially and bilaterally symmetrical animals is:  
A. motility  
B. reproduction  
C. cephalization  
D. how food is obtained
- Which of the following characteristics is not common to the annelids?  
A. a closed circulatory system carries oxygen and dissolves nutrients  
B. body segmentation allows for their characteristic movement  
C. they have a pseudocoelom and a digestive tract that is not surrounded with mesoderm  
D. they have excretory tubes in each segment and skin that serves as a respiratory organ
- Organisms which have a closed circulatory system, body segmentation, a two-opening, tube-type digestive tract, and are hermaphroditic would be  
A. planaria & tapeworms  
B. leeches & earthworms  
C. nematodes & earthworms  
D. tapeworms & roundworms
- The annelids are considered to be more advanced than the cnidarians because annelids have  
A. two main tissues and a flattened body plan  
B. three main tissue types enclosed in a shell  
C. a segmented body with a closed circulatory system  
D. bilateral symmetry and tentacles with stinging cells
- A mantle, and a visceral mass, attached to a muscular foot are characteristics common to the  
A. mollusks  
B. chordates  
C. arthropods  
D. echinoderms
- Arthropods have to molt because they have  
A. an exoskeleton  
B. an endoskeleton  
C. jointed appendages  
D. body segmentation

7. Insects far outnumber the crustaceans and have a greater diversity of species. This is probably because
- A. terrestrial environments are more varied than aquatic environments
  - B. the appendages are more varied than those of the crustaceans
  - C. most insects develop by complete metamorphosis, whereas crustaceans usually molt
  - D. insects have a clearly segmented body (head, thorax and abdomen) whereas some segments may be fused in the crustaceans
8. Two characteristics found **only** in the echinoderms are
- A. an exoskeleton and a capacity for regeneration
  - B. radial symmetry and one opening digestive tube
  - C. bilaterally symmetrical larvae and separate sexes in the adults
  - D. an endoskeleton of calcareous plates, & a spiny skinned body covering
9. The water vascular system of the echinoderms serve all of the following functions except
- A. feeding
  - B. locomotion
  - C. reproduction
  - D. gas exchange
10. Due to similarities in their embryonic development, the echinoderms are thought to be closely related to
- A. mollusks
  - B. chordates
  - C. arthropods
  - D. cnidarians
11. Segmented worms differ from round and flatworms in that they have a(n)
- A. anus
  - B. scolex
  - C. coelom
  - D. endoderm
12. The earthworm has \_\_\_\_\_ pair(s) of aortic arches in its circulatory system.
- A. 1
  - B. 5
  - C. 3
  - D. 7



13. Considering the digestive system of the above organism, we might say that it
- A. has specialized parts
  - B. is simpler than tapeworms
  - C. causes the worm to be inferior to other organisms
  - D. is unsuitable to the worm's feeding & living conditions

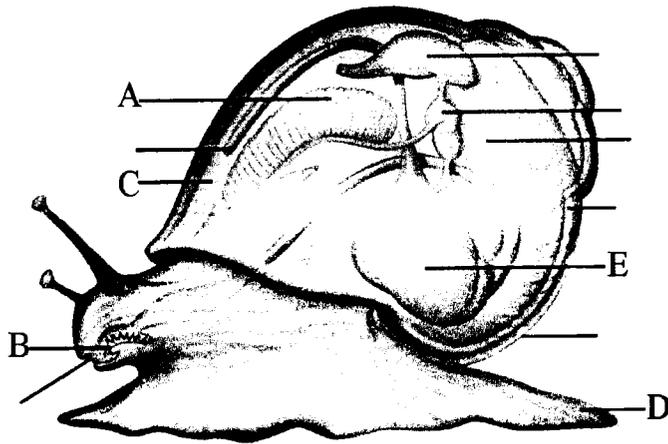
14. Sand dollars, sea stars & sea urchins belong to the phylum  
 A. annelida C. arthropoda  
 B. molluska D. echinodermata
15. The presence of a muscular \_\_\_\_\_ is a unique characteristic of the mollusks.  
 A. arm C. heart  
 B. foot D. mantle
16. From each of the following groups of animals, select the one animal that is least like the other three. Base your selection on the present classification system.  
 A. spider C. crayfish  
 B. octopus D. centipede
17. Which of the following is a "head-footed" mollusk?  
 A. oyster C. land snail  
 B. octopus D. brittle star
18. Earthworms have longitudinal muscles that function to  
 A. anchor the earthworm to its setae  
 B. move the earthworm's skeleton forward  
 C. contract and cause the earthworm's body to shorten  
 D. contract and cause the earthworm's body to push forward
19. The nervous system of an earthworm **cannot** detect  
 A. touch C. chemicals  
 B. colour D. temperature
20. The respiratory system of the earthworm can be described as  
 A. the most efficient of all vertebrates  
 B. extensive, filling most of the coelom  
 C. non-existent, the gas exchange taking place across the cuticle  
 D. unnecessary, since this simple animal does not need to respire



21. The organism above shares the same symmetry as a(n)  
 A. snail C. sea star  
 B. oyster D. octopus
22. Bivalves are  
 A. conical C. radially symmetrical  
 B. spherical D. bilaterally symmetrical

23. Which organism uses an inky screen for defence?  
 A. slug  
 B. snail  
 C. mussel  
 D. octopus
24. Annelids are considered to be more complex than cnidarians. This is because they have  
 A. radial symmetry and stinging cells  
 B. flat bodies and two main layers of cells  
 C. segmented bodies with a circulatory system  
 D. two main layers of cells and their bodies are covered by a shell
25. Adult echinoderms display \_\_\_\_\_ symmetry.  
 A. radial  
 B. spiny  
 C. lateral  
 D. bilateral
26. The clitellum & prostomium are located near the earthworm's  
 A. cuticle  
 B. esophagus  
 C. anterior end  
 D. posterior end
27. The water vascular system is used primarily for  
 A. digestion  
 B. circulation  
 C. communication  
 D. locomotion
28. Aquatic mollusks use \_\_\_\_\_ as their organs of respiration.  
 A. fins  
 B. gills  
 C. lungs  
 D. radulae
29. Fine, tube-like structures that distribute air throughout an insect's body are called  
 A. spiracles  
 B. lungs  
 C. trachea  
 D. air sacs
30. The class of arthropods with the greatest number of species is  
 A. diplopoda  
 B. arachnida  
 C. crustacea  
 D. insecta  
 E. chilopoda
31. Spiders may be distinguished from insects because they have  
 A. two antennae  
 B. jointed legs  
 C. two distinct body regions  
 D. biting mouth parts
32. Which one of the following organisms is least related to the others?  
 A. tick  
 B. tarantula  
 C. mosquito  
 D. black widow spider

**Part B: Diagram (6 marks)**



Name the labelled parts of the diagram:

A. \_\_\_\_\_

B. \_\_\_\_\_

C. \_\_\_\_\_

D. \_\_\_\_\_

E. \_\_\_\_\_

Function of A:

\_\_\_\_\_

**Part C: Short Answer (18 marks)**

1. Give the names and defining embryological characteristics of the two main groups in Kingdom Animalia (there are ONLY two possibilities): **(4 marks)**

i) \_\_\_\_\_ : \_\_\_\_\_

\_\_\_\_\_

ii) \_\_\_\_\_ : \_\_\_\_\_

\_\_\_\_\_

2. Name the two main types of symmetry found in animals. For each, give a definition (what that kind of symmetry looks like) an example organism *from this unit* that displays it (*class* or more specific here), and the advantage that it has for that particular animal in its habitat. **(8 marks)**

Name of Symmetry	Definition of Symmetry	Example Organism	Advantage for Organism

3. Explain the difference between the terms *hermaphroditic* and *dioecious*. (2 marks)

4. List 3 defining characteristics of Arthropods. Remember in this case that a *defining characteristic* is something that arthropods, and **only** arthropods, have. Then, list **one** characteristic of arthropods that shows a *specific* evolutionary link to another phylum in this unit. Be sure to name the phylum in your answer. (4 marks)

i)

---

ii)

---

iii)

---

Characteristic: \_\_\_\_\_ Phylum: \_\_\_\_\_

**Part D: Long Answer (11 Marks)**

1. Describe two evolutionary advances that organisms in this unit (i.e. annelids, mollusks, arthropods, & echinoderms) have made over their less-evolved animal ancestors. For each, describe the adaptation, the group which possesses it, and the advantage offered. (3 marks each, 6 marks)

2. Although humans and insects represent the dominant animals on earth, there is only one species of humans but over 700,000 species of insects. Use the principles you have learned in this unit to explain this phenomenon.  
**(1 mark per relevant point; 5 marks)**