Abstract

Promoting successful learning is key in developing students from novice to professionals in their respective fields of study. In the field of science, students have long practiced the art of memorization without complete understanding. To combat this common problem, Joseph Novak and D. Bob Gowin, constructed two metacognitive tools. These metacognitive tools, concept mapping and Vee heuristic, were developed with the hopes of providing students with a way to connect concepts, principles, and theories similar to their professors.

The purpose of this study was to use these two tools as a way to promote successful learning among college-level science students. Both of these metacognitive tools were given to students enrolled in a microbiology lecture-laboratory course (BIOL 2110/2111 and BIOL 3220/3221). Concept mapping and the Vee heuristic were given to students in the guise of a study guide, in hopes to promote constant use and easy access. As a way to measure students' improvement in learning, two assessments general knowledge of microbiology (GKM) and public knowledge of microbiology (PKM) were constructed and given to students periodically throughout the course of the study.

After the study's completion it was found that those students using the study guide regularly appeared to have a better understanding of the basic concepts required to successfully learn microbiology. Additionally students enrolled in BIOL 3220/3221 who used the study guide with help from a knowledgeable instructor significantly scored higher on the GKM assessment than the control group of students. Also discovered during the course of this study was nursing students attitudes towards scientific concepts. This particular find has important implications regarding the outcomes of this study.

Use of Conceptual and Procedural Knowledge Mapping to Improve Learning in a Lecture-Laboratory Microbiology Course

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the situation. I can say that working with students that knowledge became a valuable source.

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Chapter 1
Introduction

Background

Nursing is a profession in which knowledge is key to patients' well being. Foundational knowledge for nursing is built long before a nurse enters the hospitals and can last into retirement. Contributing to the bedrock of becoming a successful nurse is the study of microbiology. It is a key course and offers pre-nursing students the necessary exposure to important concepts and procedures that they will need to know on the path to their career goals. In a review of the importance of microbiology in nursing education programs, Reynolds (2006) sought to find the concepts that nursing students needed to understand in order to successfully receive licensure. The study found that in order for students to pass the licensure exam, NCLEX-RN, a basic understanding of microbiology must be present. This foundational knowledge includes, but is not limited to bacterial structure and function and the interpretation and understanding of laboratory procedures and values. Completion of BIOL 2111, Fundamentals of Microbiology, should provide students with a fundamental understanding of microbiology. Contrary to the findings of that study, the results of a survey, entitled Public Knowledge of Microbiology (PKM) (Appendix A), given to a BIOL 2111 class at East Carolina University in the Spring of 2011, showed a lack of understanding of the most basic microbiology.

The PKM survey was also administered to students enrolled in BIOL 3220, which is the microbiology course commonly taken by biology majors. The PKM asked a series of five basic microbiology questions:

1. What is a virus?
2. Why is the overuse of antibiotics bad?
3. What are bacteria?
4. Would you take antibiotics for a cold?
5. What do you think of when you hear *E.coli*?

A majority of the students in the microbiology course could not properly characterize a virus, nor did they understand why the overuse of antibiotics could be damaging to the human health and the practice of medicine. This assessment was given to students during the middle of the spring semester. When were asked where they learned this information, they responded "in BIOL 1100/1200" which is a prerequisite class students take before enrolling in BIOL 3220. These responses provided justification for a change from traditional to an alternative format to promote successful learning.

In the 1970's Joseph Novak and Bob Gowin introduced strategies in science classrooms to facilitate the development of meaningful learning experiences with students. These strategies, both concept mapping and Vee heuristic diagramming, were developed to aid students' understanding of observations made during lecture and laboratory sessions. Moreover, Novak and Gowin (1984) found that implementing these strategies could lead to students creating and connecting new and valid concepts in ways normally understood by subject-matter experts. Concept mapping and the Vee heuristic are considered meta-cognitive strategies that represent a significant change from traditional methods of instruction and have been found to improve overall student understanding of science concepts (Hewson & Hewson, 1981; Bratthen & Hewson, 1988; Uzuntiryaki & Geban, 2005; Hewson & Beeth, 1993).

Problems arise when students continue to pass classes without acquiring a sound understanding of key microbiological concepts. Studies have shown that despite performing well in a given science class, students will often retain previously acquired, incorrect notions about basic course concepts following instruction (Lightman, & Sadler, 1993; Gonzalez 1997). Further research has shown that students who are continually taught using traditional instruction will integrate new knowledge with existing understanding rather than refine their faulty understanding, which presents serious problems for students who depended upon sound fundamental understanding later in their professions. Failure to alter faulty understanding needs a well-tested method to address the problem. Applying a well-tested instrument to assess students' faulty understanding of these basic concepts will help to address the problem and offer potential solutions.

This study's intent is to aid in developing student understanding of basic microbiological concepts through methods long used in non-traditional educational settings. Research has shown that in order for meaningful learning to begin, students must become dissatisfied with their current non-scientific thinking and accept a more scientific explanation, a process that can be labeled as conceptual change. Additionally, current research models suggest that in order for successful conceptual change to occur, students must have first-hand experience with an instructional anomaly that challenges their current understanding (Hewson & Hewson, 1981; Bratthen & Hewson, 1988; Uzuntiryaki & Geban, 2005; Hewson & Beeth; Ponser, Strike, Hewson & Gertzog, 1982). For the purpose of this study, the BIOL 2111/3221 laboratories served as the environment in which students can experience such an anomaly.

Ensuring that students' understand the instructional anomaly that they experience is important. Therefore it is imperative that they have the correct tools at their disposal to recognize and adapt the changes that are occurring in their learning (Ponser, Strike, Hewson & Gertzog, 1982). In an educational setting such as that found in science laboratories, students are often unsure of the purpose, theories, and concepts that are being identified during each investigation (Gowin & Novak, 1984). As a way to guide students to actively and successfully observe the concept-changing anomaly, Novak and Gowin (1984) developed the Vee heuristic. Use of the Vee heuristic improves awareness among learners of the events taking place during an investigation.

In addition to instructional anomalies, students also need the proper tools to help them connect the main concepts associated with the scientific events they experience in class. Consequently, Novak and Gowin (1984) devised a metacognitive tool that would externalize and connect the many concepts students are expected to learn. Concept mapping provides a way for learners to construct and reconstruct the interconnection between and among a group of related concepts through the use of linking propositions.

Assessing whether meaningful learning has occurred was key to this study. In the past, educators measured learner's understanding of recently taught, isolated scientific concepts using an "achievement tests" (Halloun & Hestenes, 1985). Beginning in the 1980's, many researchers used a method of testing that intentionally exposed students to a series of attractive answer choices that reflected "students own thinking" (Sadler, Coyle, Miller, Nancy, Dussault, & Gould, 2010). This type of test was meant to distract students by incorporating misconceptions into answer choices that students were more comfortable choosing. Assessments with distracters in the answers are called Distracter Driven Multiple Choice (DDMC) tests. In addition to providing educators with an indication of the knowledge base of students, DDMC assessments also provided teachers with the ability to measure the prevalence of specific misconceptions held by students in their classes (Sadler, Coyle, Miller, Nancy, Dussault, & Gould, 2010).

This study accounted for and compared multiple factors that might affect the study by using a multi-factorial design. This type of design affords researchers the opportunity to "assess the relative importance of multiple factors" affecting the data; it also grants researchers a chance to analyze "the interactions occurring between different factors" (Barbeau, Durelle, & Aiken, 2004; Creswell, 2002; Marcobal, Martin-Alvarez, Moreno-Arribas, & Munoz, 2006; Mertens, 2005; Ray, Patel, Shih, Macaraeg, & Wu, 2009). For this study, the factors that might affect the use of concept mapping and Vee heuristic for learners included their use in the presence or absence of a knowledgeable instructor. Additionally, a consideration for the course of study individual students are pursing (i.e. nursing or scientist) altered their willingness to learn scientific concepts. This study used metacognitive tools and assessments to meet the demands of implementing and measuring meaningful learning in science classrooms.

To promote successful learning, this project organized concept mapping and Vee heuristic strategies, placed in a study guide that was provided to students in BIOL 2111/3221. These educational tools were developed, printed, and bound together into a study guide, as a way to allow for easy access for students. The goal of the study guide was to promote the understanding of lecture-based concepts and laboratory-based concepts and procedures. The lecture-based concepts were assessed using in-class, mid-term, and final examinations. To measure laboratory-based concepts, the study used instructor-created exams, scores on concept maps, and answers to Vee heuristic questions. As a way to measure laboratory related concept, the researcher constructed an assessment entitled Public Knowledge about Microbiology (PKM) Survey. The PKM survey used the DDMC method to identify the misconceptions present in each of the study's participants. The second assessment, titled Microbe Study Survey (GKM), measured students' general knowledge of microbiology.

The overall study design was a quasi-experimental, with multi-factorial, non-equivalent control groups. Students were not randomly selected. The study participants consisted of 48 students selected from BIOL 2110/11 and 48 students selected from BIOL 3220/21. All courses were taught in the fall semester of 2011.

Problem Statement

This research endavor set out to investigate the lack of understanding of microbiological content and procedures existing among pre-nursing college students. This project hypothesized that by implementing a study guide focusing on concept mapping and the Vee heuristic students would achieve more meaningful learning by developing a more sophisticated awareness of concepts, theories, and principles used during laboratory investigations. Furthermore, this project attempted to determine the effect of using concept maps and Vee heuristic questions as pre-lab and post-lab assignments on students' laboratory performance and understanding. This study measured student's changed on research-developed assessments and on lecture and laboratory course grades as a result of the experimental treatment.

Purpose Statement

The study's purpose was to assist students in learning and understanding of general and applied scientific concepts and procedures of microbiology. The study had students practice and use concept mapping and the Vee heuristic as study tools to improve their learning of microbiological principles and practices. The investigation was conducted using a multi-factorial, non-equivalent control group design.

Research Questions

1. Will use of conceptual knowledge mapping promote successful understanding of lecture-based concepts?
2. Will use of the Vee heuristic promote successful understanding of laboratory-based concepts and procedures?
3. Will use of conceptual and procedural knowledge mapping promote understanding of laboratory related concepts?

Sub-set question 1. Does using concept mapping and Vee heuristic in a laboratory class improve students' public knowledge about microbiology?

Sub-set question 2. Does using concept mapping and answering Vee heuristic questions in a laboratory class improve students' overall knowledge of microbiology?

Limitations

The scope of this study was limited to students enrolled BIOL 2110/2111 and BIOL 3220/3221 in the fall semester, 2011. Additionally, students who signed consent forms and agreed to participate in the study were not penalized for withdrawing from the study at any time throughout the semester.

Summary

Chapter 1 introduces the importance of learning fundamental scientific concepts, specifically in the field of microbiology. Moreover, the first chapter discusses the importance of microbiology and its laboratory practices for those students who are pursuing a career in a health-related field (i.e. nursing) or into the field of biological sciences. Studies have shown that students often retain rather than abandon scientifically faulty information and disregard valid scientific concepts they fail to understand. The first chapter introduces the use of concept mapping and the Vee heuristic as a way to resolve that problem.

Chapter 2 provides a review and discussion of the literature, including students' acceptance of invalid scientific concepts through maintaining prior misconceptions, and the effect this phenomenon has on students' ability to integrate reasonable scientific concepts. To identify and address misleading understandings of scientific concepts, Hewson & Hewson, (1981), developed specific methods to teach for conceptual change. Teaching for conceptual change provides an opening for using new and well-documented instructional methods like concept mapping and the Vee heuristic. In addition, Chapter 2 reports on the successful use of concept mapping and the Vee heuristic in science classrooms, to promote teaching for conceptual change. Both concept mapping and the Vee heuristic will be explained in detail concerning their individual strengths and their success when used as a cohesive unit.

Chapter 3 focuses on methodology and provides an explanation of the study's design, a quasi-experimental multi-factorial, non-equivalent control group design. Also included is a description of student participants, location of the study, and procedures for collection of data from the student. Chapter 3 also presents a discussion of the grading system used to score the study guide and the surveys.

Results of the study are reviewed in Chapter 4 including comparison of grades for students who used the study guides versus those who did not. Descriptive data are summarized in Chapter 4, revealing average scores given to students for their concept maps as well as their Vee heuristic answers. Additional descriptive data are presented for students' average scores for the surveys, average lab-based mid-term and final scores, and lecture-based, mid-term, and final examination scores. The chapter is organized beginning with concept map scores followed by Vee heuristic question scores, and then scores to all assessments.

Chapter 5 contains a detailed discussion of the study guides' effect, primarily the extent to which students were capable of properly connecting scientific concepts and answering basic questions related to the material they studied in the microbiology course. Secondly, Chapter 5 provides an examination of the success of the study guide in promoting successful learning of basic microbiological concepts. Lastly, Chapter 5 will bring to light a phenomenon that may occur among students lacking interest in the pursuit of science as a career goal.

Chapter 2
Literature Review

Introduction

One of the major hindrances to students acquiring a sound understanding of science is thought to come from the misconceptions they hold. These faulty understandings may negatively impact students' ability to accept conflicting valid scientific concepts (Hewson & Hewson, 1981; Bratthen & Hewson, 1988). If prior misconceptions are woven into the knowledge structure of students, it is a challenging task to learn and understand basic concepts and procedures in any field, especially microbiology. In order for students to relinquish their faulty prior knowledge, they must have an experience that causes them a sense of displeasure about their misconception and more open to accepting a knowledgeable fact. Hewson (1981) described this phenomenon as conceptual change. Conceptual change is something that is capable of occurring in a laboratory setting. Laboratory investigations require students to personally address their faulty prior knowledge while physically seeing a knowledgeable fact occur in their presence. To help students understand the scientific concepts and procedures they are expected to learn, this study introduced concept mapping and the Vee heuristic as a tool for helping students overcome their prior misconceptions (Hewson & Hewson, 1981; Bratthen & Hewson, 1988; Uzuntiryaki & Geban, 2005; Hewson & Beeth, 1993). The review of literature provides a series of studies that offer justification for using both concept mapping and the Vee heuristic in a lecture-laboratory setting. Furthermore these past studies also give insight into answering the following research questions:

1. *Will use of conceptual knowledge mapping promote successful understanding of lecture-based concepts?*

2. *Will use of the Vee heuristic promote successful understanding of laboratory-based concepts and procedures?*
3. *Will use of conceptual and procedural knowledge mapping promote understanding of laboratory related concepts?*

Sub-set question 1. Does using concept mapping and Vee heuristic in a laboratory class improve students' overall public knowledge about microbiology?

Sub-set question 2. *Does using concept mapping and answering Vee heuristic questions in a laboratory class improve students' overall knowledge of microbiology?*

Conceptual Change

Current research documents the negative effects of prior knowledge on student understanding of basic science concepts and the benefits of teaching for conceptual change. As researchers began examining the difficulty that students were having accepting new conceptual knowledge Driver (1989) discussed that providing students with conceptual change materials could help alleviate the problem. In a study conducted by Hewson and Hewson (1981), it was shown that students with faulty prior knowledge had a difficult time integrating new scientific concepts into their existing knowledge structure. These researchers also claimed that students who received instructional material via conceptual change methodology would show a progressive improvement in understanding and acceptance of valid scientific concepts.

To apply a conceptual change methodology in a science classroom, Hewson and Thorley (1989) proposed four conditions that must be "implicitly or explicitly" decided upon and applied by students. The first condition that must be decided by students is whether the conception is intelligible to them. The second and third conditions have students deciding if the scientific conception is plausible and fruitful, respectively. The fourth condition needed to promote meaningful learning via conceptual change if the conception is dissatisfying to students. The goal of these conditions is to assist in facilitating an overall dissatisfaction with a concept that was once thought to be held to a higher degree of comprehension, but due to the loss of plausibility and fruitfulness is soon dropped in rank, making a new intelligible concept readily accepted (Hewson and Thorley, 1989).

To test and extend the results discussed by Hewson and Hewson (1981), further studies were conducted to measure the effectiveness of teaching for conceptual change versus traditional instruction. Both Hewson and Hewson (1983) and Hewson and Braathen (1988) administered pre- and post tests to science students who were either taught with traditional instruction or taught for conceptual change. Each of the studies reported the same findings: Students taught for conceptual change showed significant increases in test scores in comparison to their traditional instruction counterparts. Despite teaching for conceptual change, Hewson and Hewson (1983) acknowledged that some misconceptions remain difficult to alter. The researchers concluded:

> "Individuals possessing alternative conceptions find them useful (intelligible, plausible, and even fruitful) to some extent. The more established alternative conceptions are likely to be more useful to the individual and therefore more difficult to eliminate...the instructional strategy has to be designed in such a way that the individual is convinced that the scientific conception is more useful than the existing alternative conception."

How does one design a strategy that convinces an individual that the valid scientific concepts are more useful than their alternative conceptions? Research has shown that creating a state of disequilibrium within students, a series of events that yield unexpected results, should cause students to question, even reject their prior misconceptions (Uzuntiryaki & Geban, 2005). To test this hypothesis, researchers introduced a specific form of conceptual change instruction meant to cause disequilibrium among students in a pre-college science classroom. This form of conceptual change instruction utilized concept mapping and was hypothesized to directly address students' misconceptions, while providing opportunities to create more valid understandings of scientific conceptual knowledge (Uzuntiryaki & Geban, 2005). Using concept mapping to instruct for conceptual change led to improved student understanding of science concepts. Concept mapping was used also in undergraduate biology courses and yielded the same desirable learning results (Sungur, Tekkaya, & Geban, 2001).

Concept Mapping

Throughout the 1970's and entering into the early 2000's, there has been a struggle to prescribe a definitive meaning to successful learning. Kolb and Fry (1975) described learning as a cycle that students must fully experience in order to gain meaningful understandings. This cycle, described by Kolb and Fry requires that learners "experience, reflect, theorize, and test new knowledge" (Hay, Kinchin & Lygo-Baker, 2008). More than twenty years later, Joseph Novak (1998) expanded upon Kolb and Fry's theory by declaring that learning could be separated into two categories, meaningful learning and rote learning. Novak explained that meaningful learning occurs when three important factors are in place, the first being relevant prior knowledge.

Availability of prior information about a subject is a prime factor for students to learn new information without it becoming insignificant (Hay, Kinchin & Lygo-Baker, 2008; Novak, 1998). Secondly, in order for meaningful learning to occur, meaningful material must be present. Meaningful material described, as "the knowledge that is being learned must be relevant to other knowledge and must contain significant concepts and propositions" (Hay, Kinchin & Lygo-Baker, 2008; Novak, 1998). Finally, Novak places the responsibility for meaningful learning in the hands of students. Novak (1998) declares that in order for meaningful learning to occur learners must choose to learn and relate new knowledge to prior knowledge in a "nontrivial way" (Hay, Kinchin & Lygo-Baker, 2008; Novak, 1998).

The literature provides clarification about the ways concept mapping promotes learning for conceptual change. Concept maps serve as a metacognitive tool for students to both promote and assess their conceptual knowledge and understanding. Use of concept mapping enables students to "visualize" their thinking in order to pinpoint faulty understanding (Gowin & Novak, 1984). The recognition of faulty conceptions when compared to scientific conceptions should provide the unexpected results needed to create disequilibrium, as discussed by Uzuntiryaki and Geban (2005). Educators have willingly employed concept maps in college science classrooms for some time, and have used them to monitor and address students' misconceptions, thus providing an environment ripe for conceptual change instruction.

Inclusion of prior knowledge in meaningful learning is extremely important, as it is mentioned at least twice in the definition. Researchers have suggested that large classes, especially those found in universities, are often venues where students' prior knowledge is unattended (Hay, Kinchin & Lygo-Baker, 2008). Though this is not purposeful, failure to recognize and address students' prior knowledge can hinder meaningful learning, as experts will construct lessons that are inaccessible to students but are considered excellent by other experts (Hay, Kinchin & Lygo-Baker, 2008). Instructors and students need a well-validated form to discern and document prior knowledge. Moreover, there was researcher identified a need to measure levels of understanding indicated by prior knowledge and changes that occurred in conceptual comprehension throughout a lesson (Hay, Kinchin & Lygo-Baker, 2008). Numerous studies of concept mapping have documented the tool's effectiveness in promoting meaningful learning (Roth & Roychoudhury, 1993; Heinze-Fry & Novak, 1990; Buntting, Coll & Campbell, 2006; Chiou, 2008).

Researchers have taken an active role in promoting student learning by attempting to assess whether meaningful learning has occurred during conceptual change lessons. Novak and Musonda (1991) began a twelve-year expedition of altering the current paradigm that elementary school students' could not understand abstract scientific concepts. Using a well-tested set of conceptual change materials termed "audio-tutorial lessons (A-T)," Novak and Musonda (1991) experimented with first and second grade students. As part of the study, concept maps were constructed and scored after the lessons based on interviews with students who were members of experimental and control groups. Concept maps were used to determine the frequency at which students were able to make valid and invalid conceptual connections with course content. Students in the first and second grade who used using conceptual change materials were found to have fewer misconceptions than first, second, seventh, tenth, and twelfth grade students who did not use conceptual change materials. Concept mapping was shown to provide accurate portrayals of students' knowledge, while additionally providing instructors with much needed insight into the knowledge structure of their students.

Researchers began to explore the effects of using concept mapping with older students, particularly in intermediate schools. Concept maps maintained their identity as effective metacognitive tools used to provide a visual image of structural knowledge that instructors could use to assess students' understanding (Johnson & Thomas, 1992; Novak, 1985; Wandersee, 1990; West, Farmer, & Wolf, 199; Rye & Rubba, 1998). As a way to validate claims of meaningful learning made by earlier researchers, conceptual map scores began being compared to student scores on various traditional types of assessments. During the late 1990's, Rice, Ryan, and Samson (1998) introduced concept mapping to a seventh-grade science class in an attempt to gauge achievement of instructional knowledge through scoring proper propositional linking phrases between concepts, and grades received on multiple-choice tests. The study revealed two important factors regarding concept mapping. First, high concept mapping scores directly correlated to high scores on multiple-choice testing. Second, concept mapping successfully provided researchers and teachers with a quantitative measurement of scientific achievement in the classroom (Rice, Ryan & Samson, 1998).

Studies further tested the capabilities of concept mapping with students who generally performed below average in basic science classrooms. In these low-achieving classrooms, concept mapping helped to improve students' comprehension of science related text, thus cultivating an environment in which successful learning could be advanced. Furthermore, the integration of new material into students' knowledge structure without access to prior knowledge was less complicated when using the visual guide provided by concept mapping (Guastello, Beasley & Sinatra, 2000). Use of concept mapping continued to produce similar outcomes on varying grade levels, including students in fifth and eighth grades. Both Asan (2007) and Uzuntiryaki and Geban (2005) introduced concept mapping into science classrooms, and measured students' knowledge structure by using conceptual-based tests. Researchers reported that high scores on concept maps correlated with high scores on conceptual assessments. Students' scores on both concept mapping and conceptual knowledge assessments provided further evidence that concept mapping is a reliable indicator of student knowledge (Uzuntiryaki & Geban, 2005; Asan, 2007).

As students continue move forward on their academic journey, the subjects they begin to study become increasingly abstract. Theories and ideas become a series of tangled webs weaved of complex concepts, however at the core of any subject the fundamental concepts remain the same (Novak & Gowin, 1985). It is through the mapping of basic concepts that students are able to successfully integrate and properly tie together newly introduced, progressively more complex ideas into their knowledge structure. Similar to practices conducted in middle school, researchers began as early as 1985 measuring student achievement in high school classes through the introduction of concept mapping. Fraser and Edwards (1985) investigated the effects concept mapping had on student achievement in high school classrooms. Students' achievement in the classroom was measured by their success on end-of-unit tests. During a four-week period, students were taught about and expected to construct concept maps. Throughout the course of the study, students received remediation on concept mapping techniques, correction of errors, and integration of new knowledge into their concept maps. Students who showed mastery on concept mapping scored significantly higher on end-of-unit tests than did other students who had not gained the same level of mapping proficiency (Fraser & Edwards, 1985). Though results from the study yielded positive results for concept mapping in high schools, the sample size of those that mastered the technique of using concept maps was not great enough to confidently report causality (Fraser & Edwards, 1985).

In the early 1990's research focused on whether concept mapping affected learning among high school students enrolled in science courses. Roth and Roychoudhury (1993) explored student achievement, both individually and in groups, when constructing concept maps. Concept mapping did not promote the same significant increase in learning in this study as it had in studies that came before or after. Students in groups were shown to have little growth on a series of maps constructed throughout the course of the study (Roth & Roychoudhury, 1993). The lack of growth was attributed to a social phenomenon among the students that resulted in pressure from a majority group that lead to acceptance of ideas despite the understanding of a minority collective. Roth and Roychodhury (1993) did not attempt to correct any misconceptions present in students' concept maps, and instead allowed students to figure on their own or with help from outside sources (teacher, textbook, etc.). Concept mapping has researcher has consistently shown that in addition to mapping out understanding, instructors need to address and correct misconceptions for students to learn successfully (Novak & Gowin, 1984; Pinto & Zeitz, 1997; Hay, Kinchin & Lygo-Baker, 2008).

Unlike study conducted by Roth and Roychoudhury (1993), some researchers used concept mapping in conjunction with other learning materials to promote successful learning. Two studies introduced concept mapping combined with conceptual change materials into high school biology courses. Concept maps allowed students and instructors to visualize their understanding of basic scientific concepts. Conceptual change materials addressed misconceptions present in students' concept maps, and by causing students to become uncomfortable with their prior misconceptions and then presenting them with a more valid concept, learning improved (Hewson and Thorley, 1989; Uzuntiryaki & Geban, 2005). Sungur, Tekkaya, and Geban (2001) introduced concept mapping along with a conceptual change text into a 10th grade biology class. Proper use of both these educational tools resulted in meaningful contributions to students' understanding. Conceptual change materials along with concept mapping produced similar results for a study with 11th grade biology students (Al-Khawaldeh and Al-Olaiat, 2007).

Upon finishing their time being enrolled in university level courses, students are expected to have begun the process of understanding concepts like experts in their respective fields. Research into students understanding has shown expertise to be lacking, with far too many students failing to gain a basic understanding of science concepts (Lightman, & Sadler, 1993; Gonzalez 1997; Hay, Kinchin, & De-Leij, 2005; Hay & Kinchin, 2008). Near the end of the 1980's, meaningful learning in science began to become the focal point for college-based research. Okebukola and Jegede (1988) documented a lack of students' understanding of concepts presented in college-level biology courses. To promote meaningful learning in science courses, Okebukola and

Jegede (1988) introduced concept mapping into a college biology class. Before treatment involving the introduction of concept mapping in the classroom was administered, an assessment was given to the research sample to students' basic understandings of biological principles for the course. Researchers discovered that many students shared a similar, yet inadequate comprehension of core biological concepts. Following concept mapping instruction and practice, students in experimental groups showed a significant increase in understanding of concepts on in-class assessments. Moreover, based on the assessment results, these students were considered to have developed meaningful learning (Okebukola & Jegede, 1988). Okebukola (1990) reported similar results in an earlier study with students using concept mapping in two college-level courses that focused on abstract concepts in genetics and ecology courses. Again, Okebukola found that students using a concept mapping strategy reported significant increases in their understanding of the subject area. This finding represents a consistent trend across research studies when concept mapping is introduced to students in a science classroom (Heinze-Fry & Novak, 1990; Buntting, Coll & Campbell, 2006; Chiou, 2008).

Meaningful learning requires that students retain great sums of information while incorporating new concepts over extended periods of time (Hewson and Thorley, 1989; Uzuntiryaki & Geban, 2005). Investigations into concept mapping's ability to be an effective tool for improved learning in university-level science classrooms have been persistent. In 2005,Hay, De-Leij, and Kinchin introduced concept maps into an undergraduate microbiology course and an introductory cell biology course. In each researcher's course, the use of concept mapping led to an improved understanding of both microbiology and cell biology. Moreover, each course instructor was capable of addressing students' alternative conceptions with new lessons intended to first explain why the students' prior understandings were incorrect and provide justification for the proper scientific conceptions (Gershoni, Yarden, & Marbach-Ad, 2005; Hay, Kinchin, & De-Leij, 2005). The success of concept mapping as a tool for promoting students' meaningful learning has been repeated in many types of college classrooms. Studies in accounting and medical education classes have reported that concept mapping helped students achieve meaningful learning, while putting an end to rote memorization; a practice which plagues many classrooms (Pinto & Zeitz, 1997; Fonseca, Extremina & da Fonseca, 2004; Chiou, 2008). Though it has often been studied as a stand alone tool, concept mapping is not a quick fix to faulty conceptual understandings held by many students. Novak and Gowin (1984) introduced concept mapping with the Vee heuristic to further supplement meaningful learning that was to take place in science courses.

Vee Heuristic

Laboratory-based courses have the potential to facilitate successful learning through conceptual change by providing students hands-on experiences with core conceptual experimental procedures. However, traditional lecture-laboratory based classes are troubled by deficient explanations of the purpose and relationship of laboratory investigations to course content, therefore making meaningful learning a difficult goal to reach. Studies have shown that learning in a laboratory setting has the potential for disrupting students' learning of fundamental concepts, theories, and principles they are expected to learn in lecture (Qin, 1997; Wilson & Stevnsvold, 1991; Roth, 1990). To promote meaningful learning, Novak and Gowin (1984) developed the

Vee heuristic to help students assimilate and organize new conceptual knowledge by showing them how and why scientific knowledge is assimilated.

Acquiring and understanding new conceptual knowledge and the development of expertise is the goal of meaningful learning. Experts use techniques to “store and recall domain-specific knowledge” to integrate concepts and procedures to solve problems that occur in laboratories (Mestre, Dufresne, Gerace & Hardiman, 1993). Comparatively, novice students acquire knowledge in a sequential manner, which hinders an all-inclusive understanding. Research has shown that when novices receive high quality training they can begin to solve problems in a manner resembling that of experts (Mestre, Dufresne, Gerace & Hardiman, 1993). Similar to concept mapping, the Vee heuristic provides students with an opportunity to arrange concepts in a hierarchy. The hierarchy provided by the Vee heuristic purposefully guides students through the process of solving problems, efficiently by using “underlying themes (e.g. principles, concepts, theories, etc.) similar to those found in laboratory activities (Mestre, Dufresne, Gerace & Hardiman, 1993). The Vee heuristic’s ability to highlight these themes, and their effect on novice students’ learning has been well documented in several studies.

Lehman, Carter, and Kahle (1983) sought to show the benefits of using the Vee heuristic in a science classroom. Vee mapping and concept mapping were introduced into an introductory high school biology class along with a laboratory to promote meaningful learning. Students’ achievement was measured using pre- and post- tests designed to assess understanding, rather than rote memorization. Introducing the Vee heuristic into a biology class and laboratory resulted in improved scores on the meaningful learning assessment, however scores were not significantly different from the control group. In a following study Lehman, Carter, and Kahle (1983) researchers introduced the Vee heuristic into elementary education majors' science laboratory course. Future science teachers found using the Vee heuristic to be helpful for problem solving (Roth & Roychoudhury, 1993). Additionally students stated that using the Vee heuristic helped them organize and construct new knowledge, allowing them to better understand and teach future science classes (Roth & Roychoudhury, 1993).

Instructors often measure students' understanding of laboratory investigations by assessing the quality of their students' lab reports. McLean (1999) continued this tradition, assessing high school science students' laboratory reports. While grading these reports, students were unable to connect the purpose of an investigation with its procedure. As a way to promote successful learning by ensuring students understand how both concepts and procedures intertwine during a laboratory investigation, the Vee heuristic was introduced into the classroom. Following its introduction into McLeans' class, the Vee heuristic was shown to help clarify the link between lecture-based concepts and laboratory procedures. McLean measured increases in clarification by comparing students' pre-Vee diagram lab reports to those written after the introduction and use of the Vee diagram, with the writing in the later reports.

Distractor-Driven Multiple-Choice Test

Both concept mapping and the Vee heuristic promote successful learning by suppressing rote memorization and encouraging the development of conceptual understanding. Prior to the last 20 years, there has not been a durable method to characterize conceptual change among students' using concept maps or the Vee heuristic. Current research on the cognitive models of learning has resulted in the development and use of a new type of assessment tool. This new assessment tool, called the distractor-driven multiple-choice test, evaluates the conceptual change taking place among students (Sadler, Coyle, Miller, Nancy, Dussault, & Gould, 2010).

Halloun and Hestenes (1985) originated the process of constructing distractor-driven multiple-choice tests by requiring introductory physics students' to write answers for an earlier version of a basic physics test. Written answers that mirrored common misconceptions were identified and used as "distractor" choices in addition to one correct answer in the construction of a multiple-choice test item. Distractor- driven answer choices are meant to be attractive to students who maintain preconceived faulty notions, which differ from a scientific understanding about the concept (Sadler, Coyle, Miller, Nancy, Dussault, & Gould, 2010; Halloun & Hestenes, 1985). The attraction for students derives from the similarity in "a choice that clearly reflects their [students'] own thinking about a concept;" instead of picking an answer "that reminds them of what a teacher said in class, for example a keyword or vocabulary" (Sadler, Coyle, Miller, Nancy, Dussault, & Gould, 2010). At the conclusion of their study, Halloun and Hestenes determined that the construction and use of a distractor-driven multiple-choice test allows for a simple yet detailed way of discerning a spectrum of commonly held but faulty knowledge of basic science concepts.

Use of conceptual mapping and Vee heuristic methodologies have been shown over time to be useful in promoting successful learning in science students. Concept maps were used to help students visualize perceptions of concepts and their linkage to each other. The paradigm of connecting and explaining concepts is thought to promote successful learning among students. After its initial development by Novak and Gowin, concept maps became a metacognitive tool that numerous researchers attempted to implement in their classrooms. Conclusions found in the Okebukola and Jegede (1988) study showed that college students using concept maps exhibited meaningful learning when compared to their peers. More contemporary studies conducted by Gershoni, Yarden, and Marbach-Ad, 2005, as well as, Hay, Kinchin, and De-Leij, 2005 resulted in a similar outcome found by Okebukola and Jegede (1988). The Vee heuristic introduced by Novak and Gowin sought to connect principles and theories learned in lecture with the experimental methods conducted in laboratories. Researchers have been able to identify this connection in studies conducted with science students. Studies by Lehman, Carter, and Kahle (1983), as well as, Roth and Roychoudhury (1993) documented that students using Vee heuristic garnered better understanding of laboratory science concepts.

This study weaves both methods developed by Novak and Gowin into a supplemental study guide both methods in order to determine the effects on two different sets of students. The first set of treatment groups involved science majors and the second group was composed of nursing students. The effects of the study guide were measured using a series of assessments, which will be further discussed in the next chapter.

Chapter 3
Methodology

Introduction

The purpose of this study was to promote and measure successful learning in a lecture-laboratory course using a study guide constructed to include two metacognitive tools, concept mapping and Vee heuristic questions. Measurement of successful learning for students in these courses was assessed by using a series of instruments that included distractor-driven multiple-choice exams, mid-term, and final exams. After gathering the required information various treatment options were formed, which included using the study guide with an instructor and using the study guide alone. The following research questions were answered:

1. *Will use of conceptual knowledge mapping promote successful understanding of lecture-based concepts?*

Student learning of lecture-based concepts should improve if the independent variable, conceptual knowledge mapping, is applied. The dependent variable, end of course grades, was used to measure the difference in learning between experimental and control groups. If students' learning improves, then students receiving the treatment should have higher scores on end of grade scores than their counterparts in the control group.

2. *Will use of the Vee heuristic promote successful understanding of laboratory-based concepts and procedures?*

Student learning of laboratory-based concepts should improve if the independent variable, answering of Vee heuristic questions, is applied. The dependent variable, end of course grades, was used to measure the difference in learning between experimental and control groups. If students' learning improves, then students receiving treatment should have higher scores on end of course grades than their counterparts in the control group.

3. *Will use of conceptual and procedural knowledge mapping promote understanding of laboratory related concepts?*

If students are able to successfully connect concepts from the laboratory course using conceptual and procedural knowledge mapping, then a change may occur in students' improved understanding of microbiology. Improved learning will be measured by using end of course grades, a dependent variable for this study.

Sub-set question 1. Does using concept mapping and Vee heuristic in a laboratory class improve students' public knowledge about microbiology?

Concept mapping and the Vee heuristic, the independent variables, were predicted to improve learning in the laboratory course. The application of these two educational tools was also predicted to improve students' understanding of everyday microbiology concepts. In order to measure this increase in understanding of public knowledge, an assessment titled the Public Knowledge of Microbiology (PKM) was created and scored, serving as a dependent variable.

Sub-set question 2. Does using concept mapping and answering Vee heuristic questions in a laboratory class improve students' overall knowledge of microbiology?

Concept mapping and the Vee heuristic, the independent variables, were introduced to promote an increase in learning in a laboratory course. The application of these two educational tools were also predicted to improve students' general understanding of microbiology. In order to measure this increase in general understanding of microbiology, the General Knowledge of Microbiology (GKM) (Appendix B) served as the dependent variable and was administered and scored on three separate occasions.

Study guides were given to students in two microbiology laboratory courses, BIOL 2111/3221, in Fall 2011. Scores were assigned and collected for both concept maps and Vee heuristic questions. These scores provided the researcher with additional insight into how students performed when using these two metacognitive tools. The study guide used concept mapping and Vee heuristic to promote successful learning of basic scientific concepts. Concept mapping and the Vee heuristic help students to focus on bringing together knowledge gained from theories, principles, and their relation to methods that support them, through activities and applications. Using concept mapping and answering Vee heuristic questions located in the study guide was predicted to result in positive gains in laboratory learning.

Research design

This investigation used a quasi-experimental design with multi-factorial, non-equivalent control groups. This study was considered quasi-experimental because none of the treatment or control groups of students were selected by random assignment. Furthermore, members of the two experimental groups (G_I, G_{NI}) and the one control group (G_C) received the same pre-test (O_{PK} and O_{GK}) and post-test (O_{PK} and O_{GK}), while only the experimental groups underwent treatment (X_I and X_{NI}). Fidelity checks (X_{FC}) occurred during weeks 4 and 8 throughout the course of this study. The process of comparing experimental group(s) to a control group should help support findings about the treatment (use of the study guide) effects on student learning. The research design diagram (Table 1), provided below, depicts how events occurred throughout the semester

Table 1 Research Design

Week Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
G_I				X_I-->											X_I
				X_{FC}				X_{FC}							
				O_{PK}				O_{PK}					O_{PK}		
				O_{GK}				O_{GK}					O_{GK}		
G_{NI}				X_{NI}-->											X_{NI}
				X_{FC}				X_{FC}							
				O_{PK}				O_{PK}					O_{PK}		
				O_{GK}				O_{GK}					O_{GK}		
G_C				O_{PK}				O_{PK}					O_{PK}		
				O_{GK}				O_{GK}					O_{GK}		

including assessments, fidelity checks, and treatments.

Multi-factorial designs have been widely used in scientific and educational studies, and this design was adapted for this investigation. The multi-factorial designed experiment offers investigators an opportunity to "assess the relative importance of multiple factors" affecting the data. The design also grants researchers a chance to analyze "the interactions occurring between different factors"(Barbeau, Durelle, & Aiken, 2004; Creswell, 2002; Marcobal, Martin-Alvarez, Moreno-Arribas, & Munoz, 2006; Mertens, 2005; Ray, Patel, Shih, Macaraeg, & Wu, 2009). To facilitate the multi-factorial design, this study applied different conditions regarding the use of the microbiology study guide. Using multi-factorial groups provided the researcher with an idea of how well the study guide works with students whose educational goals differ

(Factor 1: nursing vs. biology majors) and with students in laboratory sections with or without the presence of an instructor (Factor 2: study guide only vs. study guide with instructor) who is knowledgeable and experienced in the use concept maps and the Vee heuristic. If both nursing and biology-major students who use the study guide only perform as well as students who have access to the study guide and a knowledgeable, experienced instructor, the claim can then be made that the study guide alone is an effective learning tool for students to use on their own. However, if nursing and biology-major students without access to an instructor fail to perform as well as their study guide plus instructor counterparts, the claim can be made that additional access to a knowledgeable, experienced instructor may be necessary for students to improve learning of microbiology concepts and procedures using the two metacognitive tools, concept mapping and the Vee heuristic routines.

To provide further validity to the study, a series of fidelity checks in the form of pre-post data and mid-term data, were conducted over the course of the study. The checks permitted the researcher to document use of the metacognitive tools, to monitor the study progress, and to justify any necessary adjustments as needed throughout the investigation. These checks were necessary to ensure that a valid test was conducted, that the proposed intervention was uniformly applied throughout the study and that the intervention had a measurable effect on student learning. The duration of the study was 15 weeks, the entire fall semester 2011.

Subjects

The study was conducted at East Carolina University during the fall semester of 2011. East Carolina University is a research university located in Pitt County in eastern North Carolina, and has an enrollment of 27,000 students. According to the East Carolina University Undergraduate Catalog, students are required to pass a range of courses specified by the General College at East Carolina University. These courses, which include humanities and fine arts, social sciences, basic college-level algebra courses, and one science course accompanied by a laboratory, must be completed before graduation. Furthermore, neither biology nor nursing students can declare a major before successfully completing the General College courses. These courses are meant to expose students to the basic principles necessary for scholarship. Students who have finished their foundational curriculum and have declared a major in Biology must additionally enroll in a series of chemistry courses each with an accompanying laboratory section. Contrary to their biology major counterparts, students who declare nursing as a major are not required to complete a laboratory-based science class until they reach microbiology. According to course catalogue description, many core classes for nursing students' focus on health assessment and patient care.

Each fall semester, approximately 2 lecture sections of BIOL 2110 and 9 laboratory sections of BIOL 2111 (Fundamentals of Microbiology and Laboratory, respectively) are offered for approximately 144 nursing students. One lecture section of BIOL 3220 and 6 laboratory sections of BIOL 3221 (Microbiology and Laboratory, respectively) are offered for 96 biology majors. The course catalogue descriptions are as follows:

2110, 2111. Fundamentals of Microbiology and Laboratory (3,1)(F,SS) (FC:SC)

3 lectures and 2 2-hour labs per week. May not be counted toward BIOL major or minor. CHEM P for 2110: CHEM 1120, 1130 or BIOL 1100 and CHEM 1150; 2.75 GPA or consent of instructor; RP for 2110; BIOL 1050 1051 or 1100, 1101. P/C for 2111; BIOL 2110. General study of microorganisms and their importance to humans. Emphasis on fundamental life processes, including a brief introduction to epidemiology and immunology.

3220, 3221. Microbiology (4,0) (F) 3 lectures and 2 2-hour labs per week. P: BIOL 1200, 1201; CHEM 2650 or 2750. Structure, physiology, disease, environmental relationships, and molecular biology of microbes.

Students participating in this study registered for one of two laboratory sections of either BIOL 2111 or BIOL 3221, depending on their focus of study. For students in the Fundamentals of Microbiology Laboratory course (BIOL 2111), there were three course sections offered on Mondays during fall 2011. In the morning laboratory course, students received the study guide with additional help from an instructor. The Monday afternoon course, BIOL 2111, served as the control, receiving neither a study guide nor additional help from an instructor. There was also an evening laboratory section on Monday. The evening class served as a second experimental group, receiving study guides without help from an instructor. All BIOL 2111 laboratory sections participating in this study were taught by the same biology graduate student, also known as a Teaching Assistant (T.A). BIOL 3221 differed from the BIOL 2111 course in that it met twice a week each Monday and Wednesday. The first section of BIOL 3221 met during mornings, this class received study guides alone, with no accompanying input by an instructor. Another section of BIOL 3221 met at noon, and members of this group received study guides along with assistance from an instructor. Both the first and second sections were taught by the same T.A. However, for the control group, which met each Tuesday and Thursday at noon, the laboratory class was taught by a different T.A.

Each section of Fundamentals of Microbiology and Microbiology laboratory enrolls sixteen students. This study used three sections selected from each course, BIOL 2111 and 3221, for a total sample size of 96 participating students. Students enrolled in each section were asked to participate in a voluntary experiment. Students who were willing to volunteer for this study were required to read and sign an IRB-approved consent form (Appendix C). The total number of students in the BIOL 2111 course that agreed to fully participate in this study included 15 students in the control group, 10 in the treatment group with accompanying instructor, and 16 for the treatment group with no instructor. Treatment and control groups were chosen based on the available teaching assistants. The researcher previously worked with each of the teaching assistants on past projects, and was guaranteed their full support with the use of study guides. Sections that were to be used as treatment and control groups were randomly selected.

Course Materials

The general microbiology curriculum for students majoring in biology or pre-nursing take lecture and laboratory course for one semester East Carolina University. Though the lecture and laboratory courses can be taken together, the lecture and laboratory are not designed to follow one another. Instead each laboratory lesson is considered independent of its lecture-section counterpart.

Biology faculty at East Carolina University developed the laboratory manual used for both BIOL 2111/3221, an example of a laboratory investigation can be found in Appendix D (Cayer & Gee, 2011). Provided below is a complete list of all laboratory investigations completed by students enrolled in BIOL 2111 and BIOL 3221:

1. Effectiveness of Hand Scrubbing
2. Epidemiology and a Simulated Epidemic
3. Use and Care of the Microscope
4. Simple Stains and Negative Stains
5. The Gram Stain
6. Structural Stain Example: The Capsule Stain
7. Microbes in the Environment and Streaking for Isolation
8. Dilution techniques: Serial Dilution and plating; Spread and Spot plating
9. Special Medias for Bacterial Isolation
10. Carbohydrate Catabolism
11. Protein Catabolism
12. Bacterial Respiration and the Effects of Oxygen upon bacterial growth
13. Physical Methods of Controlling Microbial Growth: Heat
14. Physical Methods of Controlling Microbial Growth: UV
15. Antimicrobial agents: Disinfectants and Antiseptics
16. Antimicrobial agents: Antibiotics
17. Bacteria of the Skin
18. Bacteria of the Respiratory Tract
19. Bacteria of the Gastrointestinal Tract

20. Bacteria of the Urogenital Tract

21. Water contamination

22. Food Contamination

Each laboratory investigation is intended to teach students specific principles important to microbiology, an example of which can be seen in both "Simple Stains and Negative Stains" and "The Gram Stain" laboratory investigations. Each of these experiments prepares students to examine and acquaint themselves with the qualitative aspects of microbiology. Many of the later investigations have both quantitative and qualitative portions that require students to apply learned principles and theories to situations presented during lab. Laboratory investigation lengths varied among each course. Many experiments were completed in a week's time for students enrolled in BIOL 3221. However, for students enrolled in BIOL 2111, laboratory investigations would often require two weeks to complete. Additionally, students were advised that because the lab was only held once a week, multiple experiments would be performed during one session of class.

Research Materials

The researcher constructed the study guide used for this investigation. The study guide, titled "Microbiology Study Guide" (Appendix E), was developed following a pilot study conducted Summer Session 1, 2011. The intent of the pilot study was to determine whether use of Vee diagramming with embedded concept maps could be properly executed and maintained for the duration of the 5-week laboratory course.

During Summer Session 1, 2011, a group of 16 nursing students enrolled in a microbiology laboratory course were introduced to Vee diagramming and concept mapping. The introductory lesson included proper uses of Vee diagramming and concept mapping along with potential benefits of proper use. For a series of laboratory investigations completed throughout the five-week summer session, students were asked to complete a Vee diagram as a study aide and to construct a concept map based on concepts central to each day's lab investigation and procedures. To ensure that students were actively using the study guides, the researcher introduced student-led discussions about each investigation, reviewing concepts, procedures, and results and how this information could be included in students' Vee diagrams or concept maps. Students seemed to acquire a good understanding of how each of these metacognitive tools worked and readily participated in follow-up discussions. Toward the end of the summer session negative attitudes toward tool use declined.

As the end of the first summer session approached, some students expressed disappointment with using the Vee diagram. The class was asked to describe the problems encountered with the Vee diagram and nursing students reported that they were rewriting previously read lab procedures. At the same time, students were generally positive and expressed that continued use of concept mapping helped them improve their understanding of core concepts in microbiology. To maintain the strategies found in the blueprint of the Vee diagram without using the traditional V-diagram protocol, the researcher developed a series of question prompts that preserved the content as well as the intent of the Vee-heuristic. Students agreed that the use of Vee heuristic questions (Appendix E*)* as a substitute for the Vee Diagram, would help to improve their knowledge of the conceptual and procedural content of an investigation without generating negative attitudes towards its use.

As a way to ensure proper and continued use of the Microbiology Study Guide, fidelity checks were performed throughout the course of the Fall semester 2011 study. Fidelity checks were video recorded during weeks 4 and 8.

Procedure

Students in each of the four treatment groups (2 BIOL 2111/ 2 BIOL 3221) were provided with training in the use of study guides. They received introductions to, instructions about, and practice using concept mapping and answering Vee heuristic questions a month after classes began. Each student was given a study guide that included two examples of concept maps. One concept map depicted members of a family as individual concepts, and their connection to one another was described through use of propositional links. The second concept map made use of concepts taught to most students pursuing a career in science or pre-health that were included in prior, introductory level biology courses.

Both BIOL 3221 and BIOL 2111 courses met for different amounts of time during the week. BIOL 3221 classes met twice each week for two hours per class; BIOL 2111 classes met once each week for three hours. At the beginning of each class, students were given a quiz based on that day's laboratory investigation, or in the case of BIOL 2111, the series of laboratory investigations for that week. The purpose of these pre-lab quizzes was to ensure that students had read and understood the introduction, materials, and procedures associated with the corresponding day's experiment. After each quiz was completed, TA's would begin a lecture, where they provided students with an overview of basic principles, theories, and laboratory techniques used in the day's investigation. Following lecture, students (depending on the day) would either review the previous day's results or begin a new laboratory investigation. When starting a new experiment, students worked in groups of two and collaborated as a team when reviewing results.

Study guide sections that coincided with the first month of laboratory investigations were not completed. Included in those investigations were knowledge of the "Effectiveness of Hand Scrubbing", "Epidemiology", and "Use and Care of the Microscope." These laboratory experiments were omitted as part of the study because the study guide was not ready for distribution during this time.

The collection of dependent variable measurements started with laboratory 9, "Special Medias for Bacterial Isolation." For treatment groups using the study guides with help from an instructor, class began with an evaluation of pre/post concept maps and answers to Vee heuristic questions. During this beginning portion of the study, students were assisted in their attempts to answer Vee heuristic questions and build better concept maps. Additionally, this time provided students with opportunities to ask questions of the researcher or lab TA. Treatment groups receiving only the study guide varied in their use of the guide, depending on the time allotted by the teaching assistant. At the semester's completion, the researcher collected all study guides to perform further quantitative and qualitative analysis of students' concept maps and their answers to Vee heuristic questions.

Measurement

This study can be considered “field based” as majority of the research was carried out in a series of operating laboratories. This type of study ensured proper use of materials by using periodic fidelity test and added additional strength and validity to collected data. Instruments including study guides and assessments were used in the field due to the nature of the study.

Qualitative, in class assessments of pre and post concept mapping and Vee heuristic answers were conducted by the researcher and lab TA. During this time, both the teaching assistant and researcher looked for completed concept maps. This included looking for properly indicated concepts, proper use of propositional links, and a well distinguished hierarchy within the map. When reviewing the Vee heuristic questions in class, the teaching assistant and researcher were looking for complete and sensible answers. The teaching assistants performed the same functions in courses where additional help from the researcher was not part of the treatment. This exercise provided TAs and the researcher an opportunity to determine whether students had grasped elemental knowledge necessary to use the metacognitive tools on their own to improve understanding of laboratory investigations. Additionally, the researcher and teaching assistant determined if students properly understood the application of that knowledge when performing lab experiments. Scores given after collection of study guides were measured to determine if proficiency rates differed among the two treatment groups. Scores for both concept maps and answered Vee heuristic follow a well established method constructed by Novak and Gowin (1984) and Kinchin, De-Leij, and Hay (2005).

The method for scoring concept maps is based on the suggestion from Novak and Gowin (1984) that each portion the map be given a particular number of points. For the concept maps constructed in all study guides a total of 25 points were allotted. Concept maps were dissected based on research from Kinchin, De-Leij, and Hay (2005). Provided is a list how each concept map deconstructed into individual points:

1. *Propositions*: Meaningful relationships were sought out between two concepts. Each relationship needed to be shown with a connecting line and a linking proposition. If all relationships had these factors and were valid, then that map would receive a total of 10 points. Students were awarded partial credit if some relationships had linking propositions. In this instance, awarded credits were based on if more than half or less than half of the connecting points had valid propositions.

2. *Hierarchy*: Concept maps were studied analyzed to determine if students began their maps with more general ideas and lead eventually to more specific ideas. If done properly, students were awarded a full 5 points. If students performed this task incorrectly, they were awarded fewer points based on the number of concepts out of order.

3. *Cross links*: Linking concepts to one another is an extremely important part of concept mapping. Concept maps were reviewed to determine if there was valid cross-linking between concepts. If the cross-links were valid and properly explained via propositional links, then students were awarded 5 points. During the review of the concept map, if the researcher noticed places were cross-linking should have occurred then points were subtracted.

4. *Examples*: Specific events or objects that are valid instances of those designated by the concept label were scored 5 points.

Novak and Gowin (1984) also provided a specific method for grading Vee heuristic diagram. For this study, this method was adapted for Vee heuristic questions. Provided are both the questions and numerical scores provided to students based on how they answered the questions:

1. *What is the general purpose of this investigation?*

   0 points-No Focus question is identified.

   1 point-A question is identified, but does not focus upon the objects and the major event or the conceptual components of the investigation.

   2 points-A focus question is identified and includes concepts, but does not suggest objects or the major event or the wrong objects and event are identified in relation to the rest of the laboratory exercise.

   3 points-A clear focus question is identified.

2. *Why is this lab investigation important?*

   0 points-No object or event are identified.

   1 point-The major event or the objects are identified and are consistent with the focus question, or an event and object are identified, but are inconsistent with the focus question.

   2 points-The major event with accompanying object is identified, and is consistent with the focus question.

   3 points-The major event with accompanying object is identified, and is consistent with the focus question, but also suggests what records will be taken.

3. *How will you perform today's lab investigation?*

0 points-No conceptual side is identified.

1 points-A few concepts are identified, but without principles and theory, or a principle written is the knowledge claim sought in the laboratory exercises.

2 points-Concepts and at least one type of principle (conceptual or methodological) or concepts and relevant theory are identified.

3 points-Concepts and two types of principles are identified, or concepts, one type of principle, and a relevant theory are identified.

4 points-Concepts, two types of principles, and a relevant theory are identified.

4. *What will you learn today?*

0 points-No knowledge claim is identified.

1 point-Claim is unrelated to the conceptual side of the Vee

2 points-Knowledge claims include a concept used in an improper context or a generalization that is inconsistent with the records and transformation.

3 points-Knowledge claims includes the concepts from the focus question and is derived from the records and transformation.

4 points-Knowledge claims include concepts from the focus question and is derived from the records and transformation, but the knowledge claim leads to a new focus question.

The microbiology assessments, "Public Knowledge about Microbiology" (PKM) and "Microbe Study Survey" (GKM), were administered within the first month of the semester. The GKM survey was developed in 2010 by Sokoll (2010) and was provided by one of the studies authors. The "Microbe Study Survey" was a sixteen question, multiple-choice assessment. This survey assessed students understanding of basic concepts taught in an introductory microbiology course.

The Public Knowledge about Microbiology Survey was developed in the Spring Semester 2011. Open-ended questions were generated using five questions developed by the Wisconsin Program for Scientific Teaching, and can be seen in their video interviews of people on the street, titled *A Tiny World* (http://scientificteaching.wisc.edu/media.htm). The video documents a series of interviews with members of the general public who were asked five misconception-based questions about microbiology. The five questions asked are as follows:

1. What is a virus?
2. Why is the overuse of antibiotics bad?
3. Would you take antibiotics for a cold?
4. What are bacteria
5. What do you think of when I say E. Coli?

The makers of *The Tiny World* have found the video to be a useful tool with students taking both microbiology and biology courses as a way to identify and address common misconceptions entering students may hold.

To gain an understanding of the common misconceptions held by introductory level microbiology students, the same five questions were administered in an open-ended written format to a group of nursing students who were enrolled in the BIOL 2110/2111 microbiology lecture-lab course during the Spring semester of 2011. Responses provided by nursing majors to each question were grouped together based on similarity of content. For example, the following responses were written by two different students to the question "What is a virus?" "non-living organism" and "something that is not alive." These two answers were grouped into a single answer of "not a living organism."

The answers provided by nursing students were found to be similar to the answers provided by members of the general public who responded to the questions in *The Tiny World* video and represented the general public's understanding of foundational concepts in microbiology. Their responses were used as plausible distractors to develop a two-tiered, distracter-driven multiple-choice assessment. The distracter-driven multiple-choice assessment developed became the *Public Knowledge about Microbiology Survey* or PKM (Appendix A). It consists of the five microbiology-related questions provided by Wisconsin Program for Scientific Teaching, with distractor-driven options identified from among nursing students enrolled in microbiology in the Spring Semester 2011, and a second tier in which students are asked to identify where they learned the information. Both assessments were administered three times at four-week intervals during the semester.

The laboratory midterms and final exams were constructed from a pool of questions provided by all microbiology laboratory teaching assistants (T.A.s) in the biology department at East Carolina University. Questions were modified by T.A.s depending on the extent of instruction pertaining to specific concepts. Faculty in charge of microbiology labs at East Carolina University reviewed tested material to ensure validity. Performing well on these tests was interpreted as an indication of students' comprehension of the laboratory concepts, principles, and procedures.

The laboratory instructor, without the researcher's assistance, graded all midterm and final exam materials. Identities of students were protected to ensure students anonymity in this study. The researcher graded the PKM and GKM assessments. The Vee heuristic questions in the study guide used objective criteria for scoring responses to subjective essay questions.

Students enrolled in BIOL 2111 were given a four-item question survey to determine their satisfaction with the learning experiences. This survey was developed ex post facto after numerous failed attempts were made get students to involved in the study. This survey was given to students near the end of the study.

Data Analysis

All scores for this research were analyzed using SPSS software package (Version 20, SPSS, 2011). The type of analysis performed for this study included One-Way ANOVAs. In order to properly use ANOVAs various assumptions must be met, which include values in each group follow a normal curve, and the groups have equal variance on the dependent variables. These assumptions were all checked prior to computing any ANOVAs. Since this was a field-based study, there were variations in the sample size for each measurement and as a result for each analysis. These factors could be considered potential flaws that must be considered when interpreting the results of this study.

Chapter 4
Results

Introduction

The quantitative data collected for this study were analyzed using SPSS for Mac operating system. Inferential statistics include the use of ANOVAs to compare differences among treatment groups and control groups. This study followed a nested design, which implies that each group received only one treatment condition. The research conducted fits the nested design model because each course, BIOL 2111 and 3221, used two experimental sections in addition to a control.

To determine statistical significance for this study the critical value, α, was maintained at its historical of .05 level. To reduce the risk of Type I error significant levels were set at $p \leq .05$, anything above was considered non-significant and therefore an acceptance of the null hypothesis.

Data analysis is presented in this chapter in five different sections, including analysis, procedures and results. The first section presents descriptive statistics on the treatment and control groups. The second section contains the results of a one-way ANOVA. The third section provides insight regarding how the implementation of the metacognitive tools (concept mapping and Vee heuristic questions) occurred through the use of the study guide for both BIOL 2111 and 3221. The fourth section contains post-hoc data from series of attitude-based surveys given to BIOL 2111 courses on using the study guides. The fifth section contains information about trends that appeared after data analyses performed. From the data gathered the following research questions were answered:

1. *Will use of conceptual knowledge mapping promote successful understanding of lecture-based concepts?*
2. *Will use of the Vee heuristic promote successful understanding of laboratory-based concepts and procedures?*
3. *Will use of conceptual and procedural knowledge mapping promote understanding of laboratory related concepts?*

Sub-set question 1. Does using concept mapping and Vee heuristic in a laboratory class improve students overall public knowledge about microbiology over time?

Sub-set question 2. Does using concept mapping and answering Vee heuristic questions in a laboratory class improve students' overall knowledge of microbiology?

Students with incomplete study guides were removed from the main analysis of the study.

Descriptive Results

Descriptive data collected and presented include scores for concept maps, Vee heuristic questions, GKM, and PKM assessments. Concept maps were scored using techniques constructed by Novak and Gowin (1984) and Kinchin, De-Leij, and Hay (2005), which were described in Chapter 3. Likewise Vee heuristic answers were scored using the protocol provided by Novak and Gowin (1984). An attempt was made to give equal points for equal results to all members of treatment groups.

Concept Map Data

Students enrolled in BIOL 2111 using the study guide with an instructor completed 20 concept maps with an average score of 50% during the final four weeks of this study, ranging from 20% to 84%, which can be found in Table 2. Treatment groups using only the study guide failed to complete concept maps during the study. Students enrolled in BIOL 3221 did not complete any concept maps during the first four weeks of this study. However, towards the final four weeks of this study these same students completed a total of 112 concept maps. Members of the treatment group receiving help from an instructor completed 42 concept maps with an average score of 62%, ranging from a low of 24% to a high of 96% (Table 3). Students using a study guide without instructor assistance, performed better than their counterparts with 70 concept maps completed and an average score of 66%; the lowest and highest measured scores ranged from 24% to 100% (Table 3).

Table 2 BIOL 2111 Concept map scores for treatment groups at Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	0	0	0	0	0	0	20	50.40	17.24	3.85	20.0	84.0
Study Guide without Instructor	0	0	0	0	0	0	0	0	0	0	0	0

Table 3 BIOL 3221 Concept map scores for treatment groups at Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	0	0	0	0	0	0	42	62.10	19.04	2.94	24.0	96.0
Study Guide without Instructor	0	0	0	0	0	0	70	66.63	18.63	2.20	24.0	100

Vee heuristic scores for BIOL 2111 and BIOL 3221 are described in tables 4 and 5. Beginning with BIOL 2111, table 4, students' in both treatment groups failed to complete concept maps in the first four weeks of the study. During the last four weeks students who used the study guide without an instructor failed to answer any of the Vee heuristic questions. Students with access to the study guide and an instructor answered a total of 21 series of Vee heuristic questions, with an average score of 46%. The lowest score for this section was 14% and a highest of 84%. In comparison students enrolled in BIOL 3221 answered a total of 88 series of questions. Students enrolled in the laboratory course that had access to a study guide and an instructor answered 35 sets of questions with an average score of 47%. These scores ranged from a low of 21% to a high 71%. Comparatively students with access to the study guide only completed a total of 53 sets of Vee heuristic questions, with an average score of 40%. Students' scores on the Vee heuristic questions ranged from 14% to 71%.

Table 4 BIOL 2111 Vee heuristic scores for treatment groups at Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	0	0	0	0	0	0	21	46.00	18.24	3.98	14.0	84.0
Study Guide without Instructor	0	0	0	0	0	0	0	0	0	0	0	0

Table 5 BIOL 3221 Vee heuristic scores for treatment groups at Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	0	0	0	0	0	0	35	47.49	12.02	2.03	21.0	71.0
Study Guide without Instructor	0	0	0	0	0	0	53	40.74	15.76	2.16	14.0	71.0

The control group recorded more students participating in week 4 testing and these students appeared to register registered higher scores on GKM assessment. During the second set of GKM assessments scores for students who received only the study guide and those students in the control group remained close to their initial scores, and, respectively students used the study guide and received additional help from an instructor scored much higher, recording a score of 85%. The descriptive data for PKM (Table 7) shows that during week 4 when assessments were given, control groups appeared to have a higher average and participation rate than both treatment groups. A difference is seen during week 8, while both control groups and study guide only group of students, the control group appeared to average a higher score. However, students using a study guide and additional help from a knowledgeable instructor appeared to have an increase in their average scores. Results contained in Table 7 summarize overall performance on PKM assessments of students taking BIOL 2111.

Table 6 BIOL 2111 Descriptive Data for GKM Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	4	72.25	5.85	2.93	69.0	81.0	6	85.50	5.39	2.20	81.0	94.0
Study Guide without Instructor	5	68.80	18.27	8.17	50.0	94.0	14	67.46	22.53	6.02	12.50	100.0
Control	10	79.60	8.46	2.68	63.0	88.0	14	72.0	12.88	3.44	44.0	94.0

Table 7 BIOL 2111 Descriptive Data of PKM for Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	4	57.50	23.63	11.81	40	90	6	73.33	19.66	8.03	50.0	90.0
Study Guide without Instructor	5	64.0	13.42	6.0	40	70	11	64.55	26.22	7.90	20.0	100.0
Control	16	67.50	16.53	4.13	50.0	100.0	14	65.0	25.04	6.69	50.0	100.0

Table 8 contains the descriptive data for students in BIOL 3221. The descriptive data shows that during the first four weeks each of the three sections average scores were within a close range to one another. However, when comparing descriptive statistics for average scores for BIOL 3221, students using the study guide only appeared to score higher than any of the other groups. Though it should be noted that both treatment groups on average appeared to score higher on PKM assessments than did the control group students. Table 9 represents data gathered from GKM assessment for BIOL 3221, average score range from low to high 70's and mid 80's for all treatment groups and the control. Treatment group that were given the study guide with additional support from an instructor scored higher during initial testing, with a score in the 80's. However, during the second round of testing the control group scores dropped on the GKM assessment, while both treatment groups saw rises in their average scores. Moreover, the treatment group that received additional help from an instructor scored higher on the general knowledge assessment than the 3221 microbiology section that only used the study guides.

Table 8 BIOL 3221 Descriptive Data of PKM for Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	8	63	30.20	10.68	0	94.0	8	87.50	14.88	5.26	60.0	100.0
Study Guide without Instructor	7	68.57	31.85	12.04	0	90.0	7	90.0	31.85	12.04	80.0	100.0
Control	14	67.86	12.51	3.34	50.0	90.0	14	77.14	14.90	3.98	50.0	90.0

Table 9 BIOL 3221 Descriptive Data of GKM for Weeks 4 & 8

	Week 4						Week 8					
	N	Mean	Std. Deviation	Std. Error	Min	Max	N	Mean	Std. Deviation	Std. Error	Min	Max
Study Guide and Instructor	8	82.88	9.36	3.31	63	94	8	90.13	4.73	1.67	81.0	94.0
Study Guide without Instructor	7	79.43	18.91	7.15	44	100	6	86.67	6.38	2.60	81	94
Control	7	78.71	11.60	4.38	56	88	14	71.57	20.90	5.59	19	94

ANOVA

To determine the significant effects of using study guides constructed with concept maps and Vee heuristic questions in science classrooms, One-way ANOVAs were performed. As mentioned in Chapter 3, to perform a One-way ANOVA a series of assumptions must be met. These assumptions are that the dependent variables are normally distributed and each group has equal variance on the dependent variables. The analyzed data is gathered in figures and tables below. All data were analyzed using SPSS for Macintosh operating system.

The data analysis began with determining if there is any significant difference in PKM assessment and GKM assessment scores between students taking BIOL 2111 and BIOL 3221. In tables 10 and 11 provide descriptive statistics that includes means, standard deviations, and standard errors for both courses. Each of these courses includes both treatments and control sections. Table 10 contains students' descriptive statistics for the PKM. Students enrolled in BIOL 3221 courses scored on average 77% for public knowledge assessments and general knowledge assessments. However, students in BIOL 2111 scored an average of 66%. Table 11 contains the descriptive statistics for GKM. The statistics for general knowledge assessments show students enrolled in BIOL 3221 scored an average of 80%, where as students in BIOL 2111 scored an average of 76%.

Table 10 Descriptive Data for PKM BIOL 3221 and BIOL 2111 (One-way ANOVA)

	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BIOL 3221	51	77.35	20.72	2.90	71.53	83.18	0	100
BIOL 2111	52	66.92	21.19	2.93	61.02	72.82	20	100
Total	103	72.09	21.50	2.12	67.88	76.29	0	100

Table 11 Descriptive Data for GKM for BIOL 3221 and 2111 (One-Way ANOVA)

	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BIOL 3221	50	80.50	15.61	2.21	76.06	84.94	19.0	100.0
BIOL 2111	49	72.95	16.16	2.31	68.31	77.59	12.50	100.0
Total	99	76.76	16.25	1.63	73.52	80.00	12.50	100.0

Upon performing One-way ANOVA, it was determined that there was a significant difference when comparing treatment with control groups on both PKM (p = .20) and GKM (p = .013) assessments scores for BIOL 2111 and BIOL 3221 (Table 12). Comparison of means in GK and PK assessments between BIOL 2111 and BIOL 3221 can be seen in Figure 1 and 2 respectively. It can be seen that in both cases students taking BIOL 3221 scored higher than their BIOL 2111 counterparts.

Table 12 One-Way Analysis of Variance for dependent variables (PKM and GKM) for BIOL 2111 and 3221

		Sum of Squares	df	Mean Square	F	*p*
PKM	Between Groups	2800.874	1	2800.874	6.376	.013
	Within Groups	44365.339	101	439.261		
	Total	47166.214	102			
GKM	Between Groups	1411.049	1	1411.049	5.594	.020
	Within Groups	24468.622	97	252.254		
	Total	25879.672	98			

Note. *p ≤ .05

Figure 1 Comparison of GKM assessment between BIOL 3221 and BIOL 2111

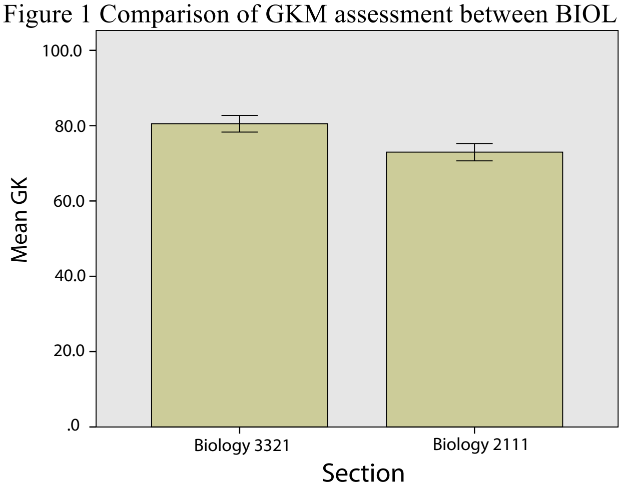
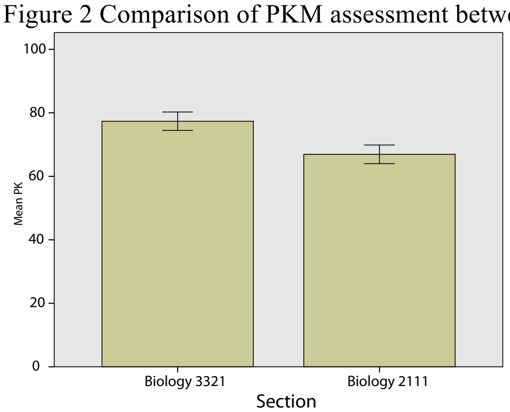


Figure 2 Comparison of PKM assessment between BIOL 3221 and BIOL 2111



To understand the impact of concept mapping and answering Vee heuristic questions on students analyses were performed for each course individually. Students' scores on GKM and PKM assessments were analyzed for BIOL 3221 between each treatment and control group pairs. Averages for scores on PKM for students in BIOL 3221 can be found in Table 13. Their mean calculated score on PKM assessments for study guide plus help from an instructor, study guide only, and control groups were 75%, 79%, and 77% respectively. Further analysis via One-way ANOVA show that there is no significant difference for PKM assessment scores. Found in Table 15 are the average scores for GKM assessments for students using a study guide plus help from an instructor, study guide only, and control groups are 86%, 83%, and 73% respectively. Upon observing collected data no differences were discovered among each group. Results from a One-way ANOVA showed that there was a significant difference, p = .033, for GKM assessment scores (Table 15) among students in BIOL 3221. This significant difference appeared between students using the study guide with a knowledgeable instructor and the control group, Figure 3 shows the difference among the three groups.

Table 13 BIOL 3221 Descriptive Data of PKM assessment scores (One-way ANOVA)

	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Study guide and Instructor	16	75.25	25.48	6.37	61.68	88.82	0	100.0
Study guide without Instructor	14	79.29	24.64	6.59	65.06	93.51	0	100.0
Control	21	77.67	13.61	2.97	71.47	83.86	50.0	90.0
Total	51	77.35	20.72	2.90	71.53	83.18	0	100.0

Table 14 BIOL 3221 Descriptive Data for GKM assessment (One-way ANOVA)

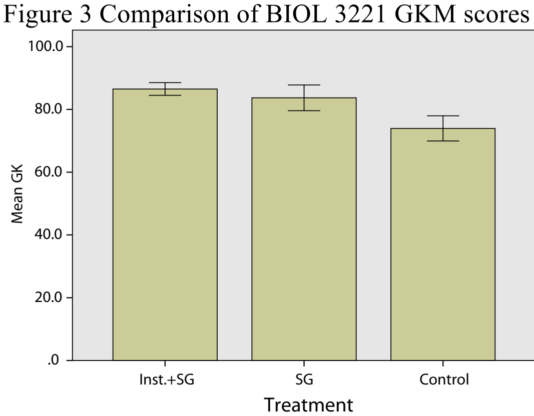
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Study guide and Instructor	16	86.50	8.08	2.02	82.19	90.81	63.0	94.0
Study guide without Instructor	13	83.69	14.79	4.10	74.76	92.63	44.0	100.0
Control	21	73.95	18.33	4.00	65.61	82.30	19.0	94.0
Total	50	80.50	15.61	2.21	76.06	84.94	19.0	100.0

Table 15 BIOL 3221 One-way ANOVA of GKM

		Sum of Squares	df	Mean Square	F	*p*
GKM	Between Groups	1608.778	2	804.389	3.661	.033
	Within Groups	10327.722	47	219.739		
	Total	11936.500	49			

Note. $*p \leq .05$

Figure 3 Comparison of BIOL 3221 GKM scores between treatment groups and control



To determine if the study guide had an overall effect on students' enrolled in BIOL 3220/3221 final grades further One-Way ANOVAs were conducted. After performing a series of analysis of variance tests it was discovered that there were no significant differences between treatment group and control groups on final grades. However, it should be noted that class averages for the treatment group in both lecture and laboratory courses appeared to be higher than the control group. These scores for both lecture and laboratory groups regarding the treatment group were 85% and 88% respectively. The control group average scores were 83% and 86% for both lecture and laboratory grades respectively. Data regarding BIOL 2111 could not be used because of a lack of access.

Data were also analyzed to determine if students scores improved on both PKM and GKM assessments over the course of the study. It was found that students in BIOL

3221 (Table 16), in particular those using the study guide along with help from a knowledgeable instructor, recorded a significant increase in their scores on PKM assessments (p = .05). The descriptive data for this assessment, (Table 17), shows students averaging 63% on PKM assessment at the beginning of this study. Towards the end of the study students scored an average of 87.5%. This difference was a significant growth based on the data collected from a One-way ANOVA, which can be seen on Table 16 and in figure 4.

Table 15 BIOL 3221 One-way ANOVA for improvement of PKM assessment scores over time

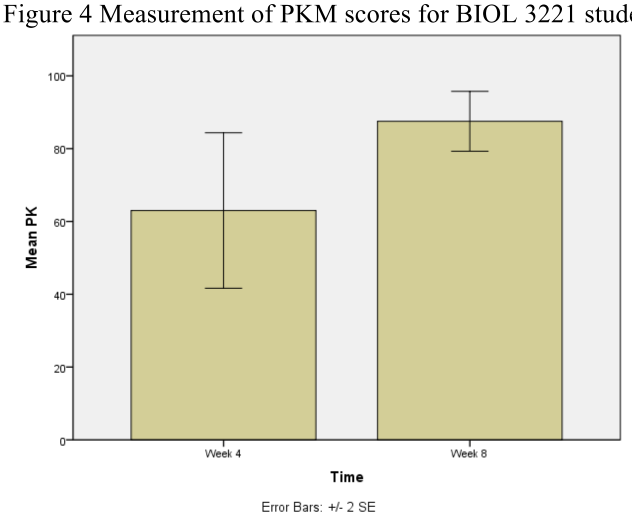
		Sum of Squares	df	Mean Square	F	*p*
PKM	Between Groups	2401.000	1	2401.000	4.583	.050
	Within Groups	7334.000	14	523.857		
	Total	9735.000	15			

Note. *p ≤ .05

Table 17 BIOL 3221 Descriptive Data for improvement of PKM assessment scores over time

	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Week 4	8	63.00	30.20	10.68	37.75	88.25	0	94.0
Week 8	8	87.50	11.65	4.12	77.76	97.24	70	100.0
Total	16	75.25	25.48	6.37	61.68	88.82	0	100.0

Figure 4 Measurement of PKM scores for BIOL 3221 students using study guide and an instructor



Attempts were made to determine if there were any statistically significant differences in scores on PKM and GKM assessment among students in BIOL 2111 that used the study guide and those that did not. Based on the analyses performed none were found. Additionally scores given to students in BIOL 3221 for their concept maps and answers to Vee heuristic were analyzed, however it was found that no significant differences existed.

Fidelity Check

Video recorded fidelity checks that occurred during weeks 4 and 8 for both BIOL 3221 and 2111. Students in BIOL 3221 were recorded explaining their process of answering Vee heuristic questions and building of concept maps. Additionally during this time students were also critiqued regarding how their answers and concept maps were constructed. Analysis of video recorded fidelity checks for students in BIOL 2111 reveled students' unwillingness to participate in this study.

ExPost Facto Analyses

Based on the number of students who agreed to take part in this study and were also enrolled in BIOL 2111, it can be said there was a high rate of attrition. A total of 14 students signed consent forms in the study guide plus instructor class, 16 in control group, and 16 in the study guide only class. Only three students actively participated in the study guide plus instructor section, and no students participated in the study guide only section. In an attempt to understand BIOL 2111 students' views on the study guide all were given an attitude survey (Appendix F). Students who used the study guide expressed that it was helpful to their learning of microbiology. However, students in both treatment groups who decided not to use the study guides stated that their lack of use was due to other priorities related to school and work. Furthermore, one student expressed that using concept maps and answering Vee heuristic questions was an uncomfortable way for her to learn.

After performing all statistical analysis on the collected data, general trends began to appear concerning both PKM and GKM assessments when comparing students using the study guide those who did not. The trends found in the descriptive data tables (6, 7, 8, 9, 10, 11) show that those students using study guides performed better on these assessments. Additionally trends for both lecture and laboratory courses revealed that students using the study guide averaged higher scores than did students in the control groups. The implications of these finds are discussed in chapter 5.

Chapter 5
Discussion

Introduction

The purpose of this study was to enhance and measure students' learning in a microbiology course, using concept mapping and Vee heuristic questions provided in a laboratory study guide. This study followed a quasi-experimental design infused with multi-factorial treatment groups. The multiple factors attributed to this investigation included difference in course of study, as some students were enrolled in a program directed towards the natural sciences. Conversely, the other groups of students were apt to pursue a field in healthcare. Additionally this study separated and examined students' learning based on their access to the metacognitive tools provided in the study guide. The study design provided students with an opportunity to receive just a study guide alone or a study guide with a knowledgeable instructor. Using multiple factors provided insight as to how different groups of students enrolled in a course in microbiology would respond to the introduction of a study guide containing two metacognitive (concept mapping and Vee heuristic questions) meant to support and enhance their in class learning. Dependent variable measures for this study included scores on public and general knowledge of microbiology assessments (PKM and GKM). These assessments tested students' basic knowledge about microbiology. Each of the assessments was given to students at four-week intervals throughout the semester. Also included in the data measurements were scores on mid-term and final exams given as part of the laboratory course. Additional knowledge measurements included scores from the lecture course semester exams. Treatment effects were statistically analyzed using scores from concept maps, answers to Vee heuristic questions, PKM assessment scores, and GKM assessment scores.

Students' scores on dependent variables were first measured to determine if high scores on one correlated with high scores on the other. After finding a significant relationship between those scores, further examination took place to see if students in one course, BIOL 3221, scored higher on the dependent variables than did their counterparts in another course, BIOL 2111. To compare these two classes One-Way ANOVAs were performed using scores on general knowledge and public knowledge of microbiology as outcome measures of learning. As a way to further examine students' learning and to determine the effects of using a study guide as a delivery mechanism for two metacognitive tools in each course, BIOL 2111 and BIOL 3221, the courses were individually separated into their treatment groups. Then One-way ANOVAs were performed using scores on PKM and GKM assessments, as outcome measures.

There were three research questions that guided the study. Each question is listed followed by the conclusions that were reached. Each of these questions is answered first before a final conclusion is drawn.

Question 1: *Will use of conceptual knowledge mapping promote successful understanding of lecture-based concepts?*

Students enrolled in BIOL 3220/3221 saw no significant differences dependent upon use of the study guide and those that did not. Though the averages grades for students using the study guide appeared higher than the control group, we cannot safely attribute that difference to use of the study guide. Unfortunately, data for students in

BIOL 2111 could not be ascertained in order to determine concept mappings achievement for this group of students.

Question 2: *Will use of the Vee heuristic promote successful understanding of laboratory-based concepts and procedures?*

The second question examined students' enrolled in BIOL 3220/3221 and in BIOL 2110/2111. Final course grades were found to not have any significant differences between students in the treatment groups and those found in the control. Except for three, students enrolled in BIOL 2111 that agreed to participate in the study failed to follow through and did not complete any of the study guides.

Question 3: *Will use of conceptual and procedural knowledge mapping promote understanding of laboratory related concepts?*

Based on the finding in question 2, we can say that students in BIOL 2111 and 3221 did not achieve significantly higher final grades than student control groups. However, it is important to note that there were improvements in scores of students using concept maps in the form of a study guide in comparison to those not using one. Therefore it can be suggested that using concepts maps may have some effect on improving students understanding of microbiological concepts.

Subsidiary Question 1: *Is there a difference in understanding of general and public knowledge of microbiology between students enrolled in BIOL 2111 and BIOL 3221?*

Initial data collected from students in both BIOL 2111 and 3221 showed no significant difference amongst the various groups. However, based on additional collected and analyzed data from students, using a One-Way ANOVA it was found that students in BIOL 3221 significantly out scored their nursing on public knowledge and general knowledge of microbiology assessments (Figures 1 and 2). These assessments were given every four weeks for 12 weeks. Additionally assessments were closed-book, with an allotted time of approximately 10 to 15 minutes to complete. Based on the earned scores it can be said that students enrolled in BIOL 3221 have a better understanding of basic microbiological concepts. Furthermore it can be presumed that BIOL 3221 students are more likely to understand and retain knowledge gained in class and put to use in both general scientific microbiological and public microbiological problems.

Subsidiary Question 2*:* *Does using concept mapping and answering Vee heuristic questions in a laboratory class improve students' overall knowledge of microbiology?*

When considering this second subsidiary question, scores obtained by students in both treatment groups versus students in the control group were examined. Students in treatment groups in both BIOL 2111 and BIOL 3221 scored higher than those students who lacked access to a study guide (Tables 6, 7, 8, and 9). BIOL 2111 students in the treatment group using only the study guide scored lower on both PKM and GKM assessments. Further analysis of scores on PKM and GKM assessments revealed significant differences in BIOL 3221 students who used only the study guide versus the control group for GKM assessments. Continued analysis of both BIOL 2111 and BIOL 3221, by One-Way ANOVA showed that students enrolled in BIOL 3221 who used the study guide with additional help from a knowledgeable instructor saw a significant increase in their GKM and PKM scores over time. This finding coincides with the study conducted by Rice, Ryan, and Samson (1998), which noted high concept map scores correlated with high scores on multiple-choice assessments. It can be safe to assume that using a study guide does help improve students' general microbiological understanding. Though other statistical analysis did not show significant differences, it would not be prudent to exclude that study guides did help students' gain better understanding of public knowledge of microbiology. This is evident in scores gained on their assessments.

The central research Question: *Does using a study guide constructed with concept mapping and Vee heuristic questions promote successful learning?*

When determining if successful learning of students took place there are a number of factors that must be considered. To begin we should attempt to determine if students understanding of both public and general knowledge of microbiology has grown over the semester. Additionally students should have strong indicators that they have retained knowledge gained both in principle (lecture) and practice (laboratory). In order to reach a conclusion for this question, results from ANOVAs and data gathered from descriptive statistics were used.

Based on both PKM and GKM assessments given to students, it was found that students using a study guide, whether it was with additional help from an instructor or using the study guide only, recorded higher scores (Tables 6, 7, 8, and 9). For example, students using the study guide with help from a knowledgeable instructor in BIOL 2111 scored an average of 85% on the GKM, however those students who were in the study guide only and control groups averaged respectively 67% and 72%. Additionally students in BIOL 3221 who used the study guide with additional help from a knowledgeable instructor and those that used the study guide only scored respectively

86%, and 83% on the GKM assessment, while the control group of students scored 73%. Moreover, those students using the study guide plus an instructor averaged higher outcome scores than the control group. Continued trend analysis of students' retention when using a study guide for both principle and applied aspects of microbiology, showed that students who used the metacognitive tools contained in the study guides out performed those students in the control groups. Therefore it is possible to assume that if students actively use metacognitive tools (concept mapping and Vee heuristic questions) during a semester that it could promote successful microbiological learning.

Limitations of the study

The nature of this study was to measure possible effects that using concept mapping and Vee heuristic questions could have on students' learning in a college level microbiology lecture-laboratory course. Since this study was conducted in the field is was subject to numerous limitations, which include:

1. Lack of active support from Biology faculty, which may have affected the importance students attributed to use of metacognitive tools contained in the study guide.
2. Researcher was perceived as an addition to the class and lacked laboratory assistant privileges as well as authority.
3. The independent variable was implemented outside of class, primarily at home by most students. Some students may have exerted more effort and time in completing the study guide while others may exerted less effort. Though this was not assessed through the course of the study any effects due to difference in time and effort should be considered.

Discussion

Before discussing the importance of successful learning in the field of microbiology, we must first discuss what science means to different groups of students. This study examined two groups of very different students. The first group of students have made a commitment and dedication to the study of biology, as it is perpetually present throughout the course of their study. Students enrolled BIOL 3220/3221 are immersed in science related study during all four years. However, their BIOL 2110/2111 counterparts lacked exposure and commitment to science study. According to East Carolina University undergraduate catalog version 2010-2011 students are required to complete at least 8 semester hours of science, which includes Biology, Chemistry, Geography, Geology, and Physics. After completion of those core courses, many nursing students study an additional 17 semester hours of science-related topics, resulting in a total of 25 total semester hours of science courses studied in four years time. However, students who have declared themselves to be Biology majors receive at minimum 80 semester hours of science study in a four-year time span, which is almost triple that of Nursing majors. Lack of science study in nursing help explain the high attrition rates for students enrolled in BIOL 2111. Further study into the attitudes of nursing students revealed insight into students pursing a career in nursing and their thoughts regarding biological sciences.

Researchers have often studied pre-nursing students attitudes about biological sciences. Through various studies a number of researchers have found that many nursing students have a great deal of anxiety regarding biological science study. In a study conducted by Nicoll and Butler (1996) it was identified that biology was a cause of anxiety among nursing students. Anxiety is considered to be a significant problem for students. It can impede successful learning and in retention of knowledge among nursing students (Zujewskyj & Davis, 1985; Phillips, 1988). Often times this anxiety was caused by lack of resources, teaching and learning, and student preparation. The presence of anxiety described by researchers could have ultimately affected the structure and learning patterns of both past and future nursing students.

In the early 1990's researchers began to question nurse educators on subjects that would be most important to teach to nursing students. In a study conducted by Courtenay (1991) a series of questionnaires were given to 43 nursing teachers and 140 nursing students. Responses from the teachers showed that the most important areas of studies were anatomy, physiology, and psychology. Interestingly sociology outranked both pharmacology and microbiology. Further investigation by Courtenay lead to the discovery that many teachers felt unprepared to teach both microbiology and pharmacology. In the same study Courtenay (1991) measured students' attitudes towards the same areas of science. It was revealed that both microbiology and pharmacology that students felt that there was a great degree of inadequate time and skill in teaching each of these subjects. Moreover, students admitted to describing, microbiology and pharmacology as two of the most difficult subjects to understand.

A contemporary study conducted by Friedel and Treagust (2005) continued researching nursing students and educator attitudes towards the biological science. Results showed that students maintained a more positive attitude towards biological sciences than did nurse educators. Nurse educators stated that they did not have enough knowledge in biological sciences to properly relate real nursing experiences to the theories covered in classrooms. Students noticed this lack of understanding; they noted biosciences received fairly little focus in nursing programs. Despite students' realization of the importance of biology in nursing, it is still heralded as the most difficult subject. There were significant changes in students' attitudes towards biology, when there was an increase in exposure. These changes in attitudes differed greatly from students' current educators. If biology is going to become more of a staple in nursing education, nursing educators need to find a better way of exposing nursing students to the concepts and principles. Additionally nurse educators must gain a better understanding of biology, because if they do not the question is raised regarding how nursing educator can expect their pupils to learn more than them (Clancy, McVicar, & Bird, 2000).

In a study conducted by Birks, Cant, Al-Motlaq, and Jones (2011) students' perspectives on biological sciences have changed. Research on nursing students revealed that they found the information regarding general nursing practices and law pertaining to nursing more interesting to their field of study. Furthermore these same students expressed that though biology was an important aspect of becoming a good nurse it was still the most anxiety inducing subject and generally disliked. Students' dislike for science became evident when discussing an anatomy and physiology lecture, one respondent stated, "I don't want to become a scientist".

Continued anxiety toward biological science has driven a wedge between students and the information needed to become nurses. As Friedel and Treagust (2005) noted, areas like genetics are improving treatments and procedures. For nurses to practice safely and knowledgeably improvements in biological science skills are needed.

Conclusions

This study was initiated during a time in which the researcher served as a teaching assistant for a microbiology laboratory. I spent a lot of my time as a TA attempting to show students the importance microbes play in the overall function of the human body. Though they seemed interested, I would often be questioned about the importance microbes' play in the field of nursing specifically. I explained basic aspects like using aseptic techniques to help maintain a sterile environment for patients. I also explained how microbial conjugation could lead to eventual antibiotic resistance. Students were still resistant and unwilling to acknowledge to the importance microbiology in their future. They often suggested that it was too complex for the things needed to become a good nurse. It was at that moment I began building a plan to prove them wrong. I thought that if I could connect concepts taught in lectures with the practices performed in laboratory, students would begin to correlate this information with the very things they would see while working. These connections included areas like universal precaution, immune response, and microbial infections. With these things in mind I began working on a study guide that could be distributed during fall 2011.

Despite my best efforts to persuade students to use the study guide there were a series of unexpected problems. Trouble took form in the significant amount of resistance I faced from nursing students in BIOL 2111. When I began developing the study guide it was done so with nursing students in mind. My initial study was conducted with a BIOL 2111 class during the summer of 2011. During my time with this class, there was little to no resistance. In fact, many students expressed a desire to learn as much as they could before the end of the semester. Students during this summer session course willingly used both concept maps and Vee heuristic diagram (Appendix G), even though it meant extra work for them. To reduce the hostility towards the study, attempts were made to connect with students by providing them with additional help outside of lecture and lab in the form of tutoring. It was not until the end of this study that I realized where I might have made a gross error.

When I began this study I assumed that my credentials as someone who has experience with laboratory-based research would gain trust easily from students. However after discussing my troubles with the teaching assistant of BIOL 2111 for fall semester of 2011, I became aware that students did not perceive me as someone knowledgeable in the field of science. Instead because of my educational background, I was now considered an outsider despite the TA claims of my scientific knowledge. Instead of approaching students with my initial talks of improving their education, it would have been more prudent to have the backing from biology instructors. This support could have easily been acquired by asking one of the professors teaching either BIOL 2110 or BIOL 3220 to serve as members on the thesis committee. With their presence, I believe that students would have more readily taken to the study guide if its approval came from a scientific authority figure. Though having students actively and consistently participate in the study proved challenging, I was able to get some students to use the study guide. Their results offered a promising future.

Students, who used the study guide, saw increases in their understanding of their general and public knowledge of microbiology. Furthermore, these students also seemed to have grasped practices that are important to understanding laboratory procedures. These claims are evident because they can be seen in steadily increasing scores on PKM, GKM, and final laboratory grades. Additionally in one instance students in BIOL 3220 had higher final lecture grades than did students in the control group. Though it should be noted that concept mapping in the lecture should have been strongly supported by both the researcher and the instructor of the course. It is safe to say that using a study guide composed of concept mapping and Vee heuristic as metacognitive tools may promote successful learning.

Recommendations

Regarding future studies, there a number a changes that can be made in order to ensure full cooperation from students. I would begin by first having professors who truly believed in using concept mapping and Vee heuristic in their classrooms be the persons to introduce it to their students. An introduction by a professor, I believe will help strengthen the validity of these methods with students. Students consider their teachers as experts in their respective fields, therefore an outward acceptance of concept mapping and the Vee heuristic would promote continued use. Additionally, concept maps and Vee heuristic questions should be apart of the laboratory notebook for the course, instead of an additional packet that students are given. Allowing the concept maps and Vee heuristic to become part of the laboratory book, provides a sense of inclusion instead of it being something additional that students feel they must to use. I found that many students viewed the study guide as more intrusive to their lives than of a normal part of the learning experience. In a future study control groups could be given access to the study guide, however they would receive no formal instruction nor help from a knowledgeable instructor. Students in all groups should be required to report on their study habits through the course of the research, allowing investigators to account for differences in assessment scores.

When attempting to measure students learning this study used various assessments along with factors that included mid-term and final examination. However, in review of the study researchers should take into account the difference in questions asked by professors on the examinations. Researchers must note the differences between questions of knowledge versus those of understanding. Researchers must also contend with students' belief when attempting to expose them to scientific knowledge. The prevalence of beliefs became grossly apparent when reading many of the responses written by students in the section of "where did you learn this?" of the PKM. For example, some students responded to the question "Would you take antibiotics for a cold?" yes, and when asked why many responded with the answer that this was the only way to get rid of a cold. Instructors must find a way to break the barrier of belief in order to help improve scientific learning.

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Appendix A (PKM)

Public Knowledge about Microbiology Survey

The goal of this survey is to determine if your knowledge about microbiology matches that of the general public. Please take a few minutes to answer the following questions. For each item, circle the letter corresponding to the response you select, a-d. Following each item you are asked to identify the source of the learning. Write your response in the space provided.

1. What are bacteria?
   a. Single cell organisms that can either help or harm an individual
   b. Small microbes that interfere with the body's normal processes
   c. Germs that can cause the body to become very sick.
   d. Things that make you very sick and cause the body problem.

   Where did you learn this information? ________________________________
   ____
   ____

2. Why is the overuse of antibiotics bad?
   a. Kills natural microflora of the body
   b. Bacteria will become resistant.
   c. Body can adjust, therefore cellular receptors will not respond.
   d. Viruses will become resistant.

   Where did you learn this information? ________________________________
   ____
   ____

3. Would you take antibiotics if you had a cold?
   a. No, cold is a virus, and cannot be treated with antibiotics
   b. Yes, but there is no need to finish them.
   c. No, because the body will fight them off.
   d. Yes, they will help the body fight against the cold.

   Where did you learn this information? ________________________________
   ____
   ____

4. What do you think of when I say E. Coli?
   a. A food borne illness.
   b. A disease found only in cows.
   c. Bacteria that causes people to become sick.
   d. G.I. tract bacteria, found in different environments

Where did you learn this information? ______________________________________
____
____

5. What is a virus?
   a. Something that makes you sick.
   b. A non-living organism that invades cells and can make you sick.
   c. Something that will stay with you forever.
   d. A strand of bacteria that can be treated antibiotics.

   Where did you learn this information? ______________________________________
   ____
   ____

6. What do you think of when you see the word MRSA?
   a. An antibiotic resistant strain of viruses.
   b. An antibiotic resistant strain of bacteria.
   c. A type of test performed in microbiology labs.
   d. A type of infection when the body's cells are out of control.

   Where did you learn this information? ______________________________________
   ____
   ____

Appendix B (GKM)

MICROBE STUDY SURVEY

Thank you for participating in this survey. The goal of this survey is to examine how taking a course in microbiology influences your knowledge, attitudes, and behaviors. Your participation is voluntary and if at any point you become uncomfortable answering the questions you may stop taking the survey. Your participation in this survey will help educators design better biology education courses and educational materials.

Participant Information

Name:____

Directions: Read each of the following items and circle the letter corresponding to the best response.

1. Antibiotics are typically prescribed by medical professionals to kill which of the following:
   a. Viruses
   b. Bacteria
   c. Fungi
   d. Fungi & Bacteria
   e. Bacteria & Viruses

2. A rod shaped microbe would be a:
   a. bacterium
   b. coccus
   c. spirillum
   d. bacillus

3. A method of asexual reproduction in bacteria in which the cell splits into two parts, each of which develops into a complete individual.
   a. meiosis
   b. binary fission
   c. vectored splitation
   d. inverse kinematics

4. The act of introducing disease germs or infectious material into an area or substance.
   a. attenuation
   b. infection
   c. contamination
   d. virulence

5. The state or condition in which the body or a part of it is invaded by pathogenic agents.
    a. contamination
    b. virulence
    c. acute
    d. infection

6. A foreign substance that stimulates the formation of antibodies that interact specifically with it:
    a. antibody
    b. antisepsis
    c. antigen
    d. antagonism

7. An organism that transmits a pathogen is called a:
    a. fomite
    b. vector
    c. contagion
    d. parasite

8. Infection caused by germs lodging and multiplying at one point in a tissue and remaining there.
    a. local infection
    b. general infection
    c. mixed infection
    d. endemic infection

9. Bacteria that prefer cold, thriving at temperatures between zero degrees centigrade and twenty five degrees centigrade.
    a. mesophile
    b. psychrophile
    c. thermophile
    d. facultative bacteria

10. A microbe that can only live in the presence of oxygen
    a. Strict (obligate) anaerobe
    b. Strict (obligate) aerobe
    c. Strict (obligate) parasite
    d. Strict (obligate) saprophyte

11. A microbe that can only survive in an area without oxygen present.
    a. strict (obligate) aerobe
    b. strict (obligate) anaerobe
    c. strict (obligate) parasite
    d. strict (obligate) saprophyte

12. Dilution or weakening of virulence of a microorganism, reducing or abolishing pathogenicity.
    a. sterilization
    b. disinfection
    c. antisepsis
    d. attenuation

13. An inanimate object to which infectious material adheres and can be transmitted.
    a. fomite
    b. vector
    c. arthropod
    d. antigen

14. A living organism or an object that is capable of transmitting infections by carrying the disease agent on its external body parts or surface.
    a. fomite
    b. mechanical vector
    c. heterotrophic bacteria
    d. parasite

15. An organism that exists as a part of the normal flora but may become pathogenic under certain conditions
    a. normal flora
    b. opportunist
    c. mycoplasma
    d. secondary infection

16. A disease that may be transmitted directly or indirectly from one individual to another.
    a. acute disease
    b. primary infection
    c. secondary infection
    d. communicable disease

Appendix C (IRB Approval)

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building• 600 Moye Boulevard • Greenville, NC 27834
Office **252-744-2914** • Fax **252-744-2284** • **www.ecu.edu/irb**

TO: Frank Crawley, PhD, Dept. of Mathematics, Science, and Instructional Technology, ECU—Mailstop 566

FROM: UMCIRB

DATE: August 19, 2011

RE: Expedited Category Research Study

TITLE: "Use of Conceptual and Procedural Knowledge Mapping to Improve Learning in a Lecture-Lab Microbiology Course"

UMCIRB #11-0518

This research study has undergone review and approval using expedited review on 5.19.11. This research study is eligible for review under an expedited category number 6 & 7 which include collection of data from voice, video, digital, or image recordings made for research purposes. It is also a research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)
The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of **8.19.11** to **8.18.12**. The approval includes the following items:

- Internal Processing Form (received date 8.17.11)
- Research Proposal (received date 8.17.11)
- Informed Consent (version date 8.19.11)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418
IRB00004973 East Carolina U IRB #4 (Behavioral/SS Summer) IORG0000418
Version 3-5-07

UMCIRB #11-0518
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Appendix D (Example Laboratory Experiment)

Lab: Effectiveness of Hand Scrubbing

Learning Objectives:

- **Evaluate the effectiveness of hand washing**
- **Look at the differences between soap and alcohol based sanitizers**
- **Explain the importance of aseptic technique in the hospital environment**

Materials: per pair:

- **Two TSA plates**
- **Soap**
- **Alcohol based sanitizer or alcohol prep pad**

Introduction & Background:

The skin is a sterile during fetal development. After, birth a baby's skin is colonized by many bacteria for the rest of his or her life. As an individual ages and changes environments, the microbial population present upon the skin changes to match the environmental conditions. The microorganisms that are more or less permanent are called normal microbiota, or more generically, normal flora. Microbes that are present for only a few days or weeks after they are acquired are called transient microbiota or flora.

Hand washing is an important aspect of aseptic technique. In fact the CDC indicates that it is the single most important aspect in controlling nosocomial(hospital-acquired) infections. However, recent studies indicate handwashing rates in hospitals are as low as 31%. Ignaz Semmelweis, a physician at Vienna General Hospital in Austria, recognized a connection between autopsies and puerperal sepsis (childbirth fever) in the 1840's. He noted that infection rates were much lower when midwives worked alone; however, when the medical students left the gross anatomy labs to help, infection rates went up. So he required the medical students to wash their hands before assisting with deliveries, and the infection rates subsequently went back down. Many physicians in the mid 19th Century went directly from performing autopsies to examining women in labor without so much as washing their hands. Semmelweis established a policy for the medical students of handwashing with a chloride of lime solution that resulted in a drop in the infant death rate due to puerperal sepsis from 12% to 1.2% in one year. When Dr. Semmelweis attempted to encourage more sanitary practices among the physicians, he was ridiculed and harassed until he had a nervous breakdown and was sent to an asylum. Ultimately, he suffered the curious irony of succumbing to an infection caused by the same organism that produces puerperal sepsis (or so the story goes). Joseph Lister, a British surgeon, also made important contributions to the concept of hand washing and surgical procedures. "Hospitalism", as the diseases septicemia, erysipelas, and pyemia began to collectively be known was the root of the overwhelming mortality rate in the hospital setting in the early and mid 1800's. Joseph Lister was aware of this, and he studied the works of other prominent scientists to learn that the infections were not caused by a chemical reaction, or an oxidation, that occurred when oxygen touched the wound, but by tiny organisms from the air.

The problem that vexed Lister the most was that of infections following compound fractures, a fracture in which the skin is broken and the bone exposed. Such a malady required surgery and had an extremely high mortality rate, especially when the individual remained in the hospital following the surgery. After learning of Louis Pasteur's work and doing his own experiments, Lister knew that he needed to keep the wound free of the microbes that were causing the infections. Joseph Lister had heard of carbolic acid (phenol) being used to remove the odors from sewage and decided to try to use it on a small boy with a compound fracture of his leg. The wound did not become infected following surgery and the only injury was burns to the boy's skin resulting from exposure to the phenol. Subsequently, Lister disinfected his surgical instruments in phenol and even performed surgeries under a mist of phenol. He even used these techniques for the removal of abscesses, a surgery considered an unnecessary risk during those days. Lister's survival rate was astonishing and other surgeons and professionals began to pay notice. For his work, Lister is commonly referred to as the "Father of Antisepsis".

A layer of oil and the structure of skin (cresses and crevices due to folding) prevent the removal of all bacteria by hand washing. Soap helps remove the oil, and the scrubbing action maximizes the removal of bacteria. Most hospital procedures require personnel to wash their hands before attending a patient, and a complete surgical scrub – removing the transient and many of the resident normal flora – is done before surgery. Around 10-15 minutes of scrubbing with soap usually removes most of the transient flora; however, it is important to note, the surgeon's hands are never sterilized. Only burning it or scraping it off could achieve that. In today's health care environment hand washing and aseptic technique are recognized and established procedures as the relationship between microbes and infection is now without question.

Effectiveness of soap and water versus alcohol based sanitizers

Note: each student in the pair will perform one of the procedures listed below:

Procedure I:

1. Divide your TSA plate into four separate quadrants (1-4) as outlined in your data sheet.
    a. The numbers will correspond to:
        i. 1- uninoculated
        ii. 2 – water only
        iii. 3- soap and water
        iv. 4- soap and water followed by drying
2. Lightly touch your two middle fingers to the quadrant labeled #1
3. Wash your hands lightly for about 30 seconds with just water and without drying your hands, touch your dry middle and index fingers of your right hand to the second quadrant
4. Wash your hands briskly for about 30 seconds with soap and water and without drying your hands, touch your dry middle and index fingers of your right hand to the third quadrant
5. Wash your hands briskly for about 30 seconds with soap and water and now dry your hands with paper towels. Touch your dry middle and index fingers of your right hand to the fourth quadrant

Procedure II: Comparison of different hand cleaning methods

1. Divide a TSA plate into 5 quadrants

2. Rub your fingers on a contaminated surface (lab bench, clothing, your arm, etc…) and touch quadrant I.
3. Moisten a paper towel with tap water and rub the right index finger on the wet towel for 20 seconds, - blot dry, and then touch quadrant-2.
4. Rub the right middle finger on an alcohol wipe for 20 seconds, - rinse it off, - blot dry, and then inoculate quadrant-3.
5. Moisten a paper towel and put some antibacterial soap on it , then rub the right ring finger for 20 seconds on the soap spot, - rinse it off, - blot dry and then inoculate quadrant-4.
6. Procure some alcohol sanitizer, rub between your fingers thoroughly, and touch your thumb to quadrant 5

Procedure III: Evaluation of hand washing efficacy: one student in each pair will use the Glo germ liquid

1. Have your partner apply 2-3 drops of Glo Germ® lotion to your hands – work around fingernails, between fingers up to your wrists on both sides. Also, scratch the palms with your fingernails
2. Expose your hands under the UV lightboard to see the extent of Glo germ coverage.
3. Have your lab partner turn on the water and apply soap to your hands. Wash hands thoroughly for at least 30 seconds. Use a fingernail brush if one is provided.
4. When you are finished, have your lab partner turn off the water and hand you a paper towel.
5. Dry your hands, and reexamine under the UV lightboard on the back lab bench.

Questions:
1. What is a surgeon trying to accomplish with a surgical scrub?

2. How do normal and transient microbiota differ?

3. If most of the transient and normal flora found on the hands are not harmful, then why must hands be scrubbed before surgery?

4. Which procedure would you predict to be more cleansing: (A) a 2-3 minute scrub with soap and water, or (B) 15-20 second scrub with an alcohol based sanitizer? Why?

MicroLab Data Sheet: Effectiveness of Hand Scrubbing

Record your results for the soap and water handwashing experiment below. Record the growth as (-) = no growth; (+) = minimal growth; (2+) = moderate growth; (3+) = heavy growth; and (4+) = maximal growth

Treatment	Relative Growth/Results
1- uninoculated	
2- soap	
3- soap and water	
4-soap and water/drying	

1- What type of results did you expect before the viewing of your plate?

2- Did your actual results correlate with your expected results? Why or why not?

Record your results for the alcohol sanitizer handwashing experiment below. Record the growth as (-) = no growth; (+) = minimal growth; (2+) = moderate growth; (3+) = heavy growth; and (4+) = maximal growth

Finger/Treatment	Relative Growth/Results
Unwashed/ all finger touch	
Index – water only	
Middle – alcohol wipe	
Ring – antibacterial soap	
Thumb – alcohol sanitizer	

3- Which treatment, if any, was the most effective compared to the unwashed section of your plate from Procedure I?

4- Which treatment, if any, was the most effective compared to the unwashed section of your plate from Procedure II?

5- According to your results with the GloGerm liquid, how effective was your handwashing? Justify your answer.

Appendix E (3221 Microbiology Study Guide)

Microbiology Study Guide
BIOL 3221

Maurice Smith

2011

Table of Contents

Microbiology Study Guide

The purpose of this study guide is to introduce you to two study aids (Concept Mapping and the Vee Heuristic) that have been pilot-tested with students enrolled in microbiology classes at ECU. Both of these methods were field-tested with microbiology lab classes during the Spring Semester and Summer Session 1, 2011. Nursing majors used concept mapping and found that its use greatly improved their understanding of key microbiology concepts taught in lecture and in the laboratory section of the course. The mechanics of using the Vee Heuristic proved problematic and it was revised during the Summer Session with the help of nursing majors. The sections that follow explain how these two study aids are to be used during the microbiology laboratory courses this semester, for both nursing and biology majors.

Concept mapping has been used for more than 25 years in high school and college science courses with much success. It has been used as a learning tool in college-level biology, chemistry, and physics courses and more recently in cellular and microbiology courses. Concept mapping provides users with a visual road map and a schematic summary of newly learned concepts through the use of propositional linking phrases and hierarchical arrays. There are several rules to consider when making concept maps and these rules are discussed on the paragraphs that follow.

This study guides contains a series of questions that will help you understand the reason for completing the laboratory investigation. These questions consist of pre-lab (4) and post-lab (5) questions and are derived from another education method that has been used with great success in several laboratory-based classes. The questions stem from an educational tool called the V-diagram, which connects concepts covered in class with experiments done in lab. For our purpose we will be using these questions as a way to see what concepts, principles and ideas you are familiar with before being taught the material (this gives you a chance to recognize what you know and don't know yet), and how your ideas have changed after the lecture and lab investigation. For each laboratory investigation you are asked to answer these questions to the best of your abilities without using any in class text. Remember there is no right or wrong answer.

A guide to concept mapping

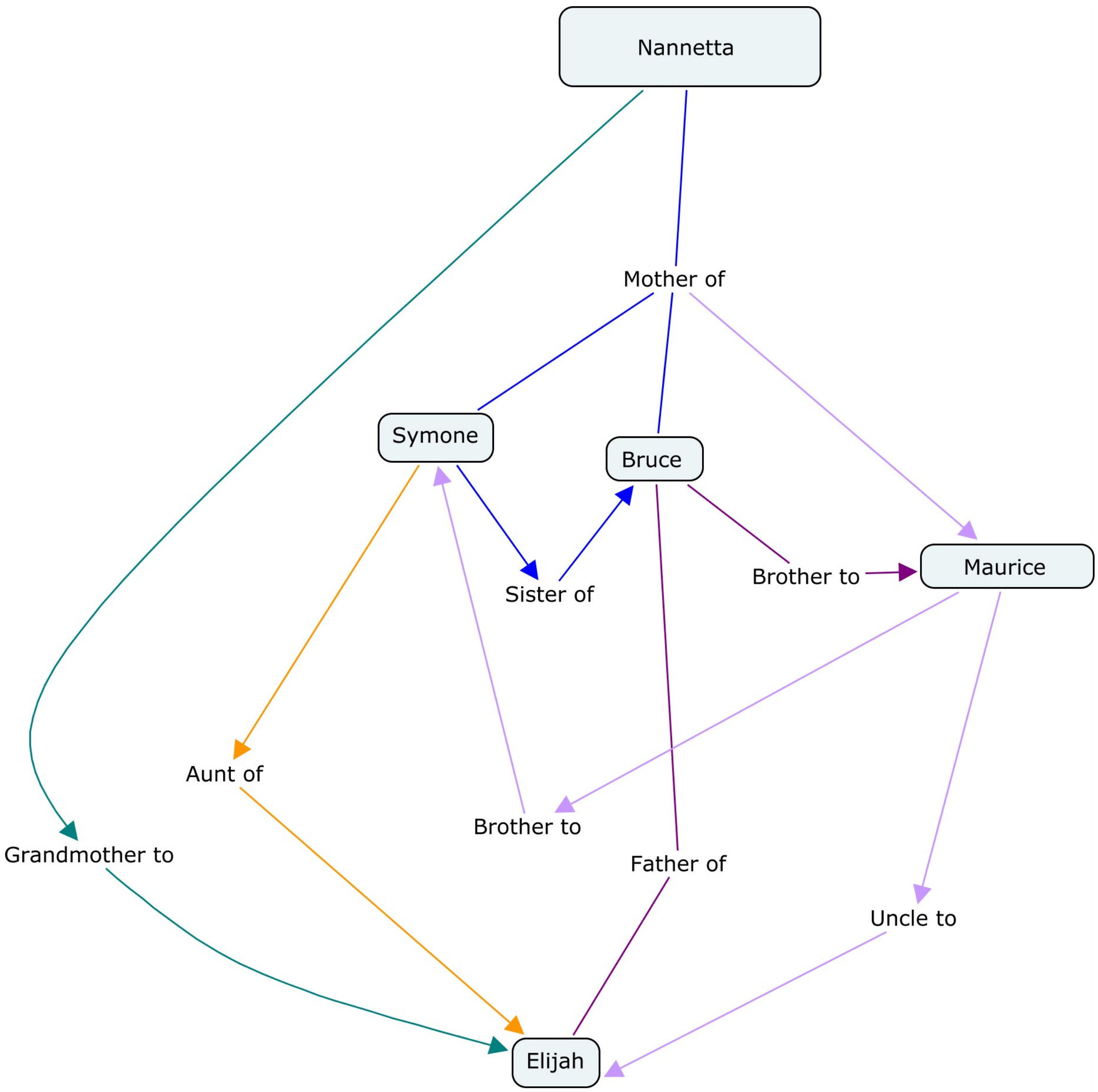
What is the definition of a concept and concept mapping? A concept is a regularity in events or objects designated by some label. Concept maps consist of several concepts intended to represent meaningful relationships between concepts in the form of propositions. Propositions are two or more concept labels linked by words in a schematic unit. A concept map represents meaningful relationship among a group of related concepts forming a hierarchical array.

There are some simple but important rules to follow, when one is constructing a concept map:

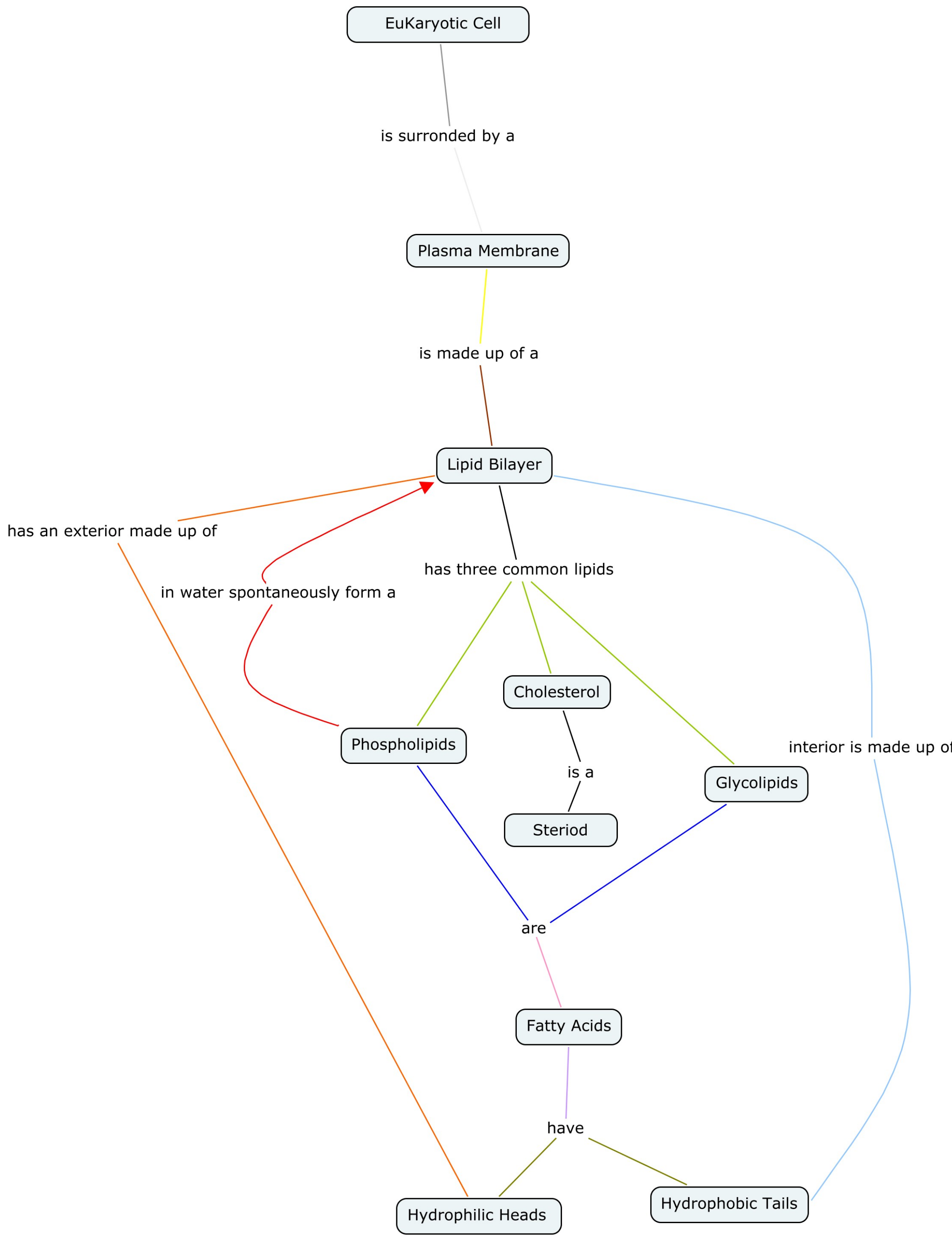
1. Consider all topics, concept, and procedures (media, end-products, and techniques) taught in class that day.
2. Arrange these concepts in a hierarchy, with the most inclusive at the top and the most specific at the bottom.
3. Begin the concept map, by putting the most inclusive concept/procedure at the top above the rest of the concepts, preferably in the middle.
4. With lines and linking phrases connect one concept to the next. Make sure when writing your linking phrases, that the proposition is valid and fully but briefly explains the connection.
5. Attempt to look for cross-links between concepts from one section to concepts in another section.
6. Concept maps can be rearranged to make the most sense for you, just ensure that your connections make sense.

*On the next page, there is an example of a concept map for you to refer to.

Concept Map Example 1: My Family Tree



Concept Map Example 2: Cell Membrane



Epidemiology
Pre-lab Vee Heuristic Questions

These questions will be used to get a sense of what you know before your laboratory instruction. Remember to not use any laboratory text, and instead answer the questions as brief but as complete as possible.

1. What is the general purpose of this investigation?

2. Why is this lab investigation important?

3. How will you perform today's lab investigation?

4. What will you learn today?

Epidemiology
Pre-lab Concept Map

Create two concept maps, one based on the lecture materials covered in your class today and one based on the laboratory procedures.

Lecture Concept Maps

Laboratory Concept Maps

Epidemiology
Post-lab Vee Heuristic Questions

These questions will be used to get a sense of what you know before your laboratory instruction. Remember to not use any laboratory text, and instead answer the questions as brief but as complete as possible.

1. What was the general purpose of this investigation?

2. Why is this lab investigation important?

3. How did you perform today's lab investigation?

4. What did you learn today?

5. How has your concept map changed, since the lab investigation?

Epidemiology
Post-lab Concept Map

Using the concepts and/or procedures that you learned today; construct a concept map to the best of your abilities.

Laboratory Concept Map

Appendix F (Micro 2111 Concept Map Attitude Survey)

The 2111 Microbiology Survey for Fall 2011

The following survey was constructed to determine you attitude towards the microbiology study guide. I have noticed that only a few nursing majors make use regularly of the study guide in their work. Your response to this survey will help me understand study guide use and to better work to support your learning in the Microbiology course. Please read each question and circle the number that corresponds to your feelings, then provide a brief explanation for your attitude.

Question 1: I feel that the study guide has helped me prepare for Microbiology laboratory and class.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

Explain:____

____

Question 2: Answering the pre/post Vee Heuristic questions helps me determine the core principle each laboratory investigation is testing.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

Explain:____

____

Question 3: Constructing pre/post concept maps helps me map out my understanding of the core concepts covered in lecture and laboratory.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

Explain:____

____

Question 4: Constructing pre/post concept maps helps me determine any inaccuracies in my understanding of microbiological concepts.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1	2	3	4	5

Explain:____

____

Appendix G Vee diagram