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## Development of a Concept Exploration Based Teaching Methodology for Undergraduate Chemistry Education

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DEVELOPMENT OF A CONCEPT EXPLORATION BASED TEACHING  
METHODOLOGY FOR UNDERGRADUATE CHEMISTRY EDUCATION

by

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A DISSERTATION

Submitted to the graduate faculty of The University of Alabama at Birmingham,  
in partial fulfillment of the requirements for the degree of  
Doctor of Philosophy

BIRMINGHAM, ALABAMA

2014

# DEVELOPMENT OF A CONCEPT EXPLORATION BASED TEACHING METHODOLOGY FOR UNDERGRADUATE CHEMISTRY EDUCATION

NICOLE GRAY

INTERDISCIPLINARY ENGINEERING

## ABSTRACT

Science in general has traditionally been noted as a difficult subject because of its specialized language, mathematical and abstract concepts, and the amount of content to be learned in a semester. In particular, students are believed to base their attitudes towards science-related disciplines on their perceived abilities in understanding or succeeding in a course. Other factors may also contribute to this lack of interest, such as students' metacognitive skills. Concept mapping and computer-aided tools may be used to assist students in building hierarchical knowledge bases that allow them to visually represent connections between concepts. Therefore, the purpose of this study was to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course.

This study consisted of three phases of implementation (control, treatment 1, and treatment 2 groups) over a three semester period. Phase 1 consisted of the control group, phase 2 consisted of the first treatment group with the addition of the four concept mapping homework assignments in the curriculum and phase 3 consisted of the second treatment group with the integration of the same four concept mapping assignments as phase 2 with the addition of using the Creonto "Intro Chemistry" ontology software.

Students in all three phases were assessed using standardized examination questions that were based on the four concept mapping topics and pre- and post- surveys administered at the beginning and end of the semester. Students in phase 2 and 3 groups were also assessed from their constructed concept maps to measure their abilities to explain connections between key concepts.

The results of this study suggest that students who created concept maps using the Creonto “Intro Chemistry” software performed better on exams and were able to make more connections when creating concept maps compared to students who did not create concept maps or use computers to assist them. For the exams, there was a statistically significant difference between treatment groups’ exams 1 and 3 mean scores. For the concept maps, there was a statistically significant difference in students’ abilities to explain connections between key concepts. There was no statistically significant difference in attitudes toward chemistry between groups in this study. However, there was a significant statistical difference in metacognitive skills between the groups. More research is needed to gain a better insight into factors that might have affected students in the course.

**Keywords:** Chemistry education, Concept Mapping, Ontology, Attitudes towards chemistry, Metacognitive skills

## ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Craig McClure for his effort and support with this avenue of chemistry education research that we took on together. It was a learning experience for me and an opportunity to gain some new skills that I will bring along with me throughout my career.

I would like to thank Dr. Scott Snyder for providing advice along the way and being as enthusiastic about the study as I was. His support and statistical expertise was very much appreciated. I also would like to thank Dr. Alan Shih for providing continuous support and for his connections to Dr. George Koomullil. Many thanks go to Dr. George Koomullil and his staff, notable Nikhil Chhaochharia without them none of this would have been possible. I would also like to thank Dr. Peter Walsh for stepping in when I needed him the most. A special thanks also goes to all of the students who participated in this study. Additionally to all my committee members, thank you for all your essential feedback during meetings and advisements to continue keeping the ball rolling with this study.

Thank you to Dr. Louis Dale for his support and encouragement throughout my graduate studies and to Mr. Elijah Nyairo for constantly pushing me to “keep moving forward”. Additional thanks to the School of Engineering, the Department of Mechanical Engineering, and the Department of Chemistry. Lastly, but certainly not least, I would like to thank God, my husband, and family for all of their support and being a shoulder to lean on.

## TABLE OF CONTENTS

	Page
ABSTRACT .....	ii
ACKNOWLEDGMENTS .....	iv
LIST OF FIGURES .....	ix
LIST OF TABLES .....	x
LIST OF ABBREVIATIONS .....	xii
CHAPTER	
1 INTRODUCTION .....	1
Computerized Search .....	13
2 BACKGROUND AND LITERATURE REVIEW .....	15
Learning Chemistry .....	15
Attitude Towards Chemistry .....	16
Science self-efficacy and its relationship to attitudes .....	23
Metacognition .....	32
Concept Mapping as a Tool for Subject Learning .....	39
Concept Mapping as an Assessment Tool .....	41
Concept Mapping as Learning Tools .....	46
Creating Concept Maps with the aid of Computers .....	50
Ontologies for Conceptual Learning .....	55

3 RESEARCH PLAN .....	63
Course and Participants .....	64
Research Design .....	65
Phase 1 .....	65
Phase 2 .....	66
Phase 3 .....	67
Statistical Analysis .....	67
RQ1 and RQ2.....	68
RQ3-RQ5 .....	68
RQ5 and RQ6.....	68
Summary of Research Plan .....	70
4 STUDENT SURVEY .....	72
Content Validity.....	73
Panel of Experts .....	73
Qualitative Review.....	73
Quantitative Review.....	77
Survey Reliability .....	82
5 CONCEPT MAP WORKSHOP .....	85
6 CREONTO ONTOLOGY SOFTWARE.....	91
Creonto Ontology Development .....	91
Creonto Software Interface for Students.....	96
7 RESULTS .....	100
IRB Approval.....	100

Equivalency of Groups .....	101
Attitudes towards Chemistry Survey Results .....	102
Control group pre- and post- attitude.....	102
Treatment 1 group pre- and post- attitude .....	102
Treatment 2A group pre- and post- attitude.....	103
Treatment 2B group pre- and post- attitude.....	103
Attitudes towards chemistry comparison results .....	104
Metacognitive Skills Survey Results .....	105
Control group pre- and post- metacognitive skills.....	105
Treatment 1 group pre- and post- metacognitive skills .....	105
Treatment 2A group pre- and post- metacognitive skills.....	106
Treatment 2B group pre- and post- metacognitive skills.....	106
Metacognitive skills comparison results.....	107
Concept Map Assignments Results .....	108
Concept map grading rubric reliability .....	109
Concept map keywords comparison results.....	111
Concept map connections/relationships comparison results.....	112
Attitudes towards Concept Maps .....	114
Examinations Comparison Results .....	115
Inter-rater reliability for examinations.....	115
Examinations multiple choice comparison results.....	118
Examinations short answer comparison results .....	120
Time Completing Assignments Comparison Results .....	122



Attitudes towards Creonto Software and Log-in Data.....	124
Creonto “Intro Chemistry” Log-in.....	125
8 DISCUSSION, LIMITATIONS, CONTRIBUTIONS, AND FUTURE WORK.....	127
Discussion.....	127
Attitudes towards chemistry results discussion .....	127
Metacognitive skills results discussion.....	129
Concept mapping assignments results discussion.....	132
Attitudes towards concept maps results discussion .....	133
Examinations comparison results discussion.....	134
Time completing assignments results discussion .....	135
Attitudes towards Creonto software results discussion .....	136
Limitations of Study .....	137
Contributions.....	139
Future Work .....	142
REFERENCES.....	145
APPENDIX.....	152
A IRB Approval & Student Survey .....	152
B Exams .....	156
C Concept Map Workshop Handouts .....	162
D Creonto “Intro Chemistry” Instructional Sheet.....	167
E Expert Panel Validity & Reliability Instructions.....	171
F Concept Mapping Assignments .....	174

## LIST OF FIGURES

Figure	Page
1 Schematic of Bloom’s Taxonomy for educational objectives .....	31
2 Example of the concept map “Car” from concept map workshop.....	88
3 Student group “Flower” concept map .....	89
4 Graphical user interface to create book in Creonto.....	92
5 List of chapters added to the “Intro Chemistry” book .....	93
6 Energy concept map integrated into Creonto.....	94
7 Interface used to edit concepts .....	95
8 “Intro Chemistry” book added to Creonto library.....	96
9 “Intro Chemistry book’s table of content.....	97
10 “State of Matter” topic in the “All About Matter” chapter .....	98
11 Related concepts tag cloud for “state of matter” .....	98
12 Mean hours spent on assignments comparison .....	124

## LIST OF TABLES

Table	Page
1 Statistics used to analyze research questions .....	70
2 Qualitative review revisions for Attitude section .....	74
3 Qualitative review revisions for Metacognitive section .....	75
4 Qualitative review revisions for Learning Resource .....	76
5 Minimum values of CVR for items at the $p > 0.05$ level .....	78
6 Quantitative content validity results for attitude section .....	79
7 Quantitative content validity for metacognitive skills section .....	80
8 Quantitative content validity for learning resource items .....	81
9 Test-retest survey reliability measurements .....	83
10 Internal consistency survey reliability measurements .....	84
11 Tips on constructing concept map .....	88
12 Pre-calculus mean score equivalency data .....	101
13 Attitude towards chemistry mean scores .....	104
14 Metacognitive skills mean scores .....	108
15 Inter-rater reliability concept map agreement scores .....	110
16 Keywords mean scores comparison .....	112
17 Concept map connections mean scores .....	113
18 Inter-rater reliability scores for exam rubric .....	117
19 Mean multiple choice scores .....	119

20 Mean short answer scores .....	120
21 Control short answer comparison significance .....	121
22 Treatment 1 short answer comparison significance .....	122
23 Actual number of students reported hours spent on assignments .....	123
24 Hours spent on assignments mean scores .....	123
25 Attitudes towards Creonto frequency table.....	125
26 Creonto “Intro Chemistry” log-in data.....	125

## LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CVR	Content Validity Ratio
DV	Dependent Variable
IRB	Institutional Review Board
IV	Independent Variable
n	Number of participants
M	Mean
RQ1	Research Question 1
RQ2	Research Question 2
RQ3	Research Question 3
RQ4	Research Question 4
RQ5	Research Question 5
RQ6	Research Question 6
RQ7	Research Question 7
RQ8	Research Question 8
SD	Standard Deviation
Treatment 2A	Treatment 2 (1 <sup>st</sup> section) group
Treatment 2B	Treatment 2 (2 <sup>nd</sup> section) group

## **CHAPTER 1**

### **INTRODUCTION**

In college, students are expected to take a major role in their learning process, be self-motivated, assess their learning strategies, and self-diagnose and modify any learning discrepancies they may have (Nordell, 2009). The development of students' scientific literacy is not only essential for them to succeed in a course but also a critical skill in grasping the knowledge of real world issues (De Avila Jr & Torress, 2010). This is definitely true when taking chemistry courses. Chemistry courses are often regarded as a difficult subject and are traditionally noted as being very hard to understand (Tai, Sadler, & Loehr, 2005). Most students who enroll in introductory chemistry courses may not fully understand the subject matter, and therefore may draw their own conclusions about the subject based on their own current knowledge base (Nakhleh, 1992; Pekdag, 2010). As a result, educators and researchers are spending significant time to discover innovative ways to enhance their teaching methodology to make the learning process engaging and easier to understand for their students.

Several studies in science education have investigated students' attitudes towards chemistry as being a predictor of their academic success in chemistry courses (Brandriet, Xu, Bretz, & Lewis, 2011; Kan & Akbas, 2006; McCarthy & Widanski, 2009). According to McCarthy and Widanski, students' negative attitudes towards chemistry may decrease their appreciation of the subject and result in a decline in enrollment of students in chemistry related careers (2009). Brandriet, Xu, Bretz, and Lewis (2011)

examined changes in student attitudes in two general chemistry courses and their results revealed that A and B students' attitudes significantly increased from the beginning to the end of the semester. However, D and F students' attitudes significantly decreased by the end of the semester while C students' attitudes remained the same. Therefore, their study indicated that there may be a correlation between attitudes and success in general chemistry. In another study, Bauer (2008) examined non-chemistry major students' attitudes towards chemistry using the Attitude toward the Subject of Chemistry Inventory (ASCI) survey. His study revealed that the non-chemistry majors' attitudes towards chemistry shifted from being less anxious and fearful to being more emotional and intellectually satisfied with general chemistry (Bauer, 2008). Walczak & Walczak (2009) interviewed students in a general education chemistry course about their attitudes towards science over the semester and reported that students who demonstrated a negative attitude shift indicated their frustration with their own ability to perform well in the course. With these prior studies, changes in attitudes were measured not only on the participants' attitudes towards the chemistry instruction but on the subject of chemistry. These studies revealed that students based their attitudes towards chemistry on their perceived abilities in understanding course content or succeeding in the course.

Self-efficacy is a students' belief in their own abilities to succeed at a task or in a discipline (Williams, Kurtek, & Sampson, 2011). Several studies have observed that self-efficacy is associated with the changes in students' attitudes towards the sciences (Britner, 2008; Kan & Akbas, 2006; Lawrenz, Wood, Kirchhoff, Kim, & Eisenkraft, 2009; Marra, Rodgers, Shen, & Bogue, 2009). In particular, a low science self-efficacy may contribute to a student's lack of interest or perceived lack of abilities in the sciences

(Dalgety & Coll, 2006b). Lawson, Banks, and Logvin (2007) compared self-efficacy and reasoning ability to achievement in biology using pretest and posttest self-efficacy science-oriented task questions. The results indicated that both self-efficacy and reasoning ability increased during the semester from the pretest to the posttest self-efficacy ratings. Also self-efficacy estimates were found to have a correlation with achievement for students who were able to complete concrete tasks (2007). Dalgety and Coll (2006) examined factors such as learning experiences, attitude toward chemistry, and chemistry self-efficacy that influenced students' chemistry enrollment choices using the Chemistry Attitudes and Experiences Questionnaire (CAEQ). The results showed that there was no clear relationship between students' learning experiences and their enrollment intentions to continue to take additional chemistry courses. However, the results indicated a relationship between chemistry self-efficacy and enrollment intentions for students who were academically successful in the chemistry course (Dalgety & Coll, 2006b). In another study conducted by Britner (2008), the author examined science self-efficacy beliefs between students in life, physical, and Earth science classes using several different assessments. In the Earth science classes, girls had higher course grades and reported stronger self-efficacy. In the life science classes, girls also earned higher course grades than boys but the scores did not correlate with girls having a stronger self-efficacy related to science activities. However, in the physical science classes, the girls and boys both had equally reported final course grades and self-efficacy (Britner, 2008).

Therefore, self-efficacy may significantly predict a students' achievement in science courses and thus contribute to their attitudes towards the sciences. Since self-efficacy is the beliefs that a student has about their abilities, if a student has a low self-efficacy that



contributes to their negative attitude about chemistry it may result in their lack of motivation towards learning chemistry and succeeding in a chemistry course (Reid, 2008).

Although students' attitudes towards chemistry have been shown to have an influence on achievement in chemistry, there are other factors which may contribute to this issue such, as rote learning. Previous research has shown that many students learn science concepts by using rote learning which focuses on memorization by repeating the items being studied over and over without actually considering or relating the meaning of the information (BouJaoude & Barakat, 2003; Brandt, et al., 2001; Cooper, Grove, Underwood, & Klymkowsky, 2010; Danipog & Ferido, 2011; Nakhleh, 1992). When students use rote learning they are just memorizing the information and therefore are not able to gain the complex knowledge needed to understand the concepts. According to Vachliotis, Salta, Vasiliou, & Tzougraki (2011), rote learning occurs when students are not able to relate new information to existing knowledge. Therefore, one way in which to improve the learning process for students is to encourage them to use meaningful learning. Meaningful learning is when the learned knowledge is fully understood and a student is able to relate that knowledge to prior knowledge (Ebenezer, 1992). In other words, students who are able to make connections between new and prior information, build relationships between concepts, and integrate new knowledge are considered to be learning meaningfully (Danipog & Ferido, 2011). When one learns in this manner, he/she is able to recall the information and is able to link it to related information to give them a better understanding of the topic.

In college, students are expected to possess metacognitive skills which allow them to self-assess and determine whether or not their understanding of a topic is adequate enough to complete the task at hand. These metacognitive skills fall into three categories: plan, monitor, and evaluate. Students who are able to possess these skills are said to have good metacognition (Rahman, Yasin, Ariffin, Hayati, & Yusoff, 2010). However, some students without knowledge in the subject may not be able to identify these skills and determine if their understanding of a topic is sufficient. According to Nordell, some students are able to identify the information in their notes or textbook and understand the basic information but do not know how to analyze or connect this information to use in other contexts (Nordell, 2009). This statement explains how metacognition goes hand-in-hand with cognition. Cognitive skills are used when a student acquire, retain, and transfer that knowledge to complete a task at hand. While metacognitive skills are used when a student is planning, monitoring, and evaluating that information to complete the task (Ku & Ho, 2010).

Metacognition in chemistry is essential because it may provide a way for students to become familiar with their own thinking processes and acquire a deeper understanding of the concepts taught in the curriculum (Cooper, Urena, & Stevens, 2008). For example, metacognition can be observed when students are trying to solve a problem and ask questions such as: “How might this topic relate to me?” or “What do I already know about this topic?” (Lai, 2011; Nordell, 2009). Ku and Ho (2010) examined metacognitive strategies with undergraduate students with different levels of critical thinking performance using the think-aloud method. The metacognitive strategies were analyzed using six thinking tasks and divided into planning, monitoring, and evaluating categories.

The results showed that students who exhibited good critical thinking demonstrated more metacognitive activities in planning and evaluating strategies. Therefore, a student's ability in evaluating their understanding of new concepts and awareness of how various concepts fit together tends to lead to a greater understanding of knowledge for the topic (Rickey & Stacy, 2000).

One of the main issues in acquiring these metacognitive skills is the ability to organize the information and connect key concepts together (Kozma & Russell, 1997). Therefore a learning aid such as concept mapping can be used to help students build hierarchical knowledge bases that allow them to see the connections between concepts. Concept mapping has been used in several science disciplines such as biology, physics, and chemistry (Buntting, Coll, & Campbell, 2006; Lopez, et al., 2011; Martinez, Perez, Suero, & Pardo, 2012; Morse & Jutras, 2008). Buntting, Cole, & Campbell (2006) used concept mapping in their introductory biology classes and their results showed that students found it useful as a tool for learning. Karakuyu (2010) investigated the effect of concept mapping on attitude and achievement in a physics course. The experimental group constructed concept maps as homework assignments while the control group completed traditional homework assignments on electricity. The results from their study revealed that the mean scores on the physics achievement post-test for the experimental group were higher when compared to the control group. They also found that the experimental group who used concept mapping reported to have a more positive attitude towards physics than the control group. Fechner and Sumfleth (2008) investigated whether concept mapping as a learning tool helps students understand chemical topics better than writing a summary after completing a chemical problem-solving task. The

reported results indicated that students who used the concept mapping tool outperformed the students who wrote the summaries on the achievement test scores administered after the completion of the chemical problem-solving task.

Concept mapping has been noted as a powerful tool in which students are able to make meaningful and complex connections between concepts (Ebenezer, 1992). And since chemistry is highly conceptual, a development of conceptual knowledge for the fundamental concepts may enhance students' understanding of more advanced concepts that build upon the fundamental concepts (Sirhan, 2007). This has led educators to integrate new learning resources into their classrooms in order to help students grasp the course concepts, acquire content knowledge, and process skills to make informed decisions about their learning. According to BouJaoude and Attieh, one way in which to improve the teaching/learning process is to encourage students to use meaningful learning by use of concept mapping (BouJaoude & Attieh, 2008).

Although there are several studies on the use of concept maps in the classroom, most of these concept maps have been developed by use of only keywords and linkages provided by the instructor (Francisco, Nakhleh, Nurrenbern, & Miller, 2002; Markow & Lonning, 1998; Yesiloglu, Altun, & Koseoglu, 2008). Others have been developed by researchers based on participants' interview answers (Nakhleh, 1992; Nicoll, Francisco, & Nakhleh, 2001; Pendley, Bretz, & Novak, 1994). However, there are limited studies using computer-assisted concept mapping tools to help students create these concept maps for learning (Kwon & Cifuentes, 2007; McCabe, 2011; Pernaa & Aksela, 2008). Some studies report on the comparison of students constructing concept maps by paper and pencil versus computer generated concept maps. Royer and Royer (2004) compared

the use of paper-based and computer-based concept maps for use in a biology class. The students in the computer-based concept mapping group used the Inspiration software program to create the concept maps. Inspiration helps users create diagrams, visual maps, concept maps, and outlines with its diagram and mapping tools (Inspiration Software Inc, 2012). The results indicated that the students who used the Inspiration software created more complex concept maps compared to the students who created the concept maps using only paper and pencil. The students also indicated that even with the paper and pencil created concept maps they were able to understand the concepts better, remember more things, find relationships, and organize their thoughts (Royer & Royer, 2004). In a more recent study, Erdogan (2009) compared the effects of paper-based and computer-based concept mappings versus conventional teaching on students learning about computer hardware in a computer course. The students were randomly divided into a control, experimental I and experimental II groups. Students who generated the concept maps using computers used the Inspiration software program. Pretest and posttest assessments were administered to the three groups to measure the achievement on the computer hardware unit, computer anxiety, and computer attitudes of the students. The results showed that the concept mapping groups performed better on the computer hardware achievement test compared to the conventional method group. However, the results revealed no significant difference in scores between the paper-based and computer-based concept mapping groups on the achievement test. Therefore, this study indicated that concept mapping, whether it is constructed by way of computers or by hand, can have a positive impact on students' achievement in a course.

Computer-assisted concept mapping tools only assist students in visually creating the concept maps, but do not allow students to explore the concepts and their interconnections between related concepts using the internet. Research has shown that learning through the internet through a structured learning environment may engage students as active participants in their learning process and promote inquiry and knowledge construction (Hargis, 2001). Pernaa and Aksela (2008) developed a web-based learning environment using concept maps and the web for learning chemistry. Their goal was to design a web-based learning environment for easy navigation of materials based on information in insect chemistry. The concept maps in the web environment were created by CmapTools program. CmapTools software is used to create concept maps with the possibility of adding media resources such as animations, pictures, and documents (CmapTools knowledge modeling kit, 2012). The results from the survey administered to high school chemistry teachers indicated a high acceptance of using the web-based learning materials for insect chemistry with the use of concept maps. The teachers also strongly agreed that the use of concept maps were an excellent or a good navigation tool for the web material (Pernaa & Aksela, 2008). Chou, Chen, and Dwyer (2011) examined the instructional effectiveness of different types of concept mapping for online learning about the human heart. The traditional concept mapping group received concept maps which summarized the main concepts inserted into the instructional material, and the visualized-based concept mapping group received the same instructional material that combined static heart images with the traditional concept maps. The reported results showed that students in the visualized-based concept mapping group outperformed the students in the traditional concept mapping on identification and

terminology questions. The authors attributed these results to the incorporation of the visual images of the concepts with the textual information integrated into the concept maps.

Although these previous articles used the web and concept mapping for learning, use of the web for educational purposes is still limited due to the vast amount of information provided on the internet which may be presented without relevance or have misconceptions that may hinder a novice learner (Hargis, 2001). Therefore, ontologies may be helpful in obtaining information from the internet by describing related knowledge and identifying useful and connected information in a domain of interest such as chemistry (Chen, 2009). Swartout, Patil, Knight, and Russ defined an ontology as a hierarchically structured set of terms to describe a domain, which can be used as a skeletal foundation for a knowledge base (Swartout, Patil, Knight, & Russ, 1997). According to Tsai, students who perceived the internet as a tool for learning showed more interest in the content or cognitive activities when engaged in internet-based learning activities (Tsai, 2007). Chen (2009) investigated the effectiveness of their web-based ontology concept map system using students in a mathematics course. The results indicated the system was helpful in promoting learning performance from the students. Also, the system was designed specifically for the concepts covered in the mathematics course which gave the students a more personalized learning environment. Wang, Peng, Cheng, Zhou, and Liu (2011) investigated the use of knowledge visualization maps designed from concept maps for self-regulated online learning. The reported results showed that the students had a positive attitude towards using the online learning system and they were willing to use the system for future studies. The students also indicated

from interviews that the system was easy to browse to find learning resources by clicking on a topic. Therefore, a chemistry ontology-based concept mapping learning tool may allow students to explore relevant subject matter content using the web in order to learn and understand the subject. It can also be used to help students build a concept map that may lead to better learning outcomes such as understanding of concepts, awareness of the hierarchy and interconnections amongst concepts, greater confidence about scope of knowledge and ability to acquire new information.

The purpose of this study was to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course. The following research questions were studied: RQ1: What are the changes in students' metacognitive skills throughout a semester? RQ2: How do students' attitudes change throughout a semester? RQ3: What are the changes in students' metacognitive skills from the interactions with the alternative learning aids (concept maps, ontology) compared to other students? RQ4: How do students' attitudes change from the interaction with the alternative learning aids (concept maps, ontology) compared to other students? RQ5: How does the interaction with alternative learning aids (concept maps, ontology) affect students' ability to answer exam questions about key concepts? and RQ6: How does the interaction with alternative learning aids (concept maps, ontology) affect students' ability to explain connections between key concepts? Additional research questions arose during the study to obtain a better understanding of students' attitudes towards creating concept maps and using the Creonto software: RQ7: What are students' attitudes towards creating concept maps in the chemistry course? and RQ8: What are students' attitudes towards using the Creonto software? Therefore, the



procedures used to answer the research questions were to measure the changes in metacognitive skills, attitudes, and conceptual knowledge with the use of concept maps and the chemistry ontology for students enrolled in an introductory chemistry course. This study included three phases: phase 1 (control group), phase 2 (treatment 1 group), and phase 3 (treatment 2 group). In phase 1, there was no integration of additional materials introduced into the course. Phase 2 consisted of the integration of the concept mapping learning tool into the curriculum as homework assignments throughout the semester. Phase 3 involved the integration of the same concept mapping assignments as phase 2 plus the chemistry ontology learning tools into the curriculum.

This study supported the use of ontologies for e-learning purposes and the use of ontologies in the sciences which added to the knowledge base of existing literature to promote this alternative learning tool in education. Also, this study expanded the knowledge on the use of concept mapping and computers in chemistry as a study/learning tool and pinpointed further research possibilities that identified ways to improve students' attitudes, metacognitive skills, and conceptual knowledge of chemistry concepts. The main objective of this research was to add to the knowledge base for the use of alternative learning aids in chemistry and promote the use of these learning tools for students in other academic areas.

The first chapter of this dissertation introduces the background that formulates the foundation of this project. It describes the main goals and introduces the methodology. The second chapter discusses the previous research that has been done in the area including specifically discussing related studies on factors influencing learning chemistry, concept mapping and ontologies for conceptual learning. In chapter three

through six, the methodology, instrumentation, chemistry concept mapping workshops and the chemistry ontology are discussed. Chapter seven describes the results of the research study and the final chapter ends with a summary, contributions of this research and discusses future goals of this work.

### **Computerized Search**

The articles used in this literature review are empirical articles and review articles obtained by using computer database searches. The first database used in order to obtain peer-reviewed empirical articles was ERIC. Search statements “learning strategies or metacognition and chemistry and college” with subject/descriptor terms “chemistry, college students, and metacognition” resulted in 14,122 articles. This resulted in an overwhelming number of articles. Therefore, the search was further refined by using the ERIC database with search terms “rote learning and sciences” resulted in 35 results. Electronic journals were also utilized in the search such as the Journal of Chemical Education. The search statement “rote learning” resulted in 250 results and then was limited to 2002-2012 articles and resulted in 65 results. Also from the Journal of Chemical Education, the search statement “concept maps” resulted in 157 articles. The EBSCO Host database utilizing the Academic Search Premier, Applied Science & Technology Full Text, Education Full Text, ERIC, and General Science Full Text databases were also used with the search statements “self-efficacy and chemistry and attitudes” resulting in 26 results. “Attitudes and chemistry” search statements from EBSCO Host database using the subject/descriptor terms “chemistry, student attitudes, and higher education” resulted in 1029 results. While the search statements “metacognition and chemistry” from EBSCO Host database resulted in 63 results.

Articles were also found from the EBSCO database using the search statements “concept maps and sciences” which resulted in 560 results. The Education Full Text database with search statements “computers and concept mapping” resulted in 81 results. While the search statements “internet and concept mapping” from the Education Full Text and General Science Full Text databases resulted in 41 results. Additional articles were also located from the literature studies from the above searches.

## **CHAPTER 2**

### **BACKGROUND AND LITERATURE REVIEW**

The background and literature review contains several sections that give a better understanding of the proposed research. The first section provides a brief introduction to learning chemistry in college and discusses some factors which influence why some students have difficulty in the subject, with subsections addressing students' attitudes towards chemistry and assessment of metacognitive skills. The second section provides a brief introduction to concept mapping and describes their uses in education. The third section discusses constructing concept maps with computer-aided learning tools with a sub-section that explains the use of ontologies in building active and conceptual learning environments for students.

#### **Learning Chemistry**

Chemistry is the study of the composition, structure, properties, and reactions of matter. Introductory chemistry courses are required for many disciplines and in many cases is the first science course taken by students at the college level (Tai, Sadler, & Loehr, 2005). Chemistry courses are often perceived as difficult courses and consist of highly conceptual and abstract concepts (Sirhan, 2007). Research has shown that several factors may influence students' learning of chemistry, and a few of these are listed below:

- Students' scientific literacy skills (De Avila Jr & Torress, 2010)

- Students not understanding appropriate fundamental concepts (matter, energy, atoms, elements, etc.) in the beginning of their studies (Nakhleh, 1992; Pekdag, 2010).
- Students having misconceptions about the subject and drawing their own conclusions about chemistry based on their own current knowledge base (Pekdag, 2010).
- Students using rote learning or learning by repetition instead of meaningful learning (BouJaoude & Barakat, 2003; Brandt, et al., 2001; Nakhleh, 1992; Pendley, Bretz, & Novak, 1994).
- Students' science self-efficacy which may contribute to their attitudes towards the sciences and especially chemistry (Brandriet, Xu, Bretz, & Lewis, 2011; Britner, 2008; Dalgety & Coll, 2006)

In this study, the research will focus on the students' attitudes towards chemistry and their abilities to use meaningful learning by measuring the students' changes in their opinions of their metacognitive skills and attitudes throughout a semester.

### **Attitude Towards Chemistry**

A student's attitude towards science may be a major influence on his/her academic achievement in a course (Brandriet, Xu, Bretz, & Lewis, 2011; Kan & Akbas, 2006). Attitude can be defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Xu & Lewis, 2011). Attitudes towards the sciences, therefore, are related to students' positive or negative feelings about science (Can & Boz, 2012). Students who exhibit a negative attitude towards science may not make an effort to learn and understand the meaning of concepts

that are being taught to them (Saribas & Bayram, 2009). According to Kaya and Geban, (2011) an important reason to investigate students' attitudes in the sciences is to determine the ways in which it may affect student learning. A number of factors have been associated in influencing students' attitudes towards chemistry. These factors include teaching methods, teacher attitudes, influence of parents, gender, age, student thinking processes, career interest, and past experiences in science related courses. Additionally, other influences may be related to students' achievement and problem solving abilities in prior science courses (Khan & Ali, 2012).

In a study (Lawrenz, Wood, Kirchhoff, Kim, & Eisenkraft, 2009) investigating variables affecting physics achievement, the authors collected data from 3,119 students enrolled in physics classes using an Active Physics curriculum from 68 teachers' classrooms. Out of the 68 teachers, 26 of them attended a summer workshop to introduce them to incorporating the Active Physics curricula into their classrooms. The Active Physics curriculum requires students to complete writing assignments, student presentations, and be actively involved in the development of assessment rubrics. The main themes discussed using the Active Physics curricula are related to real world issues (communication, home, medicine, predictions, sports, and transportation). The main goal of their study was to examine several variables that may be related to student achievement in physics courses such as prior physics knowledge, gender, grade level, ethnicity, attitude towards physics, and several other variables. Data were collected through the use of pre- and post- surveys and pre- and post- physics achievement tests. The surveys probed questions on students' individual characteristics, attitudes about science and physics, parental education, and perceptions of the classroom activities. The

physics achievement tests consisted of multiple choice questions that contained items related to physics concepts of motions and forces, transfer of energy, conservation of energy, and interactions of energy and matter. The students were administered both the surveys and achievement tests at the beginning and end of the semester. The data was analyzed using hierarchical linear modeling which is a regression based technique. The results showed that the students who were enrolled in the physics courses in which the teachers used the Active Physics curriculum for the majority of the school year scored higher on the physics achievement test compared to the students' whose teachers did not use the Active Physics curriculum throughout the school year. The results also showed that students who were also enrolled in the physics classes with the Active Physics curriculum being used for the majority of the school year had a narrowed gap between their physics achievement scores and attitudes towards physics; this was also consistent between the boys and girls enrolled in the classes. Therefore based on the results, students who were actively involved in the curriculum had higher scores on the physics achievement tests and exhibited a more positive attitude towards physics compared to the other students.

A study conducted (Berg, 2005) to gain insight on attitude changes and its relation to motivation and contextual factors towards learning chemistry was explored using 66 first year chemistry students. The first research questions addressed which factors are related to students' shift in attitude toward learning chemistry. A second question probed the relative significance of these factors. Pre- and post- attitude questionnaires were administered and analyzed using principal component analysis (PCA). Six students were also chosen to be interviewed who demonstrated large changes in attitudes towards

chemistry. The interviews consisted of three main questions: 1) What is your background? 2) Describe your experiences in this chemistry class throughout the semester. and 3) Do you have any further comments on questions 1 and 2? The survey data revealed that students who demonstrated negative shifts in attitudes showed 43 examples of lacking motivation while only 7 examples were noted in the students who had a positive shift in attitude at the end of the semester. Students with positive shift in attitude also had twice as many positive opinions towards instructional methods when compared to the students who demonstrated a negative shift in attitude on the survey. The results from the 6 students that were interviewed revealed that students who demonstrated a positive shift in attitude attended all offered lectures, were actively involved in the course, and asked for help when encountering difficult tasks. However, the students who demonstrated a negative shift in attitude did not attend all offered lectures, course involvement declined throughout the semester, and they did not ask for help as often when encountering difficult tasks. A student who demonstrated a negative attitude shift in attitude commented on why he did not attend all lectures: *“Usually I could not concentrate as long as I had planned, but went jogging instead”*. Another student who demonstrated a positive attitude shift commented on how they studied for the course: *“This is the method (studying continuously and staying in phase with the course) I have developed during my years of study”*. A student who demonstrated a negative shift in attitude commented on the same question and said: *“If you don’t have to study you don’t study”*. In this study, the authors concluded that the major factors related to the students’ shift in attitude towards learning chemistry was their motivational beliefs in succeeding in the course.



Brandriet, Xu, Bretz, and Lewis (2011) examined changes in student attitudes in two general chemistry courses at two universities. The first group consisted of 148 students enrolled in a general chemistry course at a Southeastern university in the United States. The second group consisted of 87 students enrolled at a Midwestern university in the United States. The main goal of the study was to measure students' attitude changes using the Attitudes towards the Subject of Chemistry Inventory version two survey (ASCIv2). The ASCIv2 is a shortened version of the original ASCI survey which consists of eight items categorized under intellectual accessibility and emotional satisfaction to measure changes in students' attitudes towards the subject of chemistry (Xu & Lewis, 2011). Data was collected at the Southeastern and Midwestern universities through the use of the pre- and post- ASCIv2 surveys. Also course grades and scores from the American Chemical Society (ACS) first semester general chemistry exam were collected. Pearson correlation was used to analyze the survey results. The results from the post survey showed a strong correlation between students' attitudes and their course achievement based on their final course grade and scores on the ACS exam. The t-test also showed an interaction between students' attitude and their course achievement with results revealing that A and B students' attitudes significantly increased from the beginning to the end of the semester. However, D and F students' attitudes significantly decreased by the end of the semester while C students' attitudes remained the same. Therefore, the study indicated that there may be a correlation between attitudes and success in general chemistry.

McCarthy and Widanski (2009) evaluated chemistry anxiety in 264 college students enrolled in introductory psychology, general chemistry, and organic chemistry

courses. The authors' goal was to evaluate the prevalence of chemistry anxiety a student may have concerning chemistry, such as their attitudes regarding learning chemistry, fear of examinations in chemistry, and fear of handling chemicals. Data was collected by asking students to complete a survey that measured their chemistry anxiety on a rating scale of 1-5 (1 = lowest chemistry anxiety and 5 = highest chemistry anxiety). An example question from the survey regarding learning chemistry anxiety was "Watching a teacher work a chemistry problem on the blackboard". Another example questions from the survey regarding fear of examinations was "Being given a pop quiz in a chemistry class". The students were asked to rate the questions on the survey with how anxious each made them. Descriptive statistics was performed and the overall means showed 1.92, 3.10, and 2.15 for attitudes regarding learning chemistry, fear of examinations in chemistry, and fear of handling chemicals. ANOVA statistics were also used to evaluate differences between genders for the chemistry anxiety. The ANOVA results showed a significant difference for chemistry examination anxiety between females and males, with females reporting a higher level of anxiety on examinations. There were no significant differences between genders for attitudes towards learning chemistry and the handling of chemicals. However ANOVA results did show a significant difference in anxiety for students who had never taken a chemistry course compared to students who had taken a chemistry course. These students reported a higher level of anxiety towards learning chemistry and chemistry examinations. Therefore, according to McCarthy and Widanski (2009), recognizing and changing students' attitudes towards chemistry may improve students' success and retention in chemistry courses.

In another study, Bauer (2008) examined 21 non-science major students' attitudes towards chemistry using the Attitude toward the Subject of Chemistry Inventory (ASCI) survey in a chemistry and society course. The ASCI is a survey designed to measure students' attitudes towards chemistry. It is presented on a seven-point scale between two adjacent adjectives which represent how a student feels about chemistry. An example of a question on the survey is: Chemistry is easy 1-2-3-4-5-6-7 hard; and students indicate on the 7-point scale their responses. Descriptive statistics results showed that from the pre- and post- ASCI survey administered to the students, their anxiety towards chemistry decreased from 62% to 48% which resulted in a nearly full standard deviation difference. The reported results also showed that the students had higher ratings on the pre-survey for anxiety and fear; while the lower ratings indicated intellectual accessibility. However, the results from the post-survey revealed that the students' attitudes towards chemistry shifted from being less anxious and fearful to being more emotional and intellectually satisfied with the subject.

A mixed-method study (Walczak & Walczak, 2009) was conducted to assess students in a general chemistry course on their changes in attitudes towards science over the semester with 36 nursing and other non-science major students. The research question addressed in this study was "Do student attitudes towards science change after taking a chemistry class with content on real-world issues?" Data was collected using a pre- and post- survey, Views on Science Technology Society (VOSTS). The VOSTS survey was used in this study to measure the students' attitudes towards science with regards to technology and the society. Interviews and the open-ended questions from the surveys were also used to explain the attitude shifts exhibited by the students in the

course. Paired t-test statistics were performed to determine if the pre- and post- VOSTS survey data was statistically significantly different. The results revealed that students' attitudes about science were not statistically significant before and after the course. However, statistically significant results were found on the survey questions that addressed topics that were closely related to topics taught in the course. Therefore the interview and open-ended questions results were analyzed to explain the results. The students who demonstrated positive attitude shifts at the end of the semester towards chemistry contributed it to the homework assignments that focused on real-world issues. However, the students who demonstrated negative attitude shifts at the end of the semester towards chemistry contributed it to their frustration with their perceived ability of performance in the course. A student's belief of their ability to perform well or complete a task in the sciences may be defined by their science self-efficacy.

**Science self-efficacy and its relationship to attitudes:** Self-efficacy is a students' belief in their own abilities to succeed at a task or in a discipline (Williams, Kurtek, & Sampson, 2011). According to Dalgety & Coll (2006) a student with a low science self-efficacy may have a lack of interest or perceived abilities to perform well in a science course. This lack of interest may not only hinder the students' attitudes towards chemistry learning but also may foster their lack of understanding of chemistry concepts and misconceptions. Several studies in science education have been conducted to evaluate the relationship of self-efficacy, attitudes and students performance in a course (Britner, 2008; Dalgety & Coll, 2006; Lawson, Banks, & Logvin, 2007; Williams, Kurtek, & Sampson, 2011).

Lawson, Banks, and Logvin (2007) compared self-efficacy and reasoning ability

to achievement in biology for 459 students enrolled in an introductory biology course. The data was collected using pretest and posttest self-efficacy science-oriented tasks questions. The self-efficacy measure included 16 science-oriented tasks questions. An example of a self-efficacy task question was: "Identify similarities and differences in the vegetation growing at different elevations on a tall mountain." The students were required to rate the questions on a 5-point Likert scale indicating their confidence in completing the task question. The reasoning ability measure was assessed using a 22-item test on reasoning patterns concerning hypothesis testing where students selected the best answer from a multiple selection of answers. An example of a reasoning ability question on the test was: "Suppose you collect 250 shells of a single snail species from the ocean. What would you expect a graph of their lengths versus frequency to look like? (A) bell-shaped (correct answer); (B) positive linear (line from the lower left to upper right); (C) negative linear (line from the upper left to lower right); (D) flat E. bimodal." Also students' biology achievement such as their final course grade was utilized in the analysis. Data was analyzed using paired z-tests and Pearson correlation. The paired sample z-tests reported results showed a significant increase in both self-efficacy and reasoning ability from the pretest to the posttest self-efficacy ratings. The Pearson correlation statistics showed an increase in both self-efficacy and reasoning ability with the results showing a correlation with the posttest self-efficacy and achievement in the biology course.

In a study conducted by Zusho, Pintrich, & Coppola (2003) in order to assess changes in students' self-regulatory strategies, 458 college students enrolled in an introductory chemistry courses were administered surveys at 5, 10, and 15 weeks

throughout the semester. The first survey administered at 5 weeks consisted of questions to assess students' self-efficacy and task value beliefs. The second and third survey administered at 10 and 15 weeks consisted of questions assessing the students' goal orientations, self-efficacy and task value beliefs, interest, anxiety, and self-regulatory strategies. The research questions proposed were based on students' motivation and cognition process. The first research question asked "What ways does motivation change during a first semester chemistry course?" Secondly, "What ways does strategy use change during a first semester chemistry course?" Thirdly, "How does motivation and cognition effect performance in chemistry?" Data were analyzed using analysis of variance (ANOVA) statistics. From the first research question, the results showed that students' motivational levels decreased over the course of the semester which included their levels of self-efficacy, task value, and performance goals. The second research question results showed a significant decrease in students' rehearsal and elaboration strategies from the 10 to 15 weeks administered surveys. However, students organizational and metacognitive skills increased from the 10 to 15 weeks administered surveys. The third research question results reported that for students who demonstrated higher levels of self-efficacy, task value, and mastery goals used deeper-processing cognitive skills (elaboration and metacognition) than other students with lower self-efficacy levels. Therefore, the authors concluded that self-efficacy was a main component in course performance while task-value came in second which showed that maintaining self-efficacy levels throughout a course may actually help in a student's performance.

Dalgety and Coll (2006) explored first-year science students' chemistry self-efficacy in a first-year chemistry course using a mixed methods study. All of the student

participants in this study voluntarily chose to enroll in this first-year chemistry course. Data was collected using the Chemistry Attitudes and Experiences Questionnaire (CAEQ) administered three times throughout the academic year. The first survey was administered to 126 students at the beginning of the semester while the second survey was administered to 102 students at the end of the semester. The final survey was administered to 84 students at the end of the second semester for students enrolled in the second part of the chemistry course. Nineteen students were chosen at the beginning of the semester and 14 students were re-interviewed at the end of the semester on their views related to their self-efficacy towards chemistry. An example of the questions that were asked on the CAEQ are: *“Explaining something that you learn in chemistry course to another person”* or *“Knowing how to convert data obtained in a chemistry experiment to get result”*. Students were required to rate the statements on a 7-point semantic differential scale from “very confident” to “not confident”. Data were also collected on the students’ gender, ethnicity, and their reasons for enrolling in a first-year chemistry course. Descriptive statistics using two-tailed z-scores that had a  $p$  value less than .05 were utilized to analyze the survey data and the results showed that the students were overall confident about their ability to perform the tasks required of them in a first-year chemistry course. From the surveys, students’ reported that they were more confident about *“Determining the appropriate units for a value”* which had a mean (beginning of semester) = 4.75, mean (end of semester) = 4.94, and mean (end of second semester) = 5.19. Students however were less confident about *“Tutoring another student in a first-year chemistry course”* with a mean (beginning of semester) = 2.94, mean (end of semester) = 3.45, and mean (end of second semester) = 3.86. The interview questions

revealed that self-efficacy was a major factor for many students' in explaining their ability to be successful in the chemistry course by describing their prior learning experiences. For example, one student at the beginning of the semester described his concerns as being "a difficulty in understanding the maths, being able to work out the answers to things, calculations". Another student explained their ability in studying for the course as "not easy at all, I think I will have to work hard, but I think I will work hard". Other students described their increase confidence and self-efficacy in chemistry by stating "I'm not having any problems this year and I don't expect it be so much harder next year that I'm all of a sudden going to have problems" Based on this study, the students had confidence in their ability to perform well in the chemistry course and this contributed not only to their increased self-efficacy but also their attitudes towards chemistry and academic success in the course.

In another study conducted by Dalgety and Coll (2006), the authors examined factors such as learning experiences, attitude toward chemistry, and chemistry self-efficacy that influenced students' chemistry enrollment choices using the Chemistry Attitudes and Experiences Questionnaire (CAEQ). The CAEQ questionnaire consists of three categories which are learning experiences, attitude toward chemistry, and chemistry self-efficacy. The CAEQ survey was administered at three times throughout the academic year during the scheduled chemistry laboratory classes. The first CAEQ was administered to 126 students at the beginning of the semester, the second CAEQ was administered to 102 students at the end of the first semester chemistry module, and the third CAEQ was administered to 84 students at the end of the second semester chemistry course. Seventeen students at the beginning of the semester were interviewed to probe

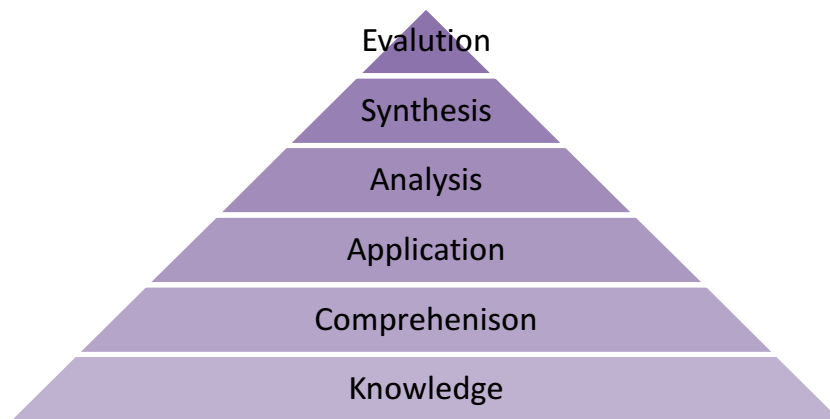


their beliefs about enrolling in a second semester chemistry course. Twelve of the 17 students interviewed at the beginning of the semester were also re-interviewed at the end of the first semester. Then seven of the 12 students interviewed at the end of the first semester that enrolled in the second semester chemistry course were re-interviewed at the end of the second semester. Descriptive statistics were utilized to analyze the CAEQ data. The results showed that there was no clear relationship between students' learning experiences and their enrollment intentions to continue to take additional chemistry courses. However, the results reported a relationship between chemistry self-efficacy and enrollment intentions for students who were academically successful in the chemistry course. The interview data also provided a more detailed explanation of the results reporting that chemistry self-efficacy and its relationship with achievement impacted enrollment intentions for students. For example one student at the beginning of the semester explained "I took chemistry before and I really liked it and I did quite well. I just like it overall". The same student at the end of the first semester explained "I am just tossing up whether to major in chemistry or biology". Another student also expressed their improved confidence in chemistry by stating at the end of the first semester "having to answer problems is difficult, at the tutorials we can go through and discuss them which makes them clear". This same student stopped attending the tutorial classes because he had a better understanding of the topics and explained his decision by stating "I didn't see any point going to tutorial when they were just going to tell me how I'd already done it". The results from the study showed that there may be a relationship between chemistry self-efficacy, chemistry achievement, and students' intention to enroll or not enroll in a second-year chemistry course.

In a more recent study (Reardon, Traverse, Feakes, Gibbes, & Rohde, 2010) investigating the determinants of chemistry course perceptions in undergraduate students using 398 students enrolled in an introductory chemistry class. The two main research questions addressed in this study were: 1) What is the relationship between chemistry course perception and general self-efficacy for students enrolled in their first undergraduate chemistry course? 2) What student characteristics (sex, ethnicity, age, and prior academic experience) are statistically significant factors of chemistry course perceptions for students enrolled in their first undergraduate chemistry course? The variable in this study that was assumed to have a relationship on chemistry course perceptions was gender, ethnicity, age, and general self-efficacy. Data collection was performed by using a 6-item chemistry course perceptions questionnaire developed by the authors. The survey was administered to the students using MRInterview which is a web-based survey program by SPSS. The survey statements probed students' beliefs about their general self-efficacy towards chemistry and had statements such as: *"Chemistry is easy for me to learn", "I am good in chemistry", "I like chemistry", "I expect to get a good grade in this chemistry class", "I expect to pass this course as long as I put in my time."* and *"Science is my strong suit."* Descriptive statistics were used to analyze the surveys and the reported results showed that retaking the course had a significant effect on students' chemistry course perceptions. The results indicated that students who had to retake the course had a lower self-efficacy towards chemistry compared to students who did not have to retake the course. The results also showed that age and ethnicity gave rise to a statistically significant difference in students' chemistry course perception. However, the largest predictor for students of chemistry course

perception was general self-efficacy. Therefore based on the results of the study, the authors concluded that for students entering their first undergraduate chemistry course, general self-efficacy was the main factor in students' chemistry course perceptions or attitudes towards chemistry.

Since self-efficacy is the beliefs a student has about their abilities, a student who has a low self-efficacy which contributes to their negative attitude about chemistry may exhibit a lack of motivation towards learning chemistry and succeeding in a chemistry course (Reid, 2008). This lack of motivation and low self-efficacy towards learning chemistry may result in a student using rote learning (Dalgety & Coll, 2006). Rote learning or learning by repetition occurs when definitions or concepts are memorized without stopping to consider the actual meaning of what is being learned (BouJaoude & Attieh, 2008; Ebenezer, 1992). A real understanding of a subject such as chemistry not only depends on the understanding of key concepts but also on the ability to produce meaningful links between these concepts (BouJaoude & Attieh, 2008; Brandt, et al., 2001; Nakhleh, 1992). This can be emphasized by Bloom's Taxonomy of educational objectives. There are six levels in the taxonomy ranging from the lowest order to the highest: knowledge, comprehension, application, analysis, synthesis, and evaluation as shown in figure 1 (Anderson & Krathwohl, 2001).



**Figure 1.** Schematic of Bloom's Taxonomy for educational objectives

The knowledge level is the process for remembering previous learned materials such as facts, terms, basic concepts, and answers. The comprehension level relates to understanding these facts by interpreting, classifying, comparing, summarizing, and explaining. The third level is application which is using prior and new knowledge to carry out or solve a problem. Analysis category is examining and breaking the information into smaller parts to determine which parts relate to one another by differentiating, organizing, and attributing the information. Synthesis is creating or putting items together to form a new pattern or solution by generating, planning, and producing the information (creative thinking processes). The final level is evaluation which is making judgments about information by checking and critiquing it (Anderson & Krathwohl, 2001). When students use all of the six levels in Bloom's Taxonomy they are considered to be using meaningful learning. Meaningful learning is when students are able to relate new knowledge to prior knowledge and build those connections to apply that knowledge to complete a task (Novak & Canas, 2008).

In educational settings, students are expected to have knowledge about their

cognition and awareness of their thinking process. Students who acquire these skills are considered to have good metacognition (Rahman, Yasin, Ariffin, Hayati, & Yusoff, 2010). These students are able to reflect on their learning process, better organize and manage new information (Stevens, 2009). As a result of numerous studies investigating the importance of students' acquiring and enhancing their metacognitive skills in the classroom (Blank, 2000; Pintrich, 2002; Spence, Yore, & Williams, 1999; Thiede, 1999), Bloom's Taxonomy was revised to include metacognitive knowledge as a new knowledge category (Anderson & Krathwohl, 2001; Krathwohl & Anderson, 2010; Krathwohl, 2002). Metacognitive skills are considered to be part of the cognitive process that students use to plan, monitor, and evaluate their learning which consequently fits under the six cognitive levels in the revised Bloom's taxonomy (Pintrich, 2002). Since metacognition involves the knowledge about a students' cognition as described in Bloom's taxonomy and awareness of their thinking process, a development of metacognitive skills may encourage students to be self-regulatory learners that are able to plan, monitor and evaluate their learning.

### **Metacognition**

It is believed that cognitive and metacognitive skills in chemistry education are essential for a student to identify in what ways their understanding of a topic is incomplete and be able to organize their own thinking to decide if further explanations are needed for a full understanding of a topic (Rickey & Stacy, 2000). The different functions cognition and metacognition serve in the learning process can be explained by their definition and examples. Cognition involves the mental process of acquiring knowledge and comprehension while metacognition involves the regulation and

awareness of ones' cognitive thinking (Rahman, Yasin, Ariffin, Hayati, & Yusoff, 2010). For example cognition can be explained as a student reading a text or the knowledge of computer programming. An example of metacognition can be explained when a student is monitoring their understanding of the text or applying their knowledge of computer programming. Metacognition, therefore, is the knowledge about one's own learning process. It also involves one's awareness, evaluation, and regulation of their thinking (Rahman, et al., 2011). Accordingly, metacognitive knowledge can be categorized into two components: the knowledge component (knowledge of one's learning process) and the regulation component (strategies one applies to complete a task) (Ku & Ho, 2010). Therefore, metacognition comprises three basic skills: 1) planning, 2) monitoring, and 3) evaluation of the learning process. These self-regulatory skills consist of ways students are able to set goals, ask themselves questions on what they already know or make connections between concepts, and re-read something they don't understand (Pintrich, 2002). Students who possess these skills are said to have good metacognition and are able to strategize their learning process to complete tasks (Rahman, Yasin, Ariffin, Hayati, & Yusoff, 2010).

Several studies in recent years have investigated the importance of metacognitive knowledge and skills for students to control their thinking process for enhanced learning (Downing, Kwong, Chan, Lam, & Downing, 2009; Ku & Ho, 2010; Magno, 2010; Rahman, et al., 2011). According to Pintrich, (2002) students who develop metacognitive skills become "more knowledgeable and responsible for their own cognition and thinking". One area of study researchers have examined is the development of students' metacognitive skills to enhance critical thinking. According to Magno, (2010) the

development of critical thinking skills is facilitated through metacognition. Ku and Ho (2010) examined metacognitive strategies with undergraduate students with different levels of critical thinking performance using the think-aloud method. The study hypothesis was based on the notion that students who demonstrated different metacognitive strategies would have different levels of thinking performance. Participants were 10 undergraduates who were divided into a high critical thinking performance and low critical thinking performance groups based on their cognitive ability, thinking disposition, academic achievement and critical thinking performance. These measures were analyzed using the Verbal Comprehension Index of the Wechsler Adult Intelligence Scale, Concern for Truth Scale, and GPA. The only difference between the two groups was their level of critical thinking performance which was measured using the Halpern's Critical Thinking Assessment Using Everyday Scenarios (HCTAES). The metacognitive strategies were analyzed using six thinking tasks and divided into planning, monitoring, and evaluating categories. Five of the tasks were scenario-based open-ended problems from the HCTAES assessment. The sixth task was developed by the authors to examine the students' argument analysis skills. The thinking tasks used in this study probed students critical thinking skills by asking questions concerning hypothesis testing, verbal reasoning, argument analysis, understanding likelihood, and decision making. The data was collected by instructing students to use the think-aloud method which involves having participants to "say whatever came to their mind as they carried out the tasks". The students' responses were coded into planning, monitoring, and evaluating categories and scored on a scale of 0 to 4. Data analysis was performed using U-test to determine differences in the critical thinking performance

between the two groups. The results showed that the high performance group scored better than the low performance group. The results also showed that students in the high critical thinking group demonstrated more metacognitive activities in planning and evaluating strategies. The study indicated that students who exhibited high critical thinking performance had enhanced metacognitive skills that resulted in these students displaying “better abilities to plan for specific steps in thinking and to revise their task approach after identifying problems”.

Magno (2010) also investigated the role of metacognitive skills in developing critical thinking skills. In this study, it was hypothesized that “critical thinking occurs when individuals use their underlying metacognitive skills and strategies”. Data was collected from 240 freshmen college students using the Metacognitive Awareness Inventory (MAI) and the Watson-Glaser Critical Thinking Appraisal (WGCTA). The study tested two models: (1) The first model tested the two factors of metacognition (knowledge of cognition and regulation of cognition); (2) The second model tested the eight factors of metacognition as it affects critical thinking (declarative knowledge, procedural knowledge, monitoring, debugging strategy, and evaluation of learning). The MAI questionnaire was used to measure metacognition and consisted of 52 items to assess the students’ knowledge of cognition and regulation. The WGCTA was used to measure critical thinking and consisted of 100 standardized test items to assess students’ critical thinking abilities using exercises that included problems, statements, arguments, and interpretations of data. Descriptive statistics showed in both models that metacognition had a significant correlation to critical thinking. The results also indicated that all of the factors of metacognition and critical thinking are significantly related. The



authors concluded that higher use of metacognitive skills may result in better critical thinking.

The importance of metacognition in chemistry education is essential because it is considered to be a key to deeper, more complex learning (Cooper, Urena, & Stevens, 2008; Rickey & Stacy, 2000). According to Rickey and Stacey (2000) there are two important reasons for students to develop metacognitive skills for the use in sciences: (1) development of students awareness of their thinking process for the understanding of ideas taught in science courses, and (2) the regulation or control of students' thinking process for success in problem solving. Metacognition in chemistry is essential because it may provide a way for students to become familiar with their own thinking process and acquire a deeper understanding of the concepts taught in the curriculum (Cooper, Urena, & Stevens, 2008). Students who acquire these metacognitive skills (planning, monitoring, and evaluation) may have a better ability to understand a task or problem and able to determine the most useful strategies to complete the task (Kaberman & Dori, 2009).

Several studies in recent years have investigated the impact of metacognition in chemistry education (Cooper & Sandi-Urena, 2009; Cooper, Urena, & Stevens, 2008; Rompayom, Tambunchong, Wongyounoi, & Dechsri, 2010). One study (Rahman, Jumani, Chaudry, Chisti, & Abbasi, 2010) was designed to investigate the impact of metacognitive awareness on performance of students in chemistry using 525 males and 375 female students enrolled in a general chemistry course. The objectives of the study were to measure metacognition for students enrolled in the chemistry course and determine the impact of metacognition on performance. The students were administered

the 52 item Metacognitive Awareness Inventory (MAI) to assess their metacognitive awareness. A 30 item achievement test developed by the researchers to assess students' performance in chemistry was also administered to the students after the completion of the MAI questionnaire. Statistical data showed that the male students had a higher mean score compared to the females on both the achievement tests (male  $M=150.2$ ,  $SD=4.7$ ; female  $M=149.9$ ,  $SD=4.9$ ) and MAI questionnaire (male  $M=20.9$ ,  $SD=10.6$ ; female  $M=20.0$ ,  $SD=14.6$ ). However, there were no statistically significant gender differences in metacognitive awareness. The Pearson correlation results also showed a positive relationship between the MAI questionnaire and achievement test score of the students. The ANOVA results further confirmed that there was a significant correlation between metacognition and students performance on the achievement test. The results showed that students who demonstrated a higher awareness of metacognitive skills scored higher on the chemistry achievement test compared to the students who had a lower awareness of metacognitive skills.

Another study (Nbina & Viko, 2010) examined the effects of instructional metacognitive self-assessment strategies for chemistry problem solving. The main objective of the study was to investigate the effects of instruction in metacognitive self-assessment on chemistry students' self-efficacy and achievement. One hundred and ninety-two students (91 boys and 101 girls) enrolled in an introductory chemistry course were participants in the study. The study was based upon a quasi-experimental non-equivalent design involving a control group and experimental group. The control group students attended normal chemistry classes where the teacher encouraged them to work hard in chemistry. However, in the experimental group the students were introduced to

self-assessment instructional program (SAIP). The SAIP is designed to help students set learning goals and to assess every step they take in completing those learning goals. The instructor in the experimental group used the SAIP to encourage students to think carefully and understand how to work through a chemistry problem. The students received extensive feedback on each step of the process from the instructor in working out these chemistry problems. Three instruments all developed by the researchers were used in this study; the Chemistry Achievement Test (CAT), Self-assessment Scale (SAS), and the Chemistry Self-efficacy Scale (CSS). The CAT consisted of 10 problem solving questions based on chemistry concepts that were taught in the chemistry course. The SAS was administered to the students to assess their self-assessment skills relevant to chemistry problem solving. Students were asked to rate the items on the SAS from very high extent to not at all based on their perceived skills in the process of solving chemistry problems. The CSS was used to measure the students' perceived self-efficacy in chemistry. Descriptive statistics showed that the students in the treatment group scored higher on the post-test CAT compared to the control group. Descriptive statistics also showed that the students' self-efficacy scales from the experimental group who used the metacognitive self-assessment strategy to complete chemistry problems were increased as compared to the decrease in self-efficacy for the control group. The results indicated that students who were able to use metacognitive strategies to solve chemistry problems performed significantly better in chemistry achievement compared to the students who were not aware of using metacognitive strategies to think step-by-step to complete the problems.

Since chemistry is traditionally taught in units and further divided into chapters,

some students may have difficulty connecting these concepts, especially novice students (Nicoll, Francisco, & Nakhleh, 2001; Sirhan, 2007). These students may have difficulty relating new knowledge to prior knowledge and build connections to apply that knowledge to the task at hand (Davenport, Yaron, Koedinger, & Klahr, 2008; Nakhleh, 1992). Therefore efforts to promote metacognition in chemistry to help students become aware of their own ideas and to visually represent the relationships between concepts have been utilized through the use of concept mapping.

### **Concept Mapping as a Tool for Subject Learning**

Chemistry is considered to be highly conceptual and requires a student to bring together conceptual knowledge for the fundamental chemical topics taught in the course (Sirhan, 2007). Students in a chemistry course have to link prior and new concepts together to get a full understanding of the topic. Concept mapping, therefore, may be used for students as an educational tool to help them visually organize key concepts, their relationships and connections between new concepts and prior knowledge (BouJaoude & Attieh, 2008).

As students create concept maps, they are organizing their own understanding of related concepts (Bentley, Kennedy, & Semsar, 2011). Concept maps are constructed by placing the most general concept at the top of the map, usually enclosed in a circle or box. The related concepts are then placed in lower positions on the maps and connected by lines or arrows to indicate their relationships. Words are also added to the connecting lines to indicate the relationship between the two concepts (Novak & Canas, 2008; Stensvold & Wilson, 1992). These linking words or phrases form meaningful statements between the concepts. It is considered that the greater the number of valid links a student

places between the concepts, the more the student understands the relationships and conceptual meaning of the topic (Ozmen, Demircioglu, & Coll, 2009). Concept maps are considered to be a tool that enhances meaningful learning and promote students' conceptual understanding of science concepts by actively engaging students because they construct the concept maps (Karakuyu, 2010; Markow & Lonning, 1998).

Concept mapping is based on the idea that concepts and their relationships are the building blocks of knowledge (Novak & Canas, 2008; Pendley, Bretz, & Novak, 1994). Experts in a subject domain like chemistry are able to organize knowledge around core concepts and determine the approaches and key concepts which are required to understand a problem. However, novice learners focus on individual pieces of information and may not have the experience or knowledge to connect key concepts together in order to understand a problem (Kozma & Russell, 1997). Therefore as an educational tool, concept mapping may be used to visually organize students' formation of links between concepts (Nicoll, Francisco, & Nakhleh, 2001). Moreover, it may also encourage students' to take a more active role in their learning process by helping them see key concepts and their connections (BouJaoude & Attieh, 2008).

The effectiveness of concept mapping in several content areas has been investigated in the sciences such as biology, physics, and chemistry (Erdem, Yilmaz, & Ozyalcim, 2009; Karakuyu, 2010; Martinez, Perez, Suero, & Pardo, 2012; Schaal, 2010). The use of concept maps range from curriculum development, assessment tools, teaching aids, and study/learning tools in education.

## **Concept Mapping as an Assessment Tool**

As an assessment tool, concept mapping can be used to evaluate students' conceptions and misconceptions about a topic. It can also be used to identify a students' knowledge before and after instruction (Novak & Canas, 2008). Additionally, concept mapping may also be utilized as a means to evaluate "students' ability to make connections between concepts" (Francisco, Nakhleh, Nurrenbern, & Miller, 2002). Furthermore, concept maps have been used as an assessment tool to measure students' variations in learning, to record changes in achievement, and to evaluate differences between expert and novice learners (Lopez, et al., 2011).

One such study (Pendley, Bretz, & Novak, 1994) examined the use of concept maps as a tool to assess learning in chemistry developed from clinical interviews from two groups of chemistry students. In this study, the first group consisted of six students enrolled in a sophomore-level physical/analytical chemistry course and the second group consisted of five first-year chemistry graduate students. In the first group, students were individually interviewed prior to any lecture about chromatography to assess their understanding of paper chromatography. After the last laboratory exercise on chromatography, the students were interviewed again to probe their understanding of concepts related to gas chromatography. The students also were given a final exam with problems related to chromatography at the end of the course. In the second group, students were also individually interviewed prior to any instruction about chromatography. After the last chromatography lecture, the students were interviewed again to probe their understanding of concepts related to chromatography. A written examination was also administered to the students with questions pertaining to

chromatography. During the interviews, the students were shown a sketch of a visual aid (a tube with some generic material in it) and asked how a sample would look after some period of time based on chromatography concepts. The students were given a red and green marker to sketch how the separation would look after a period of time. The interviewer then asked the students to explain their rationale of the sketch. Based on the students' responses, concept maps were developed for each student. In the first group three of the six students demonstrated some understanding of the concepts used in paper chromatography before a formal lecture on chromatography. After instruction these students built upon their understanding of chromatography by specifying additional concepts related to gas chromatography. However, the results showed that the students' performance on the exam questions relating to chromatography did not accurately reflect the students' understanding of chromatography concepts as seen in the developed concept maps. In the second group based on the pre-concept maps, the graduate students had a better understanding of chromatography concepts prior to instruction compared to the first group. After instruction, four of the five graduate students were able to correct their misconceptions of chromatography and showed a better integration of new concepts. Finally, the authors concluded that concept maps are a good tool to assess students' understanding by demonstrating misconceptions and changes in conceptual knowledge of chemistry.

In another study (Francisco, Nakhleh, Nurrenbern, & Miller, 2002), the authors reported on the changes in conceptual understanding for students through the use of concept mapping as an assessment tool. The authors hypothesized that student learning may be improved with the aid of concept mapping. In this study the first cycle consisted

of 446 students enrolled in an introductory chemistry course. The participants received training on constructing concept maps during lectures before giving any homework assignments on concept mapping. Concept mapping assignments included weekly homework, pre-laboratory exercises, and post-laboratory exercises. Data collected in the first cycle consisted of the students' concept maps from the post-laboratory exercises, overall course scores, student surveys, and teacher assistants' questionnaires. The second cycle examined 437 students enrolled in the same introductory chemistry course a year later. Concept maps were assigned as homework assignments and given on quizzes and examination questions. Data collected in the second cycle included concept maps from the quizzes and student surveys. The third cycle consisted of 345 students enrolled in the second semester introductory chemistry course. Assignments were given for students to construct concept maps on quizzes and examination questions. Data collected in this cycle consisted of the concept maps on quizzes and student focus group interviews. The concept maps were scored by coding the linking phrases that connected concepts as correct, correct but non-informative, incorrect, or duplicate. Based on the coding the following scoring algorithm was developed:

$$\frac{\#correct (linking phrases) - \# wrong or noninformative (linking phrases)}{total \# of connections made} \times 5$$

The algorithm is multiplied by 5 because concept map questions on quizzes were assigned a total of five points. In order for students to receive credit on the concept mapping questions, all terms were expected to have at least one connecting link in the map. Results from the focus group showed that student' attitudes towards concept maps as an evaluation tool were positive. However the student surveys showed that students expressed the lack of consistency of the grading provided by different teacher assistants.



From the teacher assistants' questionnaires, the assistants noted that the students' concept maps that produced numerous links may be an indication of the students' ability to solve multiple-step problems. The authors concluded that students who showed more cross-linking of concepts had an enhance ability to correctly solve complex problems.

In a more recent study (Yesiloglu, Altun, & Koseoglu, 2008), concept mapping was used to examine students' conceptual understanding of scientific knowledge in a science method course. Twenty-seven pre-service chemistry teacher students participated in the study. The objectives of the study were to explore the use of concept maps in assessing student teacher's understanding of scientific knowledge and to monitor the students' learning outcomes in the science method course. The students were given a scientific inquiry kit which included activities and a video program to visually introduce the students to the steps involved in the scientific method. The students were also given instruction on how to construct concept maps based on the concepts introduced in the scientific inquiry kit. These concept maps were constructed before and after the course from a list of concepts provided by the researchers. Each concept map was individually scored by giving 1 point for each correct linkage or relationship, 5 points for each level of hierarchy and 5 to 10 points for cross-links that showed correct relation between two concepts in different parts of the hierarchy. Paired sample t-test showed a statistically significant difference between the pre- and post- concept map scores. These results showed that the students gained additional understanding of the concepts after instruction on scientific inquiry and were able to relate that new knowledge in creating more defined concept maps.

Lopez et al. (2011) examined the use of concept mapping as a diagnostic assessment tool in organic chemistry. Two research questions guided their study: 1) How do concept map scores represent construct validity with other outcome measures? and 2) Can concept map performance show gaps in students' conceptual understanding in organic chemistry? Seventy students enrolled in an introductory organic chemistry class were participants in the study. The students were interviewed four times throughout the semester on organic chemistry topics. The first interview consisted of questions on structure and bonding, interview 2 on stereochemistry, interview 3 on alkyl halide reactions, and interview 4 on reactions of alkenes. During each interview students were also required to complete organic chemistry problem set activities. The students were also instructed to complete concept maps during each interview corresponding to topics taught in the class. Students were instructed to create the concept maps with as many links as possible from a given list of concept terms. The concept maps were graded by scoring the linking between concepts as "0" for incorrect or scientifically irrelevant, "1" for partially incorrect, "2" for correct but scientifically thin (technically correct but answers are too general or vague), and "3" for scientifically correct and precise. The students' final course grade was collected from their transcripts. Results showed for correlation analyses that the concept map scores had a significant correlation with the students' final organic chemistry course grades and problem solving scores. The results showed that students who demonstrated a better organized knowledge of organic chemistry concepts displayed higher levels of performance in organic chemistry.

## **Concept Maps as Learning Tools**

Although there are several studies on the use of concept mapping as an assessment tool, concept maps are also used as learning aids in the classroom. As a learning aid, concept mapping is considered to promote meaningful learning (Novak & Canas, 2008). It requires students to organize knowledge, represent relationships between concepts, and integrate new knowledge with previously learned knowledge (Bentley, Kennedy, & Semsar, 2011). Concept maps may also help students to visually identify key concepts and their connections (BouJaoude & Attieh, 2008). Several studies have reported on the use of concept maps as learning aids to enhance the understanding of key concepts taught in the sciences (Nicoll, Francisco, & Nakhleh, 2001; Stensvold & Wilson, 1992; Schaal, 2010).

Nicoll et al. (2001) explored the use of concept mapping as an integral part of a freshman-level general chemistry course. Participants in the study involved twenty students from two sections of the general chemistry course. The treatment group consisted of 10 students in which concept maps were an integral part of the course. The control group also consisted of 10 students in which concept maps were not an integral part of the course. In the control group, the professor did not use concept maps at all in the curriculum. However in the treatment group, the professor used concept maps in lecture, on exams and quizzes. Students in the treatment group were trained to construct concept maps at the beginning of the course. Concept maps were then assigned as homework assignments and on quizzes. Each student in both groups was interviewed on their understanding of bonding, electrons, electronegativity, and geometry. Based on the students' answers from the interview, concept maps were developed by the authors. The

students were not asked to draw concept maps for the data analysis in this study. Data analysis was performed using t-tests to determine any significant differences between the concept maps developed from the control and treatment groups. The concept maps from the treatment group indicated that students had developed a higher number of total links ( $t = 2.27, \alpha = .05$ ), total nodes ( $t = 1.85, \alpha = .05$ ), and total useful links ( $t = 2.40, \alpha = .05$ ). Additionally the results can be shown when comparing the total useful links (correct links) of both groups in which the average number of useful links for the treatment group was 55 compared to 34.6 for the control group. Therefore, the treatment group demonstrated more useful links compared to the control group. In more detail, eight students out of the treatment group had 70 examples of electron-bond links compared to the nine students in the control group who had 40 examples of electron-bond links. Similarly, six students in the treatment group provided a total of 45 examples of the bond-electronegativity link compared to only four students in the control group who provided only 14 examples. Therefore, the results indicate that the students in the treatment group were better able to make the connections in their knowledge base and integrate these concepts from different domains than compared to the control group.

According to Markow & Lonning (1998), construction of pre-lab and post-lab concept maps will help students understand the concepts in the experiments they will perform. In their study, students enrolled in an introductory inorganic and organic chemistry course at a small women's college were divided into the control and experimental groups based on their pretest scores on a 35-item multiple choice exam given at the beginning of the semester. All of the participants were non-science majors with a majority of the students being nursing and nutrition students. Participants in the

experimental group were introduced and practiced constructing concept maps prior to the four lab experiments used for data collection. One week before each experiment both groups were provided a list of concepts sheet. The control group was required to construct a list of objectives from the list of concepts sheet for the pre-lab assignment. The experimental group used the list of concepts sheet to construct a pre-lab concept map. After each laboratory activity, the control group used the concepts on the list of concepts sheet to write an essay explaining the chemical concepts in the experiment. The experimental group used their pre-lab concept map to add additional concepts and linkages after the experiments. One week after completing each experiment, a 25-item achievement test was administered to both groups which covered concepts encountered in the laboratory experiments. The results from the ANOVA indicated no significant differences between the two groups on 3 of the 4 achievement tests. Based on their results, the authors concluded that students who construct concept maps for the laboratory do not necessarily have higher scores on achievement tests compared to those who write essays. However, when the authors individually scored the experimental groups pre- and post-lab concept maps for experiments 2, 3, and 4, the results from the t-tests indicated a significant difference between the pre- and post-lab concept maps. The treatment groups' post-lab concept maps showed increased relationships between concepts and examples. The results showed that the students in the treatment group had a better understanding of organizing the concepts and representing their linkages after pre-lab instruction. The authors concluded that the construction of concept maps played an active role in the students' learning process by providing them with a way to connect concepts and visually see how these concepts relate to one another.

In another study (Ozmen, Demircioglu, & Coll, 2009) investigating the effects of concept mapping use on laboratory activities about acid-base chemistry, concept maps were used to demonstrate to students how concepts were linked. The study consisted of 31 students in the treatment group and 28 students in the control group. Both groups were taught the same acid base concepts such as properties of acids and bases, the pH concept, the strength of acids and bases, buffer solutions, and hydrolysis of salts. The control group was taught the concepts in lecture by the teacher providing explanations of the topics using the textbook and worked examples. The students also completed worksheets and practice activities for exams. In the treatment group, the students were taught the concepts in the laboratory by completing eight different activities. After each activity, class discussions were conducted by the teacher, and students were then required to prepare concept maps based on the concepts discussed in the laboratory. Both groups were administered a 25-item pre- and post- concept achievement test about acids and bases. The independent sample t-test showed a statistically significant difference between the control and treatment groups on the post- concept achievement test. The results revealed that the students in the treatment group had fewer misconceptions after instructions about acids and bases compared to the control group on the concept achievement test. The authors concluded that the use of concept maps in the laboratory gave students the ability to organize their ideas, to better understand the results of their laboratory activities, and to allow the teacher to identify any misconceptions in student learning.

Concept mapping has been shown that it may be helpful for students in visualizing a knowledge domain such as chemistry and build from a novice linear

structure to an expert's hierarchical base (Bentley, Kennedy, & Semsar, 2011; Novak & Canas, 2008; Schaal, 2010). However, constructing concept maps may be enhanced by the use of computer-aided tools. The aid of the computer in creating these concept maps may encourage students to be more involved in their learning process by facilitating visual thinking (Erdogan, 2009). According to Schaal, (2010) computer-aided materials may foster learning and promote self-efficacy in engaging students to learn in a more domain-specific environment to help them develop these concept maps.

### **Creating Concept Maps with the aid of Computers**

In education, computers can provide a much richer learning environment that allows “the integration of media and representations to illustrate, explain, or explore complex ideas and phenomena” (Atkins, et al., 2010) such as the concepts taught in chemistry. Modern technology therefore can provide an instantaneous feedback to the learner, support and instruction for individualized learning, enable interactive activities, engage critical thinking and problem solving skills, and encourage students to take their learning to higher standards (Glenn & D'Agostino, 2008). In that case, our main educational challenges are to identify ways in which to successfully integrate technology into the classroom for enhanced learning.

Several studies in education have examined the use of computers in helping students create more defined concept maps. These studies involve the comparison of using computer programs to create concept maps and paper/pencil-based concept maps (Kwon & Cifuentes, 2007; Royer & Royer, 2004). Royer & Royer (2004) compared the use of paper/pencil and computer-based concept maps for use in a biology class. The study consisted of 24 students in the control group and 29 students in the treatment group.

The students in the computer-based concept mapping group used the Inspiration software program to create the concept maps. Inspiration is used to help users create diagrams, visual maps, concept maps, and outlining with its diagram and mapping tools (Inspiration Software Inc, 2012). The concept maps were scored by giving 1 point for each valid relationship and example, 5 points for each valid hierarchy, and 10 points for each valid cross link. Before completing any concept maps for the study, the students were assigned several mini concept mapping activities. The students were then required to create concept maps on gene expression using the Inspiration program. The control group, however, created paper/pencil concept maps on gene expression without the use of computers. At the end of the study, both groups were given a questionnaire on their opinions of using the computer and paper/pencil to create concept maps. The t-test results indicated that the students who used the Inspiration software created more complex concept maps compared to the students who created the concept maps using paper and pencil. However, the students indicated that even with the paper and pencil created concept maps they were able to understand the concepts better, remember more things, find relationships, and organize their thoughts.

Kwon and Cifuentes (2007) investigated the comparison of computer generated concept maps for students learning science concepts using the Inspiration software program. In their study, the researchers hypothesized that students who individually and collaboratively generated concept maps using computers would perform better than students who did not generate concept maps. The second hypothesis was that students' attitudes towards concept mapping would be positive for both groups. The control group consisted of 12 students, the individual group consisted of 31 students, and the



collaborative group consisted of 31 students. At the beginning of the semester, the individual and collaborative group attended a three day workshop on computer-based concept mapping using Inspiration. The control group spent the same amount of time as the other two groups who attended the workshops but instead of learning how to create concept maps, the students were required to watch a video about an upcoming science fair. After the three days attending the workshop, the three groups were all given the same science essays to study in the classroom for four days to prepare for the comprehension exam. The students in the control group studied their notes and the science essay individually for thirty minutes. Students in the individual group also studied individually and created concept maps using the Inspiration software for thirty minutes. Students in the collaborative group studied in groups of three and created concept maps using the Inspiration software for thirty minutes. All of the groups submitted their study notes and concepts maps before taking the comprehension exam. Students were also asked to complete a learning strategy questionnaire developed by the researchers to describe the steps they took to prepare for the comprehension exam. One-way ANOVA showed that there was a significant difference between the individual, collaborative, and control groups on the comprehension exam. The Tukey's HSD post hoc test also indicated that the individual group outperformed the control group on the comprehension test. However, there was no significant difference found between the scores on the comprehension test for the individual and collaborative groups. The questionnaire results reported that students' attitudes towards using concept mapping for science learning were positive regardless of whether they individually or collaboratively created the concept maps. The students expressed that "creating those maps and studying

relationships between bubbles and links were quite helpful and fun for learning science”. The authors concluded that students’ views on creating concept maps with the use of computers were positive and may influence science concept learning.

Another study involves the use of computer programs that allow students to create concept maps with hypermedia, images, and animation (Erdem, Yilmaz, & Ozyalcim, 2009). In this study, the authors investigated the effect of concept mapping on meaningful learning of atom and bonding in a basic chemistry course. The main goal was to determine the effects of concept maps prepared using paper/pencil and a hypertext-hypermedia program. Thirty students enrolled in a basic chemistry course participated in the study. The students were randomly divided into two groups. Both groups were lectured on the concepts of atoms and bonding. The instructor explained to each group on how to prepare concept maps before requiring the students to construct concept maps on atom and bonding. In group 1, the teacher explained atoms and bonding using concept maps prepared using the computer with the hypertexts. The group 1 students then constructed their own concept maps using the hypertext-hypermedia technique. The students prepared the concept maps using text, graphics, audio, and moving images. In group 2, the instructor explained the same concepts using concept maps prepared using paper and pencil. The group 2 students then constructed their own concept maps using paper and pencil without the use of the computer. A 10-item open-ended atom and bonding knowledge test was also administered to the students as a pre- and post- test. The concept maps were analyzed by assigning 1 point for each valid relationship, 5 points for each valid hierarchy, 10 points for each valid cross-link and 1 point for each valid example. The t-test results showed a statistically significant

difference for group 1 on the pre- and post- test. However, for group 2 there was no significant difference found on the pre- and post- test. A significant difference was also reported for group 1 on the construction of the concept maps compared to group 2. The authors concluded that the students who used the hyper-text environment to create their concept maps were able to construct a greater number of correct relationships between concepts compared to the students who created the concept maps just with paper/pencil without the use of the computer. The authors state that “the advantage of this technique is the use of technology, it motivates the students and helps increase their success.”

Chou, Chen, and Dwyer (2011) examined the instructional effectiveness of different types of concept mapping for online learning about the human heart. Ninety-five undergraduate students participated in the study. The control group only received the online instructional material pertaining to the heart. The first treatment group received the same online instructional material with an additional 19 concept maps that summarized the instructional materials’ main content. The second treatment group also received the same online instructional material with an additional 19 visualized concept maps with static heart images or pictures. After completing the instructional materials, the students were administered three post-test: an identification test, terminology test, and comprehension test. The 20-item multiple choice identification test required students to identify numbered parts on a drawing of a human heart. The 20-item multiple choice terminology test measured students’ knowledge of facts, terms, and definitions. The comprehension test measured students’ understanding of the heart, its parts, internal functional, and process. The data was analyzed using one-way multivariate analysis of variance (MANOVA). The reported results showed that students in the visualized-based

concept mapping group (the second treatment group) outperformed the students in the traditional concept mapping on identification and terminology questions. There was no significant difference found between the control and treatment 1 group. The authors attributed these results to the incorporation of the visual images of the concepts with the textual information integrated into the concept maps.

Although these previous studies used the computer and concept mapping for learning, the majority of studies used some sort of computer program to help students construct the concept maps. Even with the computer generated concept maps, the reports showed that students were able to perform better on achievement tests compared to the students who did not use the computer. However, the concept maps generated on the computer did not provide students access to the internet but only a visual representation of the concept map. Although the computer generated concept maps present the relevant concepts, it does not provide a path to help students understand the relationship between concepts. For this purpose, the construction of concept maps may be enhanced by the use of the internet and ontologies. However, the web for educational purposes are still limited due to the vast amount of information provided which may be presented without relevance or has misconceptions that may hinder a novice learner (Hargis, 2001). Therefore, ontologies may be helpful in describing related knowledge and identifying useful and connected information in a domain of interest such as chemistry using the internet (Chen, 2009).

### **Ontologies for Conceptual Learning**

There are several definitions that have been reported for the term ontology. Ontology stems from the branch of philosophy called metaphysics that studies the nature

of being and was first introduced by Aristotle to classify things in the world. However, in information science the term ontology takes on a different meaning. It was first introduced to the information science disciplines during the 1990s by Artificial Intelligence researchers. The most cited definition was proposed by T.R. Gruber which defines it as “a formal, explicit specification of a shared conceptualization for a domain of interest (Gruber, 1993)”. However for educational purposes, a ontology can be defined as a hierarchically structured set of terms to describe a domain that can be used as a skeletal foundation for a knowledge base (Swartout, Patil, Knight, & Russ, 1997). Some key methods in using ontology-based e-learning tools in the classroom for learning are described below:

- 1) *Using the Ontology to Carry out an Activity.* In order to become familiar with a particular subject, ontologies could be used to classify different concepts or gain a better understanding of the underlying topics. For example, an assignment can be given to a student in a chemistry course to classify matter. This student while using the ontology has to understand the underlying logic of the subject including types of matter, their classifications, characteristics, etc. Additionally, students are using the ontology as a visual representation of the general structure of course materials (Allert, Markkanen, & Richter, 2006).
- 2) *Using Ontologies to Organize Information.* In all classrooms, the course content is derived from a vast amount of data and information. While taking a course a student has to organize, store, and retrieve this data/information for learning. Therefore, ontologies can be used to organize and store this information in a more efficient manner by keywords, definitions, concepts, and theories. Students are

able to use a more domain specific tool to gain a better understanding of the material and therefore can produce mental concept maps of the subject (Allert, Markkanen, & Richter, 2006).

Several studies in the literature have reported on the use of educational ontologies as a tool for enhanced learning that also integrates course related materials into its system for learning (Fok & Shing, 2007; He, Peng, Mao, & Wu, 2010; Pernaa & Aksela, 2008; Wang, Peng, Cheng, Zhou, & Liu, 2011). One study (Pernaa & Aksela, 2008) used concept mapping as a navigational tool for meaningful learning in a web based chemistry course. The concept maps were designed using CmapTools for an easy navigational tool to help students find relevant course information on insect chemistry. CmapTools software is used to create concept maps with the possibility of adding media resources such as animations, pictures, and documents (CmapTools knowledge modeling kit, 2012). The system consisted of four general maps, eight complex concept maps, and 11 web pages. The four general maps were designed for students to visually identify a general structure of the material. The concept mapping pages were designed to give an example of the information on the web page and help students organize the knowledge of the web page before actually viewing it. After students clicked on the web page, they would be able to view animations and several interactive molecular models. Seventeen chemistry teachers participated in the study to evaluate the web system. After using the web system, each participant was given a questionnaire to examine their opinions of the web material. The results from the survey indicated a high acceptance of using the web-based learning materials for insect chemistry with the use of concept maps. While 65%

of the teachers strongly agreed that the use of concept maps was an excellent or a good navigation tool for the web material, some of the participants expressed concern over the structure of the web material by stating: “There were too much [sic] concept maps. I did not get the whole picture”. While others had a more positive view about the system stating “Concept maps clarified the structure.”

He, Peng, Mao, and Wu, (2010) study involved e-learning models designed by integrating digital libraries and ontology-based knowledge representation. Their system, DiLight, was tailored to library and information science course related materials and included slides, lecture videos, readings, and textbooks that were presented in a digital library. Students used the DiLight system by browsing through the collection using the lecture-based browsing, ontology-based browsing, and ontology-based search. The lecture-based browsing allowed a student to browse through the lecture collection and locate specific topics and their corresponding documents. The ontology-based browsing allowed a student to navigate through the 43 types of relationships provided in the ontology and discover semantic relationships between the course topics and concepts. The ontology-based search option allowed the students to find documents that were relevantly similar to the search terms due to its searching mechanism of utilizing interconnection and associative relationships between concepts. Ten students enrolled in the library and information science course participated in the study and completed eight task using the DiLight system and Blackboard. After completing the tasks, the students were administered a questionnaire asking about the usefulness of the two systems in completing the tasks. Descriptive statistics showed that students performed better when they used the DiLight system to complete the tasks than using Blackboard. The results

also showed that the students spent less time to complete their tasks using the DiLight system than by using Blackboard. From the questionnaire, the results showed that 60% of the students agreed or strongly agreed that the ontology-based search option in DiLight was helpful in completing the tasks and finding the correct answers, while only 10% of the students strongly agreed that Blackboard was helpful. The authors concluded that e-learning technology with the use of ontologies may enhance students' learning performance and become an extension to traditional instruction methods.

In another study (Wang, Peng, Cheng, Zhou, & Liu, 2011), the authors investigated the use of knowledge visualization for self-regulated online learning. The system structure contained Java programming course material. The course materials were arranged into a knowledge visualization map with the main concepts connected to related concepts. Students were able to explore the concepts by zooming into/out of the map or by clicking "+" and "-" around the concept nodes. The knowledge visualization maps were also linked to assessment materials, learning resources (lecture slides, audio presentations, reading materials), and questions and answer discussion problems. Twenty students voluntarily accepted as participants to evaluate the JAVA system. Data was collected using a questionnaire survey and an interview to collect data on students' perceptions and reactions towards the system. Paired-sample t-test was used to evaluate the pre- and post- surveys. Boxplots were reported to describe the exploratory characteristics of the surveys by explaining students' satisfaction with the system and their satisfaction with individual functions in the system. The t-test revealed that students had a positive attitude toward online learning and they were willing to use the online learning system. The Boxplots revealed that the systems and individual functions were



perceived to be easy to use by the students. Also nineteen of the twenty participants participated in the interview portion of the research. From the interview response, all of the participants gave positive remarks about using the system. Most of the participants also suggested that the system was easy to browse to find learning resources by clicking on a topic. One participant stated, “In case I want to know more about a specific knowledge, I just click it. It is so simple and direct, saving both time and effort”. The authors concluded that although the study was conducted with a programming course, ontologies can be applied to other learning programs.

Although there have been several reported studies on the use of ontologies in the literature, most of these have been based on literature reviews (Allert, Markkanen, & Richter, 2006; Cassin, Eliot, Lesser, Rawlins, & Woolf, 2003; Fok & Shing, 2007; Sosnovsky, 2009). Other studies using ontologies for learning in the literature have been overview studies introducing the ontologies without any noteworthy results of their use (Kadivar & Lee, 2010; Chu, Lee, & Tsai, 2011). Even though prior studies as discussed previously used pre-existing computer concept maps (Chou, Chen, & Dwyer, 2011; Pernaa & Aksela, 2008) or computer generated concept maps for learning (Kwon & Cifuentes, 2007), ontologies with the use of the internet may provide additional information to a user such as textual and pictorial information with digital resources (animations, simulations, videos). Ontologies, therefore, can be built around a specific knowledge base such as the subject chemistry. It can include a vocabulary of terms, definitions, and an indication of how concepts are related (Fok & Shing, 2007). Ontologies are also cognitively structured, so that the relationships among concept nodes are clearly defined for learners (Chu, Lee, & Tsai, 2011). Students then will have a more

domain specific “database” to locate concepts and identify their relationships between them (Pernaa & Aksela, 2008) to create concept maps. Therefore, a chemistry ontology may provide students with a more valuable tool for the use in educational settings because it can be designed to search concepts in chemistry; and it can also provide the user topics related to a concept of interest which may aid in a student’s understanding of the subject.

This literature review set out to discuss issues in learning chemistry in college and describe alternative learning aids to help students in these courses. The major themes found in the literature dealt with learning college chemistry, the use of concept mapping in the classroom for educational purposes, and computer-aided learning tools. The major findings of the literature review were that the main factors in learning chemistry were students’ attitudes towards chemistry, their lack of understanding of fundamental concepts, misconceptions of chemistry concepts, and using rote learning. Other major findings indicated that concept maps were not only used as assessment tools but also as learning and study tools for student learning. The use of concept maps not only helped students in organizing course concepts but also proved to be a valuable tool for them in gaining a better cognitive understanding of the material. Finally the use of computer-aided learning tools proved to be a valuable tool for students to be able to use the internet as a structured learning environment.

This study filled a gap in the literature on the use of ontologies for e-learning purposes for the learning of the sciences. As evidence shows from the previous literature above (He, Peng, Mao, & Wu, 2010; Pernaa & Aksela, 2008; Wang, Peng, Cheng, Zhou, & Liu, 2011), these studies support the use of ontologies for e-learning purposes and the

use of ontologies in the sciences that will add to the knowledge base of existing literature to promote this alternative learning tool in education. Also, this would provide an alternative means of organizing and sharing course materials for several disciplines that can be used by not only students but tutors and teachers as well. This study also expanded the knowledge on the use of concept mapping and computers in chemistry as a study/learning tool and identified further research possibilities that identified ways to improve students' attitudes towards chemistry, conceptual understanding of chemical concepts, and metacognitive skills.

## **CHAPTER 3**

### **RESEARCH PLAN**

The purpose of this study was to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course. Therefore the goals of the proposed research were to (1) develop a concept exploration based learning methodology using concept maps as study/learning tools for learning of chemistry concepts, (2) develop an ontology-based interactive platform in which relevant information to a course can be sought, and (3) measure student outcomes through the use of examinations and surveys to assess changes in metacognition and attitudes towards chemistry. The following research questions were addressed in this study:

RQ1: What are the changes in students' metacognitive skills throughout a semester?

RQ2: How do students' attitudes change throughout a semester?

RQ3: What are the changes in students' metacognitive skills from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?

RQ4: How do students' attitudes change from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?

RQ5: How does the interaction with alternative learning aids (concept maps, ontology) affect students' ability to answer exam questions about key concepts compared to students in the control group?

RQ6: How does the interaction with alternative learning aids (concept maps, ontology) affect students' ability to explain connections between key concepts?

Additional research questions arose during the study to obtain a better understanding of students' attitudes towards creating concept maps and using the Creonto software in the introductory chemistry course.

RQ7: What are students' attitudes towards creating concept maps in the chemistry course?

RQ8: What are students' attitudes towards using the Creonto software?

### **Course and Participants**

The introductory chemistry course chosen for this study was part of a core curriculum course for non-science majors with little to no previous background in chemistry. The course is designed to introduce students to chemical principles and relevance to chemistry in the life sciences. The enrollment for the course varies between 90-180 students in each of the 5 sections offered per academic year, with the largest cohort of students being pre-nursing majors. This course was chosen because it is categorized as a general education or core requirement course and considered to be standard within the curriculum. The traditional teaching style for this course includes in-class lectures taught by PowerPoint notes which are posted on Blackboard Learn for student access. Therefore, our objective was not to change the teaching style of the course but to integrate concept mapping and the chemistry ontology into the existing curriculum and assess its effects on student learning.

This study consisted of three phases of implementation over a three semester period. Phase 1 (control group) consisted of a total of 64 out of 181 students in the

Spring semester who completed all research materials and course assignments. Phase 2 (treatment 1 group) consisted of a total of 32 out of 42 students in the Summer semester who completed all research materials and course assignments. Phase 3 (treatment 2 group) consisted of two groups due to there being two scheduled courses during the Fall semester of the study. In order to reduce confounding effects in the study, it was decided to compare the two groups in treatment 2 separately for this study to the control and treatment 1 groups. The treatment 2A group was taught in the morning and consisted of 103 of 182 students who completed all research materials and course assignments. The treatment 2B group was taught in the afternoon and consisted of 79 of 155 students who completed all research materials and course assignments.

## **Research Design**

*Phase 1* contained the control group with no integration of additional materials into the course. The control group was taught chemistry concepts by the traditional instructional format which consisted of an instructor centered approach. Materials were presented in lecture format from prepared PowerPoint notes, and students were assigned homework throughout the semester and assessed using examinations after each unit. The lecture PowerPoint slides, learning objectives, and practice examination questions were also provided to the students on Blackboard Learn. The purpose of this phase was to evaluate the effects of traditional learning aids on students' conceptual understanding of chemistry concepts, metacognitive skills, and attitudes towards chemistry. Pre- and post-surveys (Appendix A) were administered at the beginning and end of the semester to measure changes in students' opinions about their metacognitive skills and attitudes toward chemistry over the course term. Students in phase 1 (control group) were also

administered standardized examinations questions after each unit (Appendix B). The examination questions were used to compare students' abilities to explain key connections between concepts taught in the chemistry course. The questions consisted of short answer free response questions and multiple choice questions based on the central concept mapping topics.

*Phase 2* contained the first treatment group with the same traditional instructional format as the phase 1 group with the addition of the four concept mapping homework assignments (Appendix F) into the curriculum. All students were required to attend a concept mapping workshop session during the first week of courses to become familiarized with the instructions and requirements for constructing the concept maps in the course. The students all received a concept mapping instructional package that included a description and purpose of a concept map, steps to creating a concept map, how to write the descriptive phrases to show relationships between concepts, and a grading rubric (Appendix C). The concept mapping workshop format will be discussed in more detail in subsequent chapters. Pre- and post- surveys (Appendix A) were administered at the beginning and end of the semester to measure changes in the students' attitudes toward chemistry and metacognitive skills. The surveys administered also included additional survey items to measure students' opinions regarding the concept mapping intervention. Students were also assessed on their conceptual knowledge of chemistry concepts by using the same standardized examinations as described in phase 1. As with the control group, the lecture PowerPoint slides, learning objectives, and practice examination questions were also provided to the students on Blackboard Learn.

*Phase 3* contained the second treatment group with the integration of the same four concept mapping homework assignments as phase 2 with the addition of using the chemistry ontology, Creonto software “Intro Chemistry” application. The same instructional format was followed in phase 3 as was described in phases 1 and 2. As with phase 2, all students in phase 3 were also required to attend a concept mapping workshop session during the first week of the semester to become familiarized with the instructions and requirements for constructing the concept maps in the course. Additionally, students in phase 3 received an instructional sheet during the concept mapping workshop for using the Creonto “Intro Chemistry” software to help them visually see how the chemistry concepts were related to one another and assist them with composing their descriptive phrases when constructing their concept maps (Appendix D).

As with the control and treatment 1 group, the lecture PowerPoint slides, learning objectives, and practice examination questions were also provided to the students on Blackboard Learn. Pre- and post- surveys (Appendix A) were also administered at the beginning and end of the semester to measure the changes in the students’ attitudes toward chemistry and metacognitive skills. The surveys administered in this phase are the same as described in phases 1 and 2 with the additional survey items for the Creonto “Intro Chemistry” software. Students were also assessed on their conceptual knowledge of chemistry concepts by the same standardized examinations as described in phases 1 and 2.

### **Statistical Analysis**

The following portion discusses the statistical analysis used for each of the research questions.



**RQ1 and RQ2:** Paired sample t-test was used to analyze the pre- and post-survey data to measure the changes in students' attitudes towards chemistry and metacognitive skills for learning at the beginning and end of the semester. Paired sample t-test statistics was used because it determines whether there is a difference between the means in the same group. This analysis was completed for each phase of the study.

**RQ3-RQ5:** Univariate analysis of variance (ANOVA) was used to analyze the pre- and post-survey data and standardized examination multiple choice scores from all three phases. Univariate ANOVA was chosen because it determines whether there is a difference between the means of two or more different groups. The pre- and post-surveys were used to investigate *RQ3 and RQ4* using data from all three phases to measure the changes in metacognitive skills and attitudes at the beginning and end of the semester. The dependent variables were the mean metacognitive skills and attitude scores and the independent variable was group. The standardized examination multiple choice questions were used to investigate *RQ5* to measure students' abilities to answer the standardized examination multiple choice questions. The dependent variable was the multiple choice exam scores and the independent variable was group.

**RQ5 and RQ6:** Friedman test was used to analyze the standardized examination short answer questions and concept mapping scores. The standardized examination questions also included short answer questions which were used to also investigate *RQ5*. The short answer questions on the examinations were based on the concept mapping homework topics. Concept mapping scores from phase 2 and 3 were used to investigate *RQ6* to determine the ability of students to explain connections between concepts. Friedman Test was chosen because it is used to test differences between groups when the

dependent variable is ordinal. The dependent variable was the concept mapping scores and the independent variable was time.

Additional questions arose during the study to obtain a more in depth understanding of the students' attitudes towards creating concept maps and using the Creonto "Intro Chemistry" software in the course. These questions were ***What are students' attitudes towards creating concept maps in the chemistry course?*** and ***What are students attitudes towards using the Creonto software?*** Univariate ANOVA and frequency distribution analysis was used respectively to analyze students' attitudes towards concept maps and the Creonto software. Univariate ANOVA was chosen because it determines whether there is a difference between the means of two or more different groups. Frequency distributions were used because only the treatment 2 groups used the Creonto software. The frequency analysis represented a summary of the distribution of values in the sample and showed the number of occurrences in that specific category. Table 1 shows a summary of the statistical methods that were utilized to analyze the research questions.

**Table 1.** Statistics used to analyze research questions

<i><b>RQ</b></i>	<i><b>Assessment</b></i>	<i><b>Research Questions</b></i>	<i><b>Statistical Procedure</b></i>
RQ1	Pre and Post Surveys	What are the changes in students' metacognitive skills throughout a semester?	Paired sample t-test
RQ2	Pre and Post Surveys	How does students' attitude change throughout a semester?	Paired sample t-test
RQ3	Pre and Post Surveys	What are the changes in students' metacognitive skills from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?	Univariate ANOVA
RQ4	Pre and Post Surveys	How does students' attitude change from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?	Univariate ANOVA
RQ5	Exams	How does the interaction with alternative learning aids (concept maps, ontology) effect students' ability to answer exam questions about key concepts?	Univariate ANOVA and Friedman Test
RQ6	Concept maps	How does the interaction with alternative learning aids (concept maps, ontology) effect students' ability to explain connections between key concepts?	Friedman Test
RQ7	Post Survey	What are students' attitudes towards creating concept maps in the chemistry course?	Univariate ANOVA
RQ8	Post Survey	What are students' attitudes towards using the Creonto software?	Frequency distribution

### Summary of Research Plan

This research study consisted of three phases of implementation over three semesters for students enrolled in an introductory chemistry course. All students involved in each phase of the study were taught by the traditional instructor centered format with the same instructor presenting the material. Phase 1 group contained the baseline data for the study which included no intervention in the course's curriculum. Phase 2 group consisted of the first intervention of four concept mapping homework assignments that were assigned in conjunction with each unit. Students were required to

construct a concept map based on a given topic by using a provided list of key concepts. Students in phase 2 were able to use the resources (course textbook, notes, and/or internet) of their choice to help them with constructing their concept maps. The phase 3 group consisted of the second treatment group with the additional intervention of using the Creonto “Intro Chemistry” software and was composed of two sections. These sections were compared separately to reduce confounding factors that may occur if the two sections were combined. Students were assigned the same four concept mapping homework assignments as phase 2 students with the inclusion of using the Creonto software to help them with constructing their concept maps. All students in phase 2 and 3 were required to attend a concept mapping workshop session that was held the first week of their respective semester that they were enrolled in the course.

Students in all three phases were assessed using standardized examination questions that were based on the four concept mapping topics and main concepts taught in the course. These exams were administered after the completion of each unit. Students in all phases were also assessed using pre and post surveys that were administered at the beginning and end of the semester. These surveys were used to measure students’ opinions towards their attitudes about chemistry and metacognitive skills for learning. Additional survey items were used in phase 2 and 3 groups to measure students’ opinions towards the use of concept mapping for learning and the Creonto software. Students in phases 2 and 3 groups also were assessed from their constructed concept maps to measure their abilities to explain connections between key concepts with the interaction of the alternative learning aids.

## **CHAPTER 4**

### **STUDENT SURVEY**

Based on the literature review and variables of interest to measure, an initial draft of survey items was developed. The initial survey consisted of 9 declarative statements in the attitude section, 14 declarative statements in the metacognitive skills section, and 8 declarative statements in the learning resources section. The instructions were designed to ask participations to indicate their level of agreement to each statement using a five-point Likert scale. The Likert scale included the following options: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree.

Attitudes towards chemistry statements were related to students' positive or negative feelings and their perceived self-efficacy about chemistry. The self-efficacy statements were intended to probe students' perceived confidence and ability in chemistry. The metacognitive skills statements were related to the three categories of metacognition which are planning, monitoring, and evaluating. The planning statements were intended to probe students' organizational skills. The monitoring and evaluating statements were intended to probe students' awareness of their own learning and assessment skills. Finally the learning resource statements were intended to probe students' opinions about concept maps and using the Creonto software.

## **Content Validity**

In order to validate the survey, an expert panel was utilized to obtain content validity measures. Validity measures are needed to determine whether the instrument adequately measures what it is intended to measure. The content review process was guided by McKenzie, Wood, Kotecki, Clark, and Brey (1999) study which used a mixed methods process of a qualitative review followed by a quantitative review. The main procedures followed to obtain content validity for the survey was to 1) create the initial draft of the survey, 2) establish a panel of experts, 3) complete the qualitative review, and 4) complete the quantitative review.

**Panel of Experts:** Once items were developed, the initial survey items were reviewed by a panel of experts to analyze content validity. Fifteen experts from the field of chemistry and chemistry education were asked to complete the review (Appendix E). However, only eleven experts completed the review, for a 73% response rate.

**Qualitative Review:** Members of the panel completed an online Survey Monkey instrument that asked them to provide feedback regarding the directions, instrument items, and overall instrument. The reviewers were asked to provide feedback on the clarity and revision of survey items. Based on the reviewers' feedback, the following revisions were made to the survey items (Table 2).

**Table 2:** Qualitative review revisions for Attitude section

<b>Attitude Item</b>	<b>Change</b>	<b>Reason for change</b>
I am enthusiastic about learning chemistry	I am interested in learning chemistry	Wording language
I am confident that I understand science concepts	I am confident that I can understand chemistry concepts	Too Broad
I am confident in my ability to do chemistry	Item Deleted	Unclear & Vague
I am comfortable in discussing science with my peers	I am comfortable discussing chemistry concepts taught in this course with other students	Too Broad
I am confident in my ability to solve chemistry problems	I am confident in my ability to solve chemistry problems in this course	More Specific
I am confident I will succeed in this chemistry course	I am confident I will achieve a passing grade in this chemistry course	More Specific
I am able to apply my knowledge of science to the real world	I can apply my knowledge of chemistry taught in this course to situations outside the classroom	Too Broad
Understanding of chemistry is necessary for me to achieve my career goals	Chemistry understanding is necessary for me to reach my career goals	Rearrange wording to flow better
My grade in this course determines how familiar I am with course materials. Applying that knowledge in the real world has little to do with it	Item Deleted	Two Parts and Unclear

These changes were considered for clarity and wording language. The following declarative statement was also added to the attitude section: “After completing this course, I am interested in taking other chemistry courses”. After the revision of the survey items, the second draft survey consisted of 8 declarative statements in the attitude section.

**Table 3:** Qualitative review revisions for Metacognitive section

<b>Metacognitive Item</b>	<b>Change</b>	<b>Reason for change</b>
I know that I understand topics when I can see how concepts relate to one another	I know I understand concepts when I can see how they relate to one another	Rearrange wording to flow better
Before solving a problem, I set a plan (steps) in my head on how to solve it	Before solving a problem, I make a plan (steps) on how to solve it	Wording to flow better
When solving problems, I keep track of my progress and make changes if needed	When solving problems, I check my work before submitting it	Two Parts; Made more Specific
I feel the ability to connect new concepts with prior knowledge to solve problems is challenge	The ability to connect new concepts with prior knowledge is a challenge for me	Wording to flow better
I use concepts I understand to guess the best way to proceed if I don't understand how to answer a question	If I don't understand how to answer a problem, I use concepts I do understand to guess at the best way to proceed	Rearrange wording to flow better
I become nervous when I have to consider multiple procedures (steps) to complete an assignment	Item Deleted	Unclear wording and assumes nervousness as metacognition
After completing an assignment, I think back on how I completed it and about what I might do differently next time	Item Deleted	Two Parts
I try to understand a problem before attempting to solve it	I try to visualize a problem before attempting to solve it	More Specific
When I have difficulty understanding a question, I give up and skip it	When I have difficulty understanding a problem I skip it	Two Parts
I feel as if it is a waste of time to go back and check my work on assignments	Checking my working on assignments is unproductive	Two Parts
I find that to fully understand a topic just memorizing it is enough	When learning chemistry memorizing the concepts is all I need to know	More specific
The ability to organize concepts is not important for me to solve problems	For me, the ability to organize concepts is important for problem solving	Wording to flow better



I try to connect new concepts to concepts I already know in order to get a better understanding. If I don't understand a topic	When I don't understand a concept, I try to connect it to concepts I already know	Combined into one sentence
I put adequate time and effort to do well in all my courses	Item Deleted	Two Parts and Not essential

The changes in the metacognitive section were mostly due to the initial statements having two parts. After the qualitative review, the second draft survey consisted of 11 declarative statements in the metacognitive skills section.

**Table 4:** Qualitative review revisions for Learning Resource

Learning Resource Item	Change	Reason for change
I have sometimes used concept mapping in my classes to help organize course materials	I have used concept mapping to help organize course concepts	Wording to flow better
I am confident in my ability to construct concept maps for learning	No change	
Concept mapping is time consuming	No change	
Concept mapping has helped me to see links between concepts	No change	
Concept mapping is helpful because it shows me what I know and what I need to learn	No change	
Concept mapping is hard to learn how to do	Item Deleted	Repetitive
Using the computer (internet, web tutorials, etc.) helps me in my learning	The Creonto software was easy to use to complete assignments	More specific
I feel comfortable in using the computer (internet, web tutorials, etc.) in my learning	The Creonto software was beneficial to my learning in this course	More Specific

After considering the revisions of the survey items, the second draft survey consisted of

eight declarative statements in the learning resource section. The additional statement added to the learning resource section included: “The Creonto software helped me to better understand the concepts taught in this course”. This statement was added to measure the students’ opinions towards the use of the chemistry ontology, Creonto, in the course.

**Quantitative Review:** After considering reviewers input on the revision and clarity of items, each reviewer was then asked to rate each items as essential, useful but not essential, or not necessary based on the item’s ability in monitoring changes in students’ opinions about their metacognitive skills, attitudes towards chemistry, and learning resources over the course term (Appendix E). The responses for each survey item were calculated using the content validity ratio (CVR) (Lawshe, 1975). The content validity ratio formula is  $CVR = \frac{n_e - N/2}{N/2}$  where  $n_e$  is the number of panelists rating an item as “essential” and  $N$  is the total number of panelists providing ratings. Table 5 shows the minimum CVR value that must be obtained for an item to be statistically significant at the  $p < 0.05$  level. From table 5, the lowest CVR value for eleven experts is 0.59 as the minimum requirement for statistical significance.

**Table 5:** Minimum values of CVR for items at the  $p>0.05$  level

Number of Panelists	Minimum Value
5	0.99
6	0.99
7	0.99
8	0.75
9	0.78
10	0.62
11	0.59
12	0.56
13	0.54
14	0.51
15	0.49
20	0.42
25	0.37
30	0.33
35	0.31
40	0.29

In the attitude section, only two items reached statistical significance (Table 6). These items were “I am interested in learning chemistry” and “I am confident in my ability to solve chemistry problems in this course”. Additionally, two other items had a CVR value of 0.455 and 0.273, which indicated that 8 of 11 and 7 of 11 reviewers respectively rated these items as essential. Based on the feedback, some of the reviewers believed that these items were useful but needed an additional comment (open-ended) section for students to clarify their reasoning of agreement. Additionally some reviewers appeared to be unclear on rating items as essential, useful but not essential, or not necessary. For example, one reviewer wrote: “I do not exactly understand”. This confusion on the rating scale and reviewers believing that items needed an additional comment (open-ended) section for students to clarify their reasoning of agreement resulted in the remaining four items in the attitude section having a low CVR value.

**Table 6:** Quantitative content validity results for attitude section

Attitude Items	CVR Value
“I am interesting in learning chemistry”	0.636
“I am confident in my ability to solve chemistry problems in this course”	
“I am confident that I can understand chemistry concepts”	0.455
“Chemistry understanding is necessary for me to reach my career goals”	0.273
“I am comfortable discussing chemistry concepts taught in this course with other students”	-0.091
“I am confident I will achieve a passing grade in this chemistry course”	
“I can apply my knowledge of chemistry taught in this course to situations outside the classroom”	-0.273
“After completing this course, I am interested in taking other chemistry courses”	

In the metacognitive section, four items reached statistical significance (Table 7). These items were “I know I understand concepts when I can see how they relate to one another”, “Before solving a problem, I make a plan (steps) on how to solve it”, “The ability to connect new concepts with prior knowledge is a challenge for me” and “When I don’t understand a concept, I try to connect it to concepts I already know”. Additionally the remaining seven items all had positive CVR values which indicated that more than half of the reviewers rated the items as essential.

**Table 7:** “Quantitative content validity for metacognitive skills section

<b>Metacognitive Skills Items</b>	<b>CVR Value</b>
“I know I understand concepts when I can see how they relate to one another”	0.818
“Before solving a problem, I make a plan (steps) on how to solve it”  “The ability to connect new concepts with prior knowledge is a challenge for me”  “When I don’t understand a concept, I try to connect it to concepts I already know”	0.636
“When solving problems, I check my work before submitting it”	0.455
“If I don’t understand how to answer a problem, I use concepts I do understand to guess at the best way to proceed”  “I try to visualize a problem before attempting to solve it”  “Checking my work on assignments is unproductive”  “For me the ability to organize concepts is important for problem solving”	0.273
“When I have difficulty understanding a problem, I skip it”  “When learning chemistry memorizing the concepts is all I need to know”	0.091

In the learning resource section, one item reached statistical significance (Table 8). This item was “The Creonto software helped me to better understand the concepts taught in this course.” Additionally, five of the items had positive CVR values which indicated that more than half of the reviewers rated the items as essential. Based on the feedback, reviewers considered the concept map and Creonto software statements as not relevant for the course. Clarification and an explanation were given to reviewers concerning the use of concept maps and the Creonto software in the course. However, reviewers were still confused on the importance of the statements; for example, one

reviewer wrote “With respect to these items, I don’t know enough about the course to determine how essential the instructor thinks the particulars of the course learning opportunities are to learning”. This confusion on the importance of the statements to measure students’ attitudes towards concept maps and the Creonto software resulted in the low CVR ratings for the learning resource items.

**Table 8:** “Quantitative content validity for learning resource items

<b>Learning Resource Items</b>	<b>CVR Value</b>
“I have used concept mapping to help organize course concepts”	0.091
“I am confident in my ability to construct concept maps for learning”	0.273
“Concept mapping has helped me to see links between concepts”	
“Concept mapping is helpful because shows me what I know and what I need to learn”	
“Concept mapping is time consuming”	-0.455
“The Creonto software helped me to better understand the concepts taught in this course”	0.636
“The Creonto software was easy to use to complete assignments”	-0.091
“The Creonto software was beneficial to my learning in this course”	0.455

It was noted by Bunce, VandenPlas, Neiles, & Flens (2010) that content validity is a “subjective measure because it relies on the judgment of experts in the field”. This traditionally requires for those items that fall below the CVR significance level to be deleted. However, based on Lawshe’s content validity formula the following characteristics were utilized:

- When the CVR value is negative, fewer than half of the experts rated the item as essential
- When the CVR value is zero, half of the experts rated the item as essential

and half rated it as not essential

- When the CVR value is 1.00, all of the experts rated the item as essential
- When the CVR value is between zero and 1.00, more than half but less than all the experts rated the item as essential

These characteristics suggest that when the CVR value is between zero and 1.00, that more than half of the experts rated the item as essential. Therefore, the items on the survey with CVR values between zero and 1.00 were retained and items with negative values were deleted from the student survey. A final version of the revised survey (Appendix A) was utilized in the study and contained four statements in the attitude section, eleven statements in the metacognitive section, and six statements in the learning resource section.

### **Survey Reliability**

Reliability of the survey instrument was first completed using test-retest reliability using 118 student volunteers in the introductory chemistry course. Students were administered only the attitude and metacognitive sections of the survey twice approximately 2-3 weeks apart. These sections were only administered because the student volunteers had no interaction with concept mapping or the Creonto software in the introductory chemistry course. The data collected from the survey was analyzed using the correlation coefficient between the two sets of responses. The correlation coefficient indicated the degree of linear relationship between the responses. The value from the correlation coefficient range between +1.0 and -1.0 where +1.0 indicates a perfect linear positive relationship and -1.0 indicates a perfect linear negative

relationship. A correlation of 0.0 indicates a lack of linear relationship. However, a correlation value of 0.7 to 0.8 is considered as satisfactory.

Before calculating the reliability, some survey items needed to be reversed scored to properly measure reliability. Four items in the metacognitive skills section were reversed scored using the same 5-point Likert scale, where 5 indicated strongly disagree to 1 indicating strongly agree. These four items were “The ability to connect new concepts with prior knowledge is a challenge for me”, “When I have difficulty understanding a problem, I skip it”, “Checking my work on assignments is unproductive”, and “When learning chemistry memorizing the concepts is all I need to know”.

After reverse scoring the items in the metacognitive section, each section was then averaged for each participant yielding one value for the attitude and metacognitive skills section to calculate test-retest reliability. The analysis was performed using IBM SPSS Statistics software version 22. Table 9 shows the test-retest reliability correlation coefficient for the attitude and metacognitive skills sections which indicate satisfactory reliability of the survey.

**Table 9:** Test-retest survey reliability measurements

<b>Survey Sections</b>	<b>Test-Retest Reliability</b>
Attitude Section	$\alpha = 0.807$
Metacognitive Skills Section	$\alpha = 0.742$

In order to measure reliability on the entire survey, the reliability analysis was completed a second time using 103 students from the treatment 2 group. Internal consistency reliability was utilized for the second round of analysis. This type of reliability indicates



the consistency of a multiple item scale and determines if the items on that scale measures the same general construct. So in order to understand whether the items in the survey all measure “attitude towards chemistry”, “metacognitive skills”, “attitudes towards creating concept maps”, and “attitudes towards using the Creonto software”, a Cronbach’s alpha was analyzed.

Internal consistency is typically calculated using Cronbach’s alpha which is a statistics calculated from the mean correlation of each item in the scale with every other item and is represented by the following equation:

$$\alpha = \frac{K}{K - 1} \left( 1 - \frac{\sum_{i=1}^K \sigma_{Y_i}^2}{\sigma_X^2} \right)$$

The variable K represents the components or number of items measured, where  $X = Y_1 + Y_2 + Y_3 + \dots + Y_k$ ,  $\sigma_X^2$ , represents the variance of the observed total test scores, and  $\sigma_{Y_i}^2$  represents the variance of component i for that current sample of person. The value from a Cronbach’s alpha measure of  $\alpha \geq 0.9$  is considered excellent,  $0.9 > \alpha \geq 0.8$  is considered good,  $0.8 > \alpha \geq 0.7$  is considered acceptable,  $0.7 > \alpha \geq 0.6$  is considered questionable,  $0.6 > \alpha \geq 0.5$  is considered poor, and  $0.5 > \alpha$  is considered unacceptable. The analysis was performed using IBM SPSS software. From table 10, it can be seen that the survey instrument was reliable containing reliability values of good to acceptable reliability ratings. The final version of the surveys can be found in Appendix A.

**Table 10:** Internal consistency survey reliability measurements

Survey Sections	Internal Consistency reliability, Cronbach’s alpha
Attitude Section	$\alpha = 0.849$
Metacognitive Skills Section	$\alpha = 0.739$
Concept Map Section	$\alpha = 0.869$
Creonto Software Section	$\alpha = 0.885$

## **CHAPTER 5**

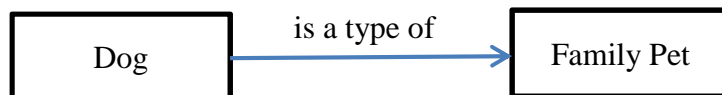
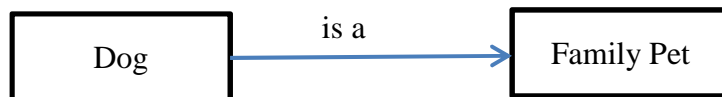
### **CONCEPT MAP WORKSHOP**

All students were required to attend a concept mapping workshop session that was held during the first week of the semester in phases 2 and 3. The concept mapping workshops were designed to familiarize students with concept mapping before assigning them as homework assignments in the course. This method was encouraged by Markow & Lonning (1998) to train students in constructing concept maps prior to assigning the concept maps as assignments. The workshop sessions were designed to be an hour and a half long training workshop. The students all received a concept mapping instructional package that included a description and purpose of a concept map, steps to creating a concept map, how to write the descriptive phrases to show relationships between concepts, and a grading rubric (Appendix C).

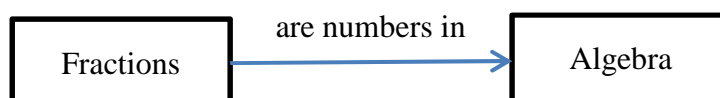
The purpose of concept mapping was explained to students to be a way for them to illustrate how the chemistry facts and concepts learned during the semester were related. After the initial introduction of explaining the purpose of concept maps in the introductory chemistry course, the proper way to compose the descriptive phrases between concepts were described. The descriptive phrases were explained to be phrases that represent a meaningful and complete relationship between two relevant concepts. It was then clarified that a meaningful and complete descriptive phrase between two relevant concepts should show a clear understanding of the relationships among the two concepts. The following examples of descriptive phrases were presented to students to

avoid when creating their concept maps to show relationships between two relevant concepts:

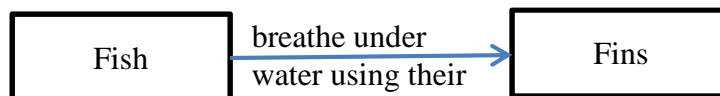
- Correct but general descriptive phrase example



- Partially correct but incomplete descriptive phrase example



- Incorrect descriptive phrase example



The majority of students had little to no previous background in chemistry; therefore simple examples were presented to give them the opportunity to brainstorm. Using these general examples, students were able to relate familiar concepts together using meaningful descriptive phrases instead of chemistry topics to gain the experience of composing descriptive phrases.

After the discussion on descriptive phrases, the process of constructing a concept map was shown to students as a class on the white board. It was stated to students that for the workshop training and homework concept maps, they would receive a central topic with a list of key concepts to construct their concept maps. Students were instructed to only use the terms listed on the list of key concepts to create their concept

maps. In order to demonstrate how to construct a concept map with a list of key concepts, I presented students with a central topic and a list of key concepts. This concept map was based around the central topic “car”. As stated above, the majority of students had little to no previous background in chemistry; therefore simple examples were presented to give them the opportunity to brainstorm. Using these general examples, students were able to relate familiar concepts together using meaningful descriptive phrases instead of chemistry topics to gain the experience of composing descriptive phrases and constructing the concept maps. Students were given the following instructions: As a class construct a concept map showing how the terms listed below are related. Your map should be constructed around the central concept: “Car”.

Concept Term List:

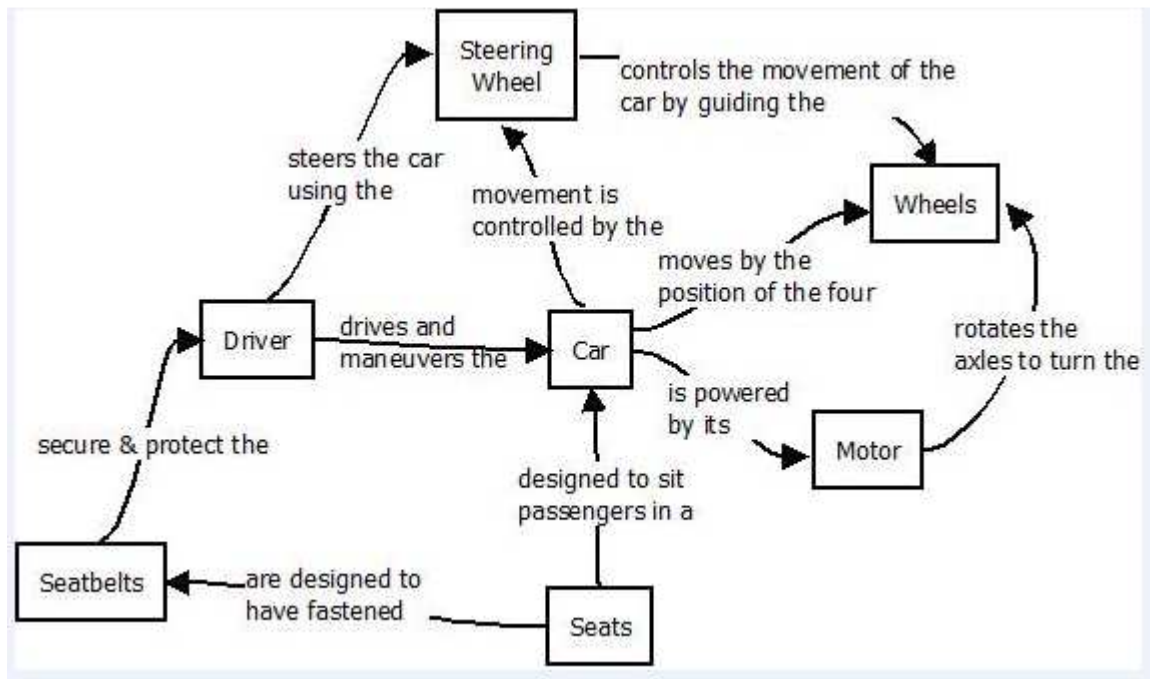
- **Car**
- Driver
- Seats
- Seatbelts
- Steering Wheel
- Wheels
- Motor

The workshop involved full participation from students in creating the concept map. Students were instructed on how to organize the concept terms in the list, how to link the related concept terms together through meaningful descriptive phrases, and to follow the tips on constructing a concept map shown in Table 11. Figure 2 shows an example of the concept map “car” created by, the workshop instructor and students. After instructing the students on how to construct a concept map around the central topic “car”, the students were assigned into groups containing 5 to 6 students to complete their own concept map.

**Table 11:** Tips on constructing concept map

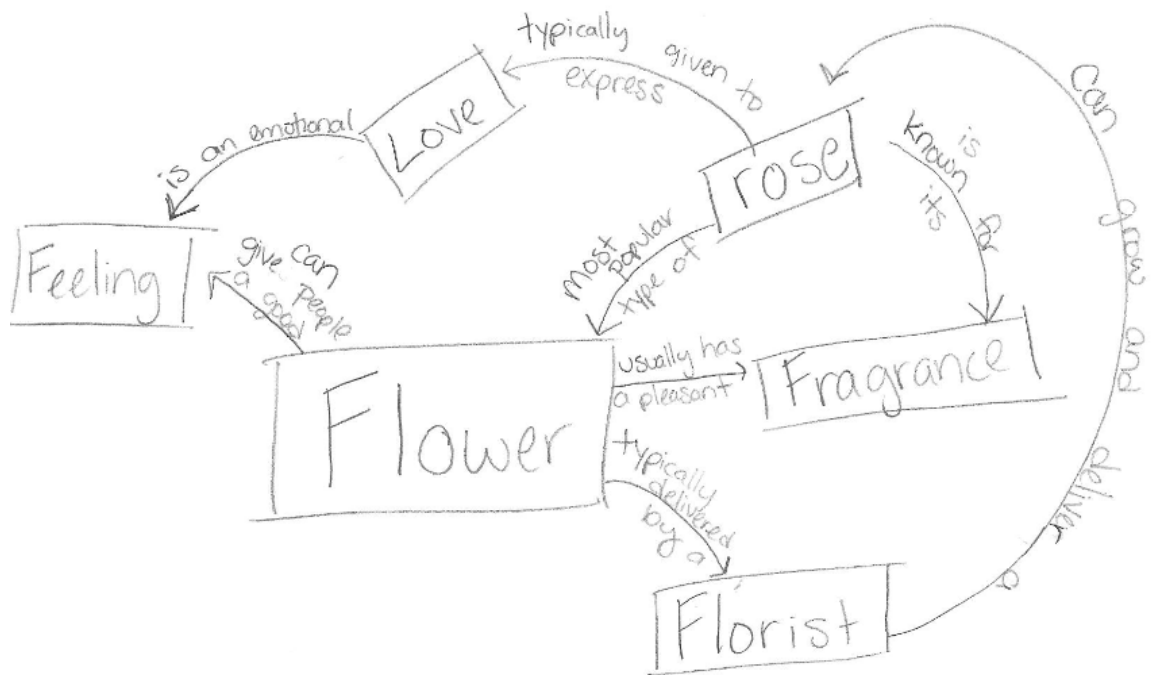
**\*Check for the following after constructing your map:**

- ✓ **Your names are included on the top of your map**
- ✓ **You have included all and only the terms provided in the list above to create your map**
- ✓ **All lines connecting your concepts are one-way arrows**
- ✓ **You have included descriptive phrases on all one-way arrows connecting your concepts**
- ✓ **Your map shows what you know about the central topic: Car**



**Figure 2.** Example of the concept map “Car” from concept map workshop

The student groups created concept maps centered on the topic “flower”. Students were asked to follow the same instructions as the one completed as a class by using the following terms: Flower, Rose, Fragrance, Love, Florist, and Feeling. After completing the group concept map, the students exchanged papers and the grading rubric was reviewed (Appendix C) to become familiar with how the concept maps would be scored. An example of one group’s “Flower” concept map is shown in Figure 3.



**Figure 3.** Student group “Flower” concept map

The concept map grading rubric was adapted from Snelson’s (2010) scoring rubric. The grading rubric consisted of two categories: 1) concepts and terminology and 2) Knowledge of the relationships among concepts. Each concept mapping assignment was worth a possible total of 8 points. The first category “concepts and terminology” points ranged from 0-4 points where 4 points were giving for using 100% of only the terms provided in the list of key concepts, 3 points for using 99%-75% of the terms provided in the list of key concepts, 2 points for using 74%-50% of the terms provided in the list of key concepts, 1 point for using 49%- 1% of the terms provided in the list of key concepts, and 0 points was giving if the student used none of the terms provided in the list of key concepts to create the concept map. The second category “knowledge of the relationships among concepts” points ranged from 0-4 points where 4 points were given for a concept map that showed all meaningful and complete descriptive phrases with a clear understanding of the relationships among the concepts, 3 points for a concept map

that showed a good understanding of the relationships among concepts with correct but general descriptive phrases, 2 points for a concept map that showed a few misunderstandings of the relationships among the concepts with partially correct and incomplete descriptive phrases, 1 point was given for a concept map that showed a lack of understanding of the relationships among the concepts with many incorrect/irrelevant descriptive phrases, and 0 points were given for a concept map that showed no understanding of the relationships among concepts without any descriptive phrases. A more in depth breakdown of the scoring for the “Knowledge of the relationships among concepts” section can be found in Appendix C.

After reviewing the grading rubric, each student was given the workshop instructor’s contact information and office hours for assistance in constructing the concept maps that would be assigned as homework assignments throughout the semester. At the end of the workshop, each student received their first concept mapping homework assignment on the central topic “Energy” to be completed individually. The remaining three concept mapping topics “Electronegativity”, “Chemical Reactions”, and “Chemical Potential Energy” were each assigned in conjunction with each unit (Appendix F). Each concept mapping assignment was due a week after it was assigned.

## **CHAPTER 6**

### **CREONTO ONTOLOGY SOFTWARE**

#### **Creonto Ontology Development**

In phase 3 (treatment 2A & 2B), the incorporation of concept maps and the chemistry ontology, Creonto, was integrated into the course curriculum. Students were encouraged to use the Creonto “Intro Chemistry” software to assist them in composing their descriptive phrases for their concept maps and to explore chemistry concepts taught in the course. The ontology used in the study was created with the Creonto software program developed by INDUS TechInnovations.

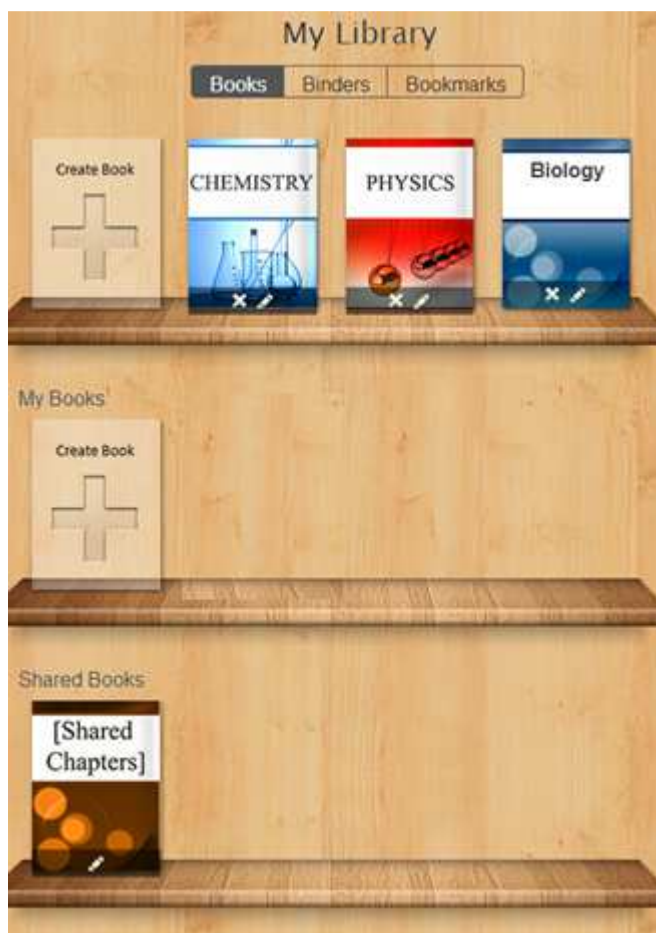
The Creonto concept-based framework for this research was developed based on master concept maps composed of main concepts and topics taught in the introductory chemistry course. The system was able to semantically connect every added concept to create the chemistry ontology with related images, videos, and web links.

In order to incorporate these master concept maps and chemistry content into the Creonto software, a web resource tool was developed that resembled the form of a chemistry book. This web-based “chemistry book” was designed using the Creonto graphical user interface (Figure 4).

The following steps were performed in developing the web-based “chemistry book”:

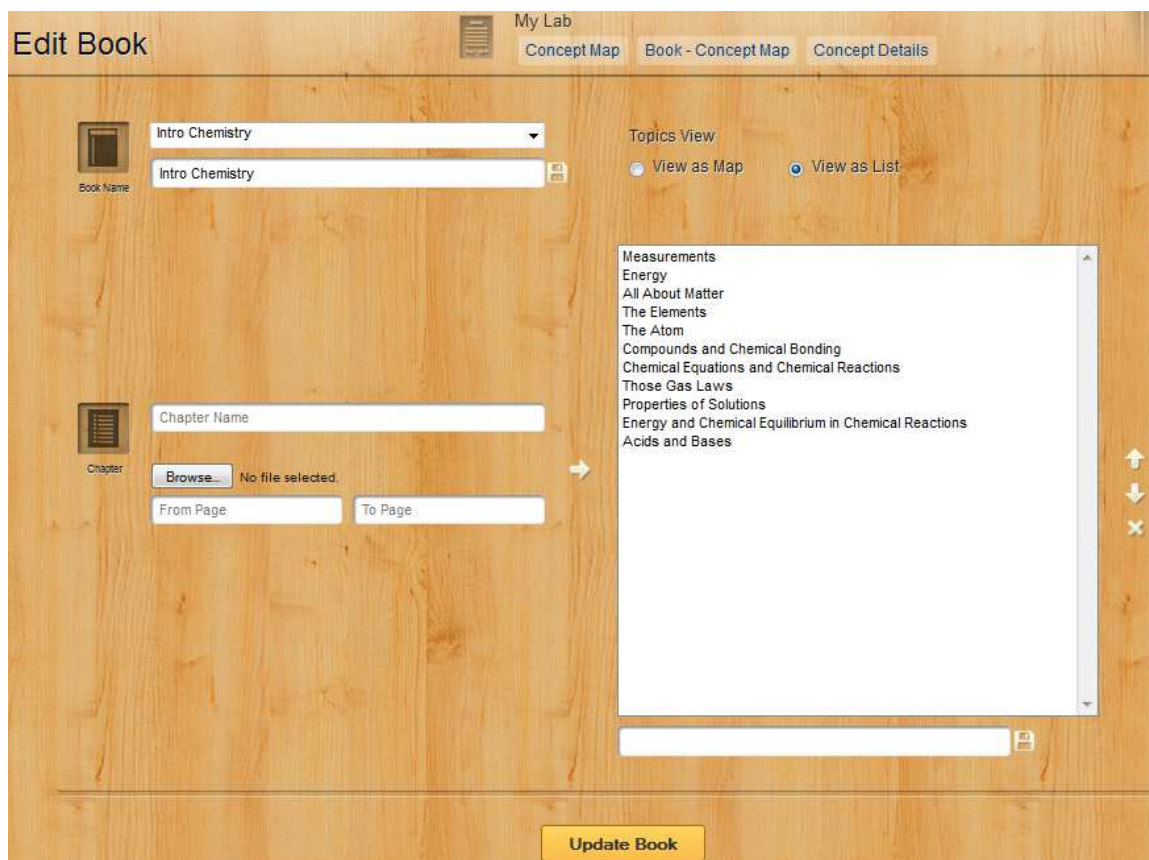


1. By clicking on the create book plus sign icon shown in Figure 4, a course specific chemistry ontology was added into the system called “Intro Chemistry”.



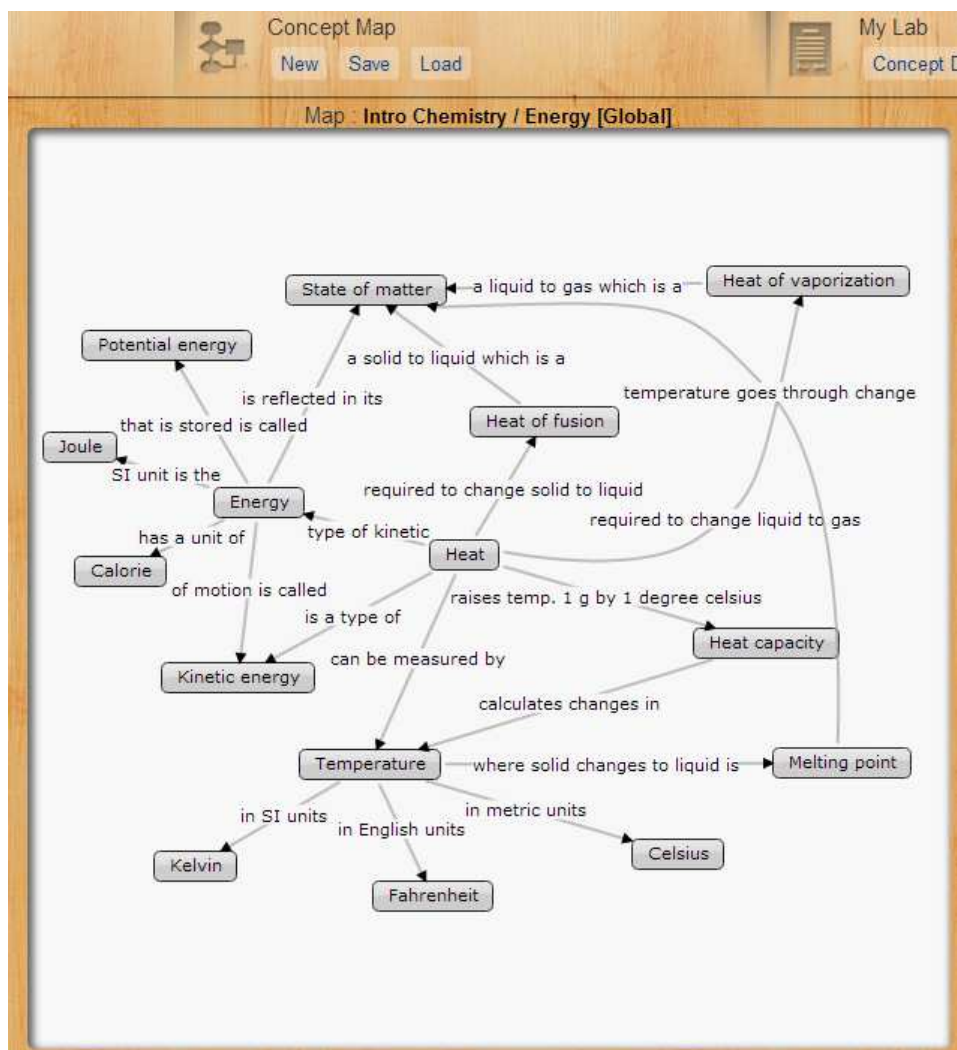
**Figure 4.** Graphical user interface to create book in Creonto

2. After the book was created, chapters were then added that were based on the main concepts taught in the chemistry course as shown in Figure 5. The chemistry course PowerPoint notes were also added during this step to each chapter.



**Figure 5.** List of chapters added to the “Intro Chemistry” book

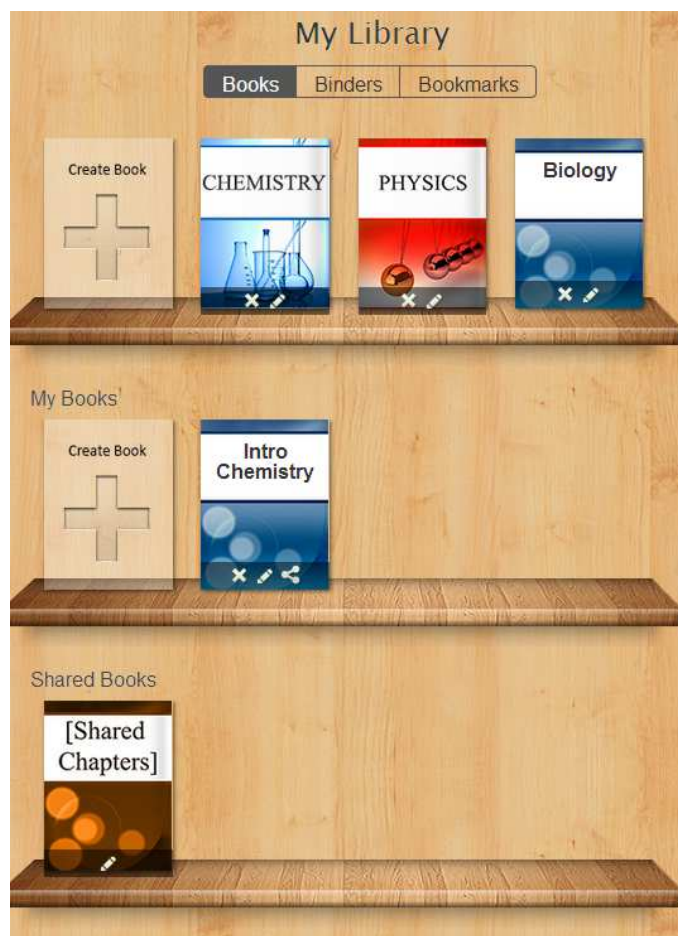
3. After adding in the chapters, key concepts were added to each chapter and chapter concept maps were constructed to derive the chemistry ontology. Figure 6 shows an example of the “Energy” chapter concept map integrated into the chemistry ontology



**Figure 6.** Energy concept map integrated into Creonto

4. In order to ensure that each concept added into the ontology displayed proper course related information; each concept was reviewed and edited by adding descriptions, videos, images, and web link resources as shown in Figure 7
5. After completing the above steps, the "Intro Chemistry" book was added into the Creonto software as shown in Figure 8.

**Figure 7.** Interface used to edit concepts

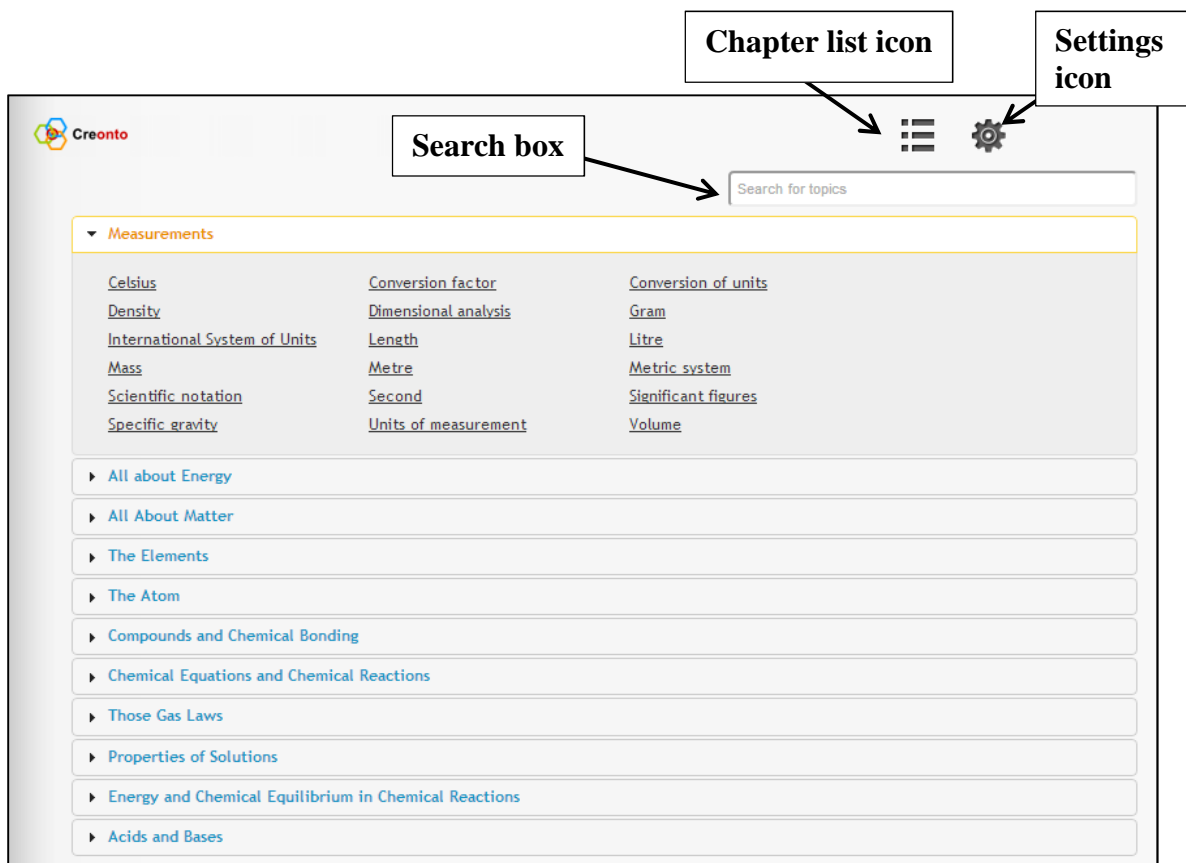


**Figure 8.** “Intro Chemistry” book added to Creonto library

### **Creonto Software Interface for Students**

Students in phase 3 (treatment 2A & 2B) were assigned the same four concept mapping homework assignments throughout the semester as phase 2 students, with the additional requirement that instructed them to use the Creonto software as an assistance tool in constructing their concept maps. In order for the students to use the system, they were provided with a unique web link that took them directly to the “Intro Chemistry” book located within the Creonto software after logging in with their school email address as username and ID number as password. The ontology configurations were designed to automatically display the “Intro Chemistry” book’s table of content with key concepts, a

chapter list icon, settings icon and a search box at the top of the page (Figure 9) upon a student's correct log-in credentials into the system.



**Figure 9.** “Intro Chemistry” book’s table of content

The table of contents showed all of the chapters with a list of concepts associated with each chapter for the “Intro Chemistry” book. Each concept located in the table of contents was interactive which allowed students to either navigate through the table of contents to find the concept they were looking for or type the key term into the search box. For example, if a student wanted to find more information about the concept “state of matter”, they would either type the concept “state of matter” into the search bar and click on the appropriate concept or click on the “All About Matter” chapter in the table of content list and a list of concept terms for that chapter will appear. They would then click



on the “state of matter” concept term and it would automatically direct them to a page with descriptions, images, videos, web links, and related concepts for “state of matter” (Figure 10). The book icon located at the top of the page stored the course’s PowerPoint notes for reference while navigating through the software.

The screenshot shows a web interface titled "All About Matter". On the left is a sidebar with a search bar and a list of topics. The "State of matter" topic is highlighted in red. On the right, the "State of matter" page is displayed, featuring a definition, two images (a molecular model and a collage of matter states), external content links, video links, and a tag cloud of related concepts.

**PowerPoint notes icon** →

**State of matter**

States of matter are the distinct forms that different phases of matter take on. Solid, liquid and gas are the most common states of matter on Earth. Historically, the distinction is made based on qualitative differences in bulk properties. Solid is the state in which matter maintains a fixed volume and shape; liquid is the state in which matter maintains a fixed volume but adapts to the shape of its container; and gas is the state in which matter expands to occupy whatever volume is available.

**External Content:**

1. State of matter - Wikipedia, the free encyclopedia

**Videos:**

1. Bill Nye: Phases of Matter
2. States of Matter
3. States of Matter

**Related Concepts for State of matter**

Chemical compound Chemical element Chemical property Chemical substance Energy Enthalpy of fusion Enthalpy of vaporization Gas Homogeneity and heterogeneity Liquid Matter Melting point Mixture Physical change Physical property Solid

**Figure 10.** “State of Matter” topic in the “All About Matter” chapter

Each concept term page also featured a “related concepts” tag cloud which represented all of the associated terms in the chapter that were related to the concept (Figure 11).

This image is a close-up of the tag cloud from Figure 10. The terms are arranged in a grid-like fashion, with "Gas" being the largest and most prominent word. Other visible words include "Chemical compound", "Chemical element", "Chemical property", "Chemical substance", "Energy", "Enthalpy of fusion", "Enthalpy of vaporization", "Homogeneity and heterogeneity", "Liquid", "Matter", "Melting point", "Mixture", "Physical change", "Physical property", and "Solid".

**Related Concepts for State of matter**

Chemical compound Chemical element Chemical property Chemical substance Energy Enthalpy of fusion Enthalpy of vaporization Gas Homogeneity and heterogeneity Liquid Matter Melting point Mixture Physical change Physical property Solid

**Figure 11.** Related concepts tag cloud for “state of matter”

In the related concepts box, the larger the font the more closely related the concept was to the term that the page was currently on. The smaller fonts represented that the concepts had a more distant relationship to the term. Each concept term in the related concepts box was interactive and when clicked automatically directed students to that term in the chapter with descriptions, videos, and external links to explore the relationships between them.



## **CHAPTER 7**

### **RESULTS**

The results of this study were used to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course. This study contained three phases of implementation which consisted of a control, treatment 1, and two treatment 2 groups (treatment 2A & 2B). The results represent data that were collected through each phase of implementation to assist in gaining a better understanding of the effects of concept maps as an educational tool and the usage of integrating a web-based tool in an introductory chemistry course. It assisted in identifying changes in students' metacognitive skills and attitudes towards chemistry at the beginning and end of the semester, student's ability to answer exam questions about key concepts, and attitudes towards constructing concept maps and integration of the web-based tool in the introductory chemistry course. Additionally, the analysis provided insight on the effect the alternative learning aids had on students' ability to explain connections between key concepts.

#### **IRB Approval**

Before conducting research using the students in the introductory chemistry courses, Institutional Review Board (IRB) approval was obtained under protocol number X121108004. All materials and methods for the research study were reviewed and approved on November 9, 2012. An updated review was also conducted and approved on November 1, 2013.

## Equivalency of Groups

In order to determine if the groups (control group, treatment 1 group, and treatment 2A & 2B groups) were similar to each other, equivalency tests were utilized. Equivalency tests were used to determine statistically if no differences exist between the groups at the beginning of the study. Therefore the learning outcomes of the study may be attributed to the learning aids provided to the treatment groups.

Each student's pre-calculus math score grades for courses completed at the University were collected at the beginning of the semester for the three groups. It is important to note that pre-calculus is a pre/corequisite for enrolling in the introductory chemistry course. The mathematical skills communicated through these courses are essential to student success in introductory chemistry. Therefore, these scores were used to establish equivalency between the groups and analyzed using ANOVA.

Univariate ANOVA was conducted to determine equivalency between the groups. The control group contained 64 students, treatment 1 group contained 32 students, treatment 2A group contained 103 students, and treatment 2B group contained 79 students. The following table 12 displays the mean pre-calculus math score grades for each group on a 4-point scale.

**Table 12.** Pre-calculus mean score equivalency data

	<b>Pre-Calculus Mean Score, M</b>	<b>Standard deviation, SD</b>
<b>Control (N=64)</b>	M = 2.516	SD = 1.392
<b>Treatment 1 (N=32)</b>	M = 2.313	SD = 1.534
<b>Treatment 2A (N=103)</b>	M = 2.913	SD = 1.422
<b>Treatment 2B (N=79)</b>	M = 2.835	SD = 1.589

The results indicated that there was no significant difference for pre-calculus scores at the  $p < 0.05$  level for the groups [ $F(3, 274) = 1.960$ ,  $p = 0.120$ ]. Specifically, the results suggest

that all groups were equivalent and show no statistical significant difference in math level based on their pre-calculus scores.

### **Attitudes towards Chemistry Survey Results**

Attitudes towards chemistry data were obtained using the pre- and post- surveys administered at the beginning and end of the semester for all groups. The survey items were intended to probe student's opinions about chemistry throughout the semester.

**Control group pre- and post- attitude:** Paired samples t-test was used to analyze the students' pre- and post- attitudes towards chemistry using the attitude section of the survey for the control group. This analysis was utilized to determine the students' attitude changes throughout a semester. The control group contained 64 students who completed both pre- & post- surveys. There were no significant differences in the pre- attitude towards chemistry mean scores ( $M=3.436$ ,  $SD=0.809$ ) and post-attitude towards chemistry mean scores ( $M=3.341$ ,  $SD=1.036$ ) for the control group;  $t(63)=0.939$ ,  $p=0.351$ . These results suggest that students in the control group attitudes towards chemistry remained relatively the same by the end of the semester.

**Treatment 1 group pre- and post- attitude:** Paired samples t-test was used to analyze the students' pre- and post- attitudes towards chemistry using the attitude section of the survey for the treatment 1 group. The pre-survey administered to the treatment 1 group was given to students at the beginning of the semester before the implementation of the concept mapping assignments into the course. The post-surveys were administered at the end of the semester. The treatment 1 group contained 32 students who completed both pre- & post surveys. There were no significant differences in the pre- attitudes towards chemistry mean scores ( $M=3.432$ ,  $SD=0.809$ ) and post-attitudes towards

chemistry mean scores ( $M=3.477$ ,  $SD=1.034$ ) for the treatment 1 group;  $t(31)=-0.414$ ,  $p=0.682$ . These results suggest that students in the treatment 1 group attitudes towards chemistry remained relatively the same by the end of the semester.

**Treatment 2A group pre- and post- attitude:** There were two sections of the introductory chemistry course offered during the implementation phase for treatment 2. Due to the scheduling of the courses, it was decided to analyze the two sections separately to avoid any confounding variables that may occur if the groups were combined. Therefore, paired samples t-test was used to analyze the students' pre- and post- attitudes towards chemistry using the attitude section of the survey for the treatment 2A group. The pre-survey administered to both treatment 2 groups were administered to students at the beginning of the semester before the implementation of the concept mapping assignments using the assistance tool, Creonto, into the course. The post-surveys were administered at the end of the semester. The treatment 2A group contained 103 students who completed both pre- & post surveys. There were no significant differences in the pre- attitudes towards chemistry mean scores ( $M=3.791$ ,  $SD=0.691$ ) and post-attitudes towards chemistry mean scores ( $M=3.682$ ,  $SD=0.854$ ) for the treatment 2A group;  $t(102)=1.708$ ,  $p=0.091$ . These results suggest that students in the treatment 2A group attitudes towards chemistry remained relatively the same by the end of the semester.

**Treatment 2B group pre- and post- attitude:** Paired samples t-test was used to analyze the students' pre- and post- attitudes towards chemistry using the attitude section of the survey for the treatment 2B group. The pre-survey administered to the treatment 2 group was given to students at the beginning of the semester before the implementation

of the concept mapping assignments using the assistance tool, Creonto, into the course. The post-surveys were administered at the end of the semester. The treatment 2B group contained 79 students who completed both pre- & post surveys. There were no significant differences in the pre- attitudes towards chemistry mean scores ( $M=3.839$ ,  $SD=0.600$ ) and post-attitudes towards chemistry mean scores ( $M=3.744$ ,  $SD=0.577$ ) for the treatment 2B group;  $t(78)=1.471$ ,  $p=0.145$ . These results suggest that students in the treatment 2B group attitudes towards chemistry remained relatively the same by the end of the semester.

**Attitudes towards chemistry comparison results:** In order to compare attitudes towards chemistry mean score (Table 13) changes from the interaction with the alternative learning aids compared to students in the control group, Univariate ANOVA was conducted. A univariate ANOVA was conducted on students' attitudes towards chemistry to compare the effects of the independent variable groups on the dependent variable attitude at the beginning and end of the semester. Results indicated there was not a significant difference between groups at the  $p<0.05$  level,  $F(2,211)=0.842$ ,  $p=0.432$ , partial eta squared=0.008. These results suggest that there was no statistically significant difference between the control, treatment 1, treatment 2A and 2B attitudes towards chemistry mean scores at the beginning and end of the semester.

**Table 13.** Attitude towards chemistry mean scores

	<b>Control, n=64</b>	<b>Treatment 1, n=32</b>	<b>Treatment 2A, n=103</b>	<b>Treatment 2B, n=79</b>
<b>Pre-Attitude Means</b>	M=3.434, SD=0.809	M=3.422, SD=0.809	M=3.791, SD=0.691	M=3.839, SD=0.601
<b>Post-Attitude Means</b>	M=3.341, SD=1.036	M=3.477, SD=1.036	M=3.682, SD=0.854	M=3.744, SD=0.577
<b><math>\Delta</math>Attitude=(PostAttitude- PreAttitude)</b>	M=-0.093, SD=0.788	M=0.055, SD=0.748	M=-0.109, SD=0.649	M=-0.095, SD=0.574

## **Metacognitive Skills Survey Results**

Metacognitive skills data were obtained using the pre- and post- surveys administered at the beginning and end of the semester for all groups. The survey items were intended to probe student's opinions about their learning styles specifically utilizing metacognitive skills. Metacognition is the knowledge about one's own learning process and involves one's awareness, evaluation, and regulation of their thinking.

**Control group pre- and post- metacognitive skills:** Paired samples t-test was used to analyze the students' pre- and post- metacognitive skills using the metacognitive skills section of the survey for the control group. This analysis was utilized to determine the students' metacognitive skills changes throughout a semester. The control group contained 64 students who completed both pre- & post- surveys. There were no statistically significant differences in the pre-metacognitive skills mean scores ( $M=3.671$ ,  $SD=0.433$ ) and post-metacognitive skills mean scores ( $M=3.624$ ,  $SD=0.441$ ) for the control group;  $t(63)=0.602$ ,  $p=0.549$ . These results suggest that students in the control group's metacognitive skills remained relatively the same throughout the semester.

**Treatment 1 group pre- and post- metacognitive skills:** Paired samples t-test was used to analyze the students' pre- and post- metacognitive skills using the metacognitive section of the survey for the treatment 1 group. The pre-survey administered to the treatment 1 group was given to students at the beginning of the semester before the implementation of the concept mapping assignments into the course. The post-surveys were administered at the end of the semester. The treatment 1 group contained 32 students who completed both pre- & post surveys. There were no statistically significant differences in the pre- metacognitive skills mean scores

( $M=3.673$ ,  $SD=0.255$ ) and post-metacognitive skills mean scores ( $M=3.756$ ,  $SD=0.373$ ) for the treatment 1 group;  $t(31)=-1.146$ ,  $p=0.261$ . These results suggest that students in the treatment 1 group metacognitive skills remained relatively the same from the beginning and end of the semester.

**Treatment 2A group pre- and post- metacognitive skills:** As stated above, there were two sections of the introductory chemistry course offered during the implementation phase for treatment 2. Therefore, paired samples t-test was used to analyze the students' pre- and post- metacognitive skills using the metacognitive section of the survey for the treatment 2A group. The pre-survey administered to the treatment 2 group was given to students at the beginning of the semester before the implementation of the concept mapping assignments using the assistance tool, Creonto "Intro Chemistry" software, into the course. The post-surveys were administered at the end of the semester. The treatment 2A group contained 103 students who completed both pre- & post surveys. There were statistically significant differences in the pre- metacognitive skills mean scores ( $M=3.866$ ,  $SD=0.395$ ) and post-metacognitive skills mean scores ( $M=3.739$ ,  $SD=0.435$ ) for the treatment 2A group;  $t(102)=3.261$ ,  $p=0.002$ . These results suggest that students' opinions at the beginning of the semester before the implementation of the concept mapping assignments using the Creonto "Intro Chemistry" software were slightly higher. However, by the end of the semester the students' opinions towards their metacognitive skills decreased.

**Treatment 2B group pre- and post- metacognitive skills:** For the 2<sup>nd</sup> section of treatment 2, paired samples t-test was also used to analyze the students' pre- and post-metacognitive skills using the metacognitive section of the survey. The pre-survey

administered to treatment 2B group was given to students at the beginning of the semester before the implementation of the concept mapping assignments using the assistance tool, Creonto, into the course. The post-surveys were administered at the end of the semester. The treatment 2B group contained 79 students who completed both pre- & post surveys. There were statistically significant differences in the pre- metacognitive skills mean scores ( $M=3.864$ ,  $SD=0.346$ ) and post-metacognitive skills mean scores ( $M=3.427$ ,  $SD=0.272$ ) for the treatment 2B group;  $t(78)=10.573$ ,  $p=0.000$ . These results suggest that students' opinions at the beginning of the semester before the implementation of the concept mapping assignments using the Creonto software were slightly higher. However, by the end of the semester the students' opinions towards their metacognitive skills decreased.

**Metacognitive skills comparison results:** In order to compare metacognitive skills changes from the interaction with the alternative learning aids compared to students in the control group, univariate ANOVA was conducted. A univariate ANOVA was conducted on students' metacognitive skills to compare the effects of the independent variable groups on the dependent variable metacognitive skills at the beginning and end of the semester. Results indicated a significant difference at the  $p<0.05$  level between the treatment groups' metacognitive skills mean scores (Table 14),  $F(2,211)=24.926$ ,  $p=0.000$ , partial eta squared=0.191. Due to the significant difference between the treatment groups' metacognitive skills, univariate ANOVA using contrast coefficients was analyzed to compare the treatment groups' metacognitive skills to the control group. The results indicated a significant difference at the  $p<0.05$  level between the groups' metacognitive skills mean scores (Table 14),  $F(3,274)=14.784$ ,  $p=0.000$ , partial eta



squared=0.139. In order to further investigate the results provided by the ANOVA, post hoc comparisons using the Scheffe test condition indicated that the mean metacognitive skills score for the control group was statistically significant different from treatment 2B with a mean difference of,  $\Delta=0.391$ . There were no differences between the control and treatment 1 and treatment 2A metacognitive skills. However, the treatment 2B group metacognitive skills were also statistically significant different from treatment 1 and treatment 2A with a mean difference of,  $\Delta=-0.519$  and  $-0.309$  respectively.

**Table 14** Metacognitive skills mean scores

	<b>Control, n=64</b>	<b>Treatment 1, n=32</b>	<b>Treatment 2A, n=103</b>	<b>Treatment 2B, n=79</b>
<b>Pre Metacognitive Means</b>	M=3.671, SD=0.434	M=3.673 SD=0.255	M=3.866, SD=0.395	M=3.864, SD=0.346
<b>Post Metacognitive Means</b>	M=3.625, SD=0.441	M=3.756, SD=0.373	M=3.739, SD=0.435	M=3.427, SD=0.272
<b><math>\Delta</math>Metacognitive=(Post Metacognitive-Pre Metacognitive)</b>	M=-0.045, SD=0.602	M=0.082, SD=0.407	M=-0.128, SD=0.397	M=-0.436, SD=0.367

### Concept Map Assignments Results

Concept mapping assignments were administered to students in the treatment 1 and both treatment 2 groups. Each treatment group were required to attend a concept mapping workshop prior to receiving their first concept mapping assignment which introduced them to the purpose and how to construct a concept map in the introductory chemistry course. Four concept mapping assignments were administered to the treatment groups during each unit on the topics: Energy, Electronegativity, Chemical Reactions, and Chemical Potential Energy. All students in the treatment groups were given a list of key terms with a designated central topic to complete their concept mapping assignments. Each concept mapping assignment was due one week after it was assigned. Students in

the treatment 1 group were allowed to use any resource (chemistry textbook, notes, PowerPoint slides, etc.) needed to construct their concept map, while students in both treatment 2 groups were instructed to use the Creonto “Intro Chemistry” software to assist them in constructing their concept maps.

**Concept map grading rubric reliability:** The concept map grading rubric was adapted from Snelson’s (2010) scoring rubric. The grading rubric consisted of two categories: 1) concepts and terminology and 2) knowledge of the relationships among concepts. Each concept mapping assignment was worth a maximum of 8 points. In order to test the concept map grading rubric to determine if the rubric produced stable and consistent results, reliability testing was utilized. Inter-rater reliability was used to assess the degree to which different raters (the Introductory Chemistry instructor and I) agree in their assessment decisions. Cohen’s kappa was used to check the reliability agreement because it corrects for the probability that raters will agree due to chance alone.

Thirteen students’ “Energy” concept mapping assignments from the treatment 1 group were randomly chosen based on the random number table generated from [stattrek.com](http://stattrek.com) on July 5, 2013. This random number table consisted of 52 random numbers produced according to the following specifications: 1) numbers were randomly selected from within the range of 1 to 52 and 2) duplicate numbers were not allowed.

Each rater was given the randomly chosen 13 students’ “Energy” concept map and graded the assignments based on the concept map grading rubric. Table 15 shows the two raters agreement scores. Rater 1 was the Introductory Chemistry instructor and rater 2 was the co-principal investigator both with backgrounds in chemistry. From the rater’s scores, both raters were in agreement for 11 out of the 13 student assignments. The

disagreement was found with students 8 and 13, in which the raters were just one point off from each other in the relationships section.

The raters' scores were then computed using IBM Statistics SPSS version 22 to check the reliability scores for the concept map rubric. Cohen's kappa was computed to check the reliability for the keywords section of the rubric and resulted in a kappa of 1.000 indicating complete agreement between the two raters. Cohen's kappa was also computed to check the reliability for the relationships section of the rubric and resulted in a kappa of 0.759 indicating substantial agreement between the two raters.

**Table 15:** Inter-rater reliability concept map agreement scores

<b>Students</b>	<b>Raters</b>	<b>Keywords</b>	<b>Relationships</b>	<b>Total</b>
<b>Student 1</b>	Rater 1	4	2	6
	Rater 2	4	2	6
<b>Student 2</b>	Rater 1	4	3	7
	Rater 2	4	3	7
<b>Student 3</b>	Rater 1	4	1	5
	Rater 2	4	1	5
<b>Student 4</b>	Rater 1	3	2	5
	Rater 2	3	2	5
<b>Student 5</b>	Rater 1	4	3	7
	Rater 2	4	3	7
<b>Student 6</b>	Rater 1	4	2	6
	Rater 2	4	2	6
<b>Student 7</b>	Rater 1	4	1	5
	Rater 2	4	1	5
<b>Student 8</b>	Rater 1	4	1	5
	Rater 2	4	2	6
<b>Student 9</b>	Rater 1	4	3	7
	Rater 2	4	3	7
<b>Student 10</b>	Rater 1	4	3	7
	Rater 2	4	3	7
<b>Student 11</b>	Rater 1	4	2	6
	Rater 2	4	2	6
<b>Student 12</b>	Rater 1	4	2	6
	Rater 2	4	2	6
<b>Student 13</b>	Rater 1	4	2	6
	Rater 2	4	1	5

From the Cohen's kappa results, the reliability of the grading rubric resulted in perfect agreement for ratings of keywords and substantial agreement for the ratings of the relationships between concepts.

**Concept map keywords comparison results:** The keywords section of the concept map grading rubric was designed to assess students' abilities to use the words provided on the list of key terms to construct their concept maps. Students were instructed to use only the terms provided without duplicating or adding other terms to construct their concept maps for each of the four assignments. Both treatment groups were assigned the exact same four concept mapping assignments with the same list of key terms. The only differences in the assignments were in the instructions.

The treatment 1 group had the following instructions: *“Construct a concept map on a separate sheet of white/copy paper showing how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **(central topic)**”*

While both treatment 2 groups had the following instructions: *“Construct a concept map on a separate sheet of white/copy paper using the Creonto software as an assistance tool to show how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **(central topic)**”*.

From the instructions, the major difference is for both treatment 2 groups to use the Creonto software as an assistance tool. Each student was allowed one week to

complete their concept mapping assignment.

Students' abilities to use the words provided on the list of key terms to construct their concept maps using resource tools of choice compared to students who used the Creonto software resource, was conducted using Friedman test. Friedman test was used to analyze students' abilities to use the key terms provided to compare the effects of the independent variable time on the dependent variable keywords at each time period. Table 16 shows each of the four concept maps' keywords mean scores for treatment 1, treatment 2A, and treatment 2B groups.

**Table 16: Keywords mean scores comparison**

	<b>Treatment 1, N=32</b>	<b>Treatment 2A, N=103</b>	<b>Treatment 2B, N=79</b>
<b>Map 1 Keywords</b>	M=3.875, SD=0.421	M=3.942, SD=0.438	M=3.899, SD=0.496
<b>Map 2 Keywords</b>	M=3.969, SD=0.177	M=3.922, SD=0.436	M=3.848, SD=0.662
<b>Map 3 Keywords</b>	M=3.594, SD=1.188	M=3.913, SD=0.562	M=3.823, SD=0.781
<b>Map 4 Keywords</b>	M=3.375, SD=1.476	M=3.806, SD=0.793	M=3.810, SD=0.786

There was not a significant statistical difference at the  $p < 0.05$  level in student's abilities to use the key terms depending on concept map for treatment 1,  $X^2(3)=3.706$ ,  $p=0.295$ .

There was also not a statistical significant different found for the treatment 2 groups,  $X^2(3)=4.091$ ,  $p=0.252$ . The results suggest that students in treatment 1, treatment 2A, and treatment 2B used a similar number of keywords when creating their concept maps.

**Concept map connections/relationships comparison results:** A comparison of students' abilities to explain connections between key concepts to construct their concept maps using resource tools of choice and students who used the Creonto software resource was conducted using Friedman test. Friedman test was used to analyze students' abilities

to explain connections between key concepts to compare the effects of the independent variables time (concept maps 1, 2, 3, and 4) on the dependent variable connections for each concept mapping assignment. Table 17 shows each of the four concept maps' connections mean scores for treatment 1, treatment 2A, and treatment 2B groups.

**Table 17:** Concept map connections mean scores

	<b>Treatment 1 N=32</b>	<b>Treatment 2A N=103</b>	<b>Treatment 2B N=79</b>
<b>Map 1 Connections</b>	M=2.438, SD=0.801	M=2.515, SD=0.670	M=2.354, SD=0.621
<b>Map 2 Connections</b>	M=2.281, SD=0.634	M=2.408, SD=0.706	M=2.177, SD=0.747
<b>Map 3 Connections</b>	M=2.656, SD=1.125	M=3.126, SD=0.667	M=3.127, SD=0.853
<b>Map 4 Connections</b>	M=2.375, SD=1.385	M=3.126, SD=0.904	M=2.975, SD=0.905

Friedman Test indicated that there was a statistically significant difference in students' abilities to explain connections between key concepts for the treatment 1 group depending on concept mapping assignments at the  $p < 0.05$  level,  $X^2(3) = 9.047$ ,  $p = 0.029$ . Further investigations using post hoc analysis using Wilcoxon signed rank tests with a Bonferroni correction applied, due to making multiple comparisons, resulted in a significance level of  $p < 0.0083$  indicated however there was no statistically significant difference between concept maps 1 and 2, 1 and 3, 1 and 4, 2 and 3, 2 and 4, and 3 and 4 for treatment 1,  $Z = -0.863$ ,  $p = 0.388$ ,  $Z = -1.190$ ,  $p = 0.234$ ,  $Z = -0.133$ ,  $p = 0.895$ ,  $Z = -1.943$ ,  $p = 0.052$ ,  $Z = -0.368$ ,  $p = 0.713$  respectively.

Friedman test also indicated there was a statistically significant difference in students' abilities to explain connections between key concepts for treatment 2 group depending on concept mapping assignments at the  $p < 0.05$  level,  $X^2(3) = 202.406$ ,  $p = 0.000$ . Post hoc analysis using Wilcoxon signed rank tests was conducted with a Bonferroni

correction applied, due to making multiple comparisons, resulting in a significance level of  $p < 0.0083$ . There were no significant differences between concept map 1 and 2,  $Z = -2.296$ ,  $p = 0.022$  and concept map 3 and 4,  $Z = -0.665$ ,  $p = 0.506$ . However, there was a statistically significant increase in connections between concept map 1 and concept maps 3 and 4,  $Z = -8.339$ ,  $p = 0.000$  and  $Z = -7.548$ ,  $p = 0.000$  respectively. There was also a statistically significant increase in connections between concepts maps 2 and concept maps 3 and 4,  $Z = -10.149$ ,  $p = 0.000$  and  $Z = -9.700$ ,  $p = 0.000$  respectively.

### **Attitudes towards Concept Maps**

In order to determine the treatment groups' attitudes towards constructing concept maps in the introductory chemistry, the students were provided with statements on the post-survey to assess their opinions. Each student in the treatment groups was provided the post-survey at the end of semester.

Univariate ANOVA was conducted to determine the students' attitudes towards concept maps mean scores for the treatment 1, treatment 2A, and treatment 2B groups. The results indicated no statistically significant difference in attitude towards concept maps mean scores for treatment 1 ( $M = 3.469$ ,  $SD = 0.995$ ), treatment 2A ( $M = 3.462$ ,  $SD = 0.781$ ), and treatment 2B ( $M = 3.365$ ,  $SD = 0.870$ ) groups;  $F(2, 211) = 0.341$ ,  $p = 0.711$ . The results suggest that students in treatment 1 who used resources of choice to create their concept maps had similar attitudes towards concept maps as the treatment 2 groups who used the Creonto "Intro Chemistry" software to assist them in constructing their concept maps.

### **Examinations Comparison Results**

Examinations were administered to students in all three phases to assess their

abilities to answer exam questions about key concepts. There were four examinations administered in class after each unit for all three phrases (Appendix B). The questions consisted of short answer free response questions and multiple choice questions based on the central concept mapping topic. The first exam questions were based on the central concept mapping topic “Energy”, the second exam based on “Electronegativity”, the third exam based on “Chemical Reactions” and the final exam based on “Chemical Potential Energy”. The main objective for the administration of the standardized examinations questions were to determine the effect of the interaction with the concept mapping (Phase 2) and concept mapping with Creonto software (Phase 3) learning aids on students’ abilities to answer exam questions about key concepts compared to the control group.

**Inter-rater reliability for examinations:** In order to determine if the examinations grading rubric produced stable and consistent results, reliability testing was conducted on the short response sections of the examinations. The multiple choice portion of the examinations was excluded because they are not considered open-ended questions. Inter-rater reliability was used to assess the degree to which different raters (the Introductory Chemistry instructor and I) agreed in assessment decisions. Cohen’s kappa was used to check the reliability agreement because it corrects for the probability that raters will agree due to chance alone.

In order to stay consistent with former reliability analysis, the same thirteen randomly chosen students from the treatment 1 group were utilized for the reliability of the examinations grading rubric for exam 4 based on the central topic “Chemical Potential Energy”. The exam contained 3 short answer questions where 2 points were given for each true/false correct response and 2 points for each correct justification using



complete sentences and proper grammar. Just 1 point was given if complete sentences/proper grammar was not used and 0 points for wrong answers. The format of the rubric was followed for the remainder three exams. The exam instructions were as followed:

“For each of the following statements, tell whether it is true or false. If false, use complete sentences and proper grammar to explain what parts of the statement make it false, and why.”

- 1) In an exothermic reaction, the reactants have only potential energy, and the products have only kinetic energy.

\*Correct answer: False (In order for reactants to react they must possess some kinetic energy and products may also have some potential energy remaining but less potential energy in products for an exothermic reaction)-4 points possible

- 2) In a reversible reaction, the activation energy is larger in the endothermic direction than the exothermic direction.

\*Correct answer: True (Knowledge of concepts of exothermic/endothermic, understanding of activation energy and applications)-2 points possible

- 3) Catalysts increase the rate of a chemical reaction by decreasing its heat of reaction.

\*Correct answer: False (Catalyst increase the rate of reaction by decreasing its activation energy not the heat of reaction)-4 points possible

Each rater was provided the thirteen randomly chosen students' short answer portion of the exam to grade. Table 18 shows the raters scores for each of the three questions on the exam. Rater 1 was the Introductory chemistry instructor and rater 2 was the co-principal

investigator. From the rater's scores, both raters were in agreement for 12 out of the 13 students' exams. The disagreement was found with student 8 where the raters were just two points in agreement off from each other for question one.

Cohen's kappa was computed to check the reliability for question 1 of the rubric and resulted in a kappa of 0.800 indicating substantial agreement between the two raters.

Cohen's kappa was also computed to check the reliability for questions 2 and 3 of the rubric and resulted in a kappa of 1.00 indicating complete agreement between the two raters.

**Table 18:** Inter-rater reliability scores for exam rubric reliability

Students	Raters	Question 1	Question 2	Question 3	Total
<b>Student 1</b>	Rater 1	2	2	0	4
	Rater 2	2	2	0	4
<b>Student 2</b>	Rater 1	0	0	0	0
	Rater 2	0	0	0	0
<b>Student 3</b>	Rater 1	0	0	4	4
	Rater 2	0	0	4	4
<b>Student 4</b>	Rater 1	4	2	4	10
	Rater 2	4	2	4	10
<b>Student 5</b>	Rater 1	0	0	4	4
	Rater 2	0	0	4	4
<b>Student 6</b>	Rater 1	0	0	2	2
	Rater 2	0	0	2	2
<b>Student 7</b>	Rater 1	0	2	4	6
	Rater 2	0	2	4	6
<b>Student 8</b>	Rater 1	2	2	4	8
	Rater 2	4	2	4	10
<b>Student 9</b>	Rater 1	0	0	2	2
	Rater 2	0	0	2	2
<b>Student 10</b>	Rater 1	0	0	0	0
	Rater 2	0	0	0	0
<b>Student 11</b>	Rater 1	0	2	4	6
	Rater 2	0	2	4	6
<b>Student 12</b>	Rater 1	0	0	4	4
	Rater 2	0	0	4	4
<b>Student 13</b>	Rater 1	0	0	0	0
	Rater 2	0	0	0	0

From the Cohen's kappa results, the reliability of the grading rubric resulted in complete agreement to substantial agreement for each of the questions between the two raters. The results indicate that the reliability of the examination grading rubric is a reliable and consistent assessment measure.

**Examinations multiple choice comparison results:** In order to compare students' abilities to answer exam questions (multiple choice) about key concepts from the interaction with the alternative learning aids compared to students in the control group, univariate ANOVA was conducted. Table 19 shows the four mean multiple choice questions examination scores for all groups. A univariate ANOVA was conducted on students' ability to answer multiple choice questions about key concepts to compare the effects of the independent variable groups on the dependent variable examination multiple choice questions at the four time periods. Results indicated a significant difference at the  $p < 0.05$  level between the treatment groups' multiple choice questions for exam 1 and 3 mean scores (Table 14),  $F(2,211)=3.759$ ,  $p=0.025$ , partial eta squared=0.034 and  $F(2,211)=5.997$ ,  $p=0.003$ , partial eta squared=0.054. There were no statistically significant differences between the treatment groups' exams 2 and 4 multiple choice mean scores,  $F(2,211)=0.637$ ,  $p=0.530$ , partial eta squared=0.006 and  $F(2,211)=2.892$ ,  $p=0.058$ , partial eta squared=0.027. Due to the significant difference between the treatment groups' exams 1 and 3 multiple choice mean scores, univariate ANOVA using contrast coefficients was analyzed to compare the treatment groups' multiple choice questions to the control group.

**Table 19: Mean multiple choice scores**

<b>Exams</b>	<b>Control n=64</b>	<b>Treatment 1 n=32</b>	<b>Treatment 2A n=103</b>	<b>Treatment 2 B n=79</b>
<b>Exam 1</b>	M=57.813, SD=28.976	M=56.250, SD=25.621	M=66.602, SD=24.795	M=70.380, SD=24.923
<b>Exam 2</b>	M=53.906, SD=18.955	M=66.667, SD=26.774	M=71.036, SD=22.258	M=71.730, SD=19.310
<b>Exam 3</b>	M=73.438, SD=18.238	M=67.708, SD=20.712	M=77.346, SD=16.144	M=79.7468, SD=15.714
<b>Exam 4</b>	M=64.688, SD=18.428	M=51.250, SD=25.368	M=56.117, SD=24.101	M=62.279, SD=22.415

The results indicated a significant difference at the  $p < 0.05$  level between the groups' exam 1 mean scores,  $F(3,274)=4.159$ ,  $p=0.007$ , partial eta squared=0.044. For exam 3 there was also statistically significant difference between the groups' exam 3 mean scores,  $F(3,274)=4.465$ ,  $p=0.004$ , partial eta squared=0.047. In order to further investigate the results provided by the ANOVA, post hoc comparisons using the Scheffe test condition indicated that the control group scored statistically significantly lower on exam 1 than treatment 2B, with a mean difference of  $\Delta = -12.567$ . Also on exam 1, there were no statistically significant differences between control and treatment 1 and treatment 2A. Also there were no statistically significant differences between treatment 2A and 2B on exam 1. While on exam 3 the treatment 1 scored statistically significantly lower than treatment 2B, with a mean difference of  $\Delta = -12.039$ . There were no statistically significant differences between treatment 2A and 2B on exam 3. Also there were no statistically significant differences between the control compared to treatment 1 and treatment 2A and 2B on exam 3.

**Table 20:** Mean short answer scores

Exams	Control n=64	Treatment 1 n=32	Treatment 2A n=103	Treatment 2 B n=79
Exam 1	M=67.969, SD=16.826	M=69.375, SD=18.826	M=71.359, SD=16.212	M=74.937, SD=14.752
Exam 2	M=75.156, SD=25.758	M=80.000, SD=21.702	M=78.252, SD=18.757	M=81.139, SD=20.191
Exam 3	M=77.969, SD=20.868	M=80.000, SD=18.837	M=86.796, SD=14.018	M=87.342, SD=13.841
Exam 4	M=51.875, SD=26.118	M=56.563, SD=28.125	M=56.505, SD=25.349	M=60.127, SD=26.481

**Examinations short answer comparison results:** In order to compare students' abilities to answer exam questions (short answer) compared to students in the control group (Table 20), Friedman's Test was conducted. Friedman's Test was used due to the short answer questions containing ordinal data. Friedman Test indicated there was a statistically significant difference on short answer questions for the control group at the  $p < 0.05$  level,  $X^2(3) = 46.355$ ,  $p = 0.000$ . Further investigations using post hoc Wilcoxon signed rank tests with a Bonferroni correction, due to multiple comparisons, resulting in a significance level set at  $p < 0.0083$  indicated there was a statistically significant difference between the short answer questions on exams 1 and 2, 1 and 3, 1 and 4, 2 and 4, and 3 and 4 for the control group (Table 21). There was no statistically significant difference between exams 2 and 3 short answer questions  $Z = -1.072$ ,  $p = 0.284$ .

**Table 21** Control short answer comparison significance

Short Answer Comparison	Posthoc Wilcoxon signed rank test results
Exam 1 and Exam 2	Z=-2.998, p=0.003
Exam 1 and Exam 3	Z=-3.396, p=0.001
Exam 1 and Exam 4	Z=-4.111, p=0.000039
Exam 2 and Exam 4	Z=-4.678, p=0.000003
Exam 3 and Exam 4	Z=-5.193, p=0.000

Friedman Test also indicated that there was a statistically significant difference in students' abilities to answer the short answer exam questions for the treatment 1 group depending on exam at the  $p < 0.05$  level,  $X^2(3) = 26.891$ ,  $p = 0.000006$ . Further investigations using post hoc Wilcoxon signed rank tests with a Bonferroni correction applied, resulting in a significance level set at  $p < 0.0083$  indicated there was a statistically significant difference between the short answer questions on exams 1 and 2, 2 and 4, and 3 and 4 for treatment 1,  $Z = -2.720$ ,  $p = 0.007$ ,  $Z = -3.558$ ,  $p = 0.000374$ , and  $Z = -3.660$ ,  $p = 0.000252$  respectively. There was no statistically significant difference between exams 1 and 3, and 1 and 4 short answer questions for treatment 1.

Friedman's test also indicated that there was a statistically significant difference in students' ability to answer the short answer questions for the treatment 2 groups depending on exam at the  $p < 0.05$  level,  $X^2(3) = 179.473$ ,  $p = 0.000$ . Further investigations using post hoc Wilcoxon signed rank test with a Bonferroni correction applied, resulting in a significance level set a  $p < 0.0083$  indicated there was a statistically significant difference between the short answer questions on all exams (Table 22). Based on the mean scores of the short answer questions for the treatment 2 groups, students were able

to increase their abilities in answering the short answer questions correctly as time progressed throughout the semester. All groups scored lower on exam 4 compared to the other exams.

**Table 22** Treatment 1 short answer comparison significance

<b>Short Answer Comparison</b>	<b>Posthoc Wilcoxon signed rank test results</b>
Exam 1 and Exam 2	Z=-4.595, p=0.000004
Exam 1 and Exam 3	Z=-8.779, p=0.000
Exam 1 and Exam 4	Z=-6.688, p=0.000
Exam 2 and Exam 3	Z=-5.190, p=0.000
Exam 2 and Exam 4	Z=-8.256, p=0.000
Exam 3 and Exam 4	Z=-9.620, p=0.000

### **Time Completing Assignments Comparison Results**

A comparison to determine the amount of time for students to complete assignments in all groups was compared. This analysis was completed to determine if there were any differences in the amount of time students needed to complete assignments with the incorporation of constructing concept maps and using the Creonto “Intro Chemistry” software in the introductory chemistry course. Students on the post-survey were asked to indicate how many hours on average each week they spent completing homework assignments for the introductory chemistry course by checking only one option: 0-1 hour, 2-3 hours, 4-5 hours, or more than 5 hours.

Frequency analysis was conducted to determine the amount of time students reported they needed to complete the homework assignments in the introductory

chemistry course. Table 20 shows the actual number of student reported hours they needed to complete the homework assignments for each group.

**Table 23:** Actual number of students reported hours spent on assignments

	<b>0-1 hour</b>	<b>2-3 hours</b>	<b>4-5 hours</b>	<b>More than 5 hours</b>
<b>Control</b>	16	42	4	2
<b>Treatment 1</b>	3	17	8	4
<b>Treatment 2A</b>	18	66	13	6
<b>Treatment 2B</b>	21	43	10	5

The results indicated that approximately 65% of the control, 53% of the treatment 1, 64% of the treatment 2A, and 54% of the treatment 2B groups spent on average 2-3 hours completing the homework assignments.

In order to determine any differences in the number of hours spent on assignments mean scores (Table 21), univariate ANOVA was conducted.

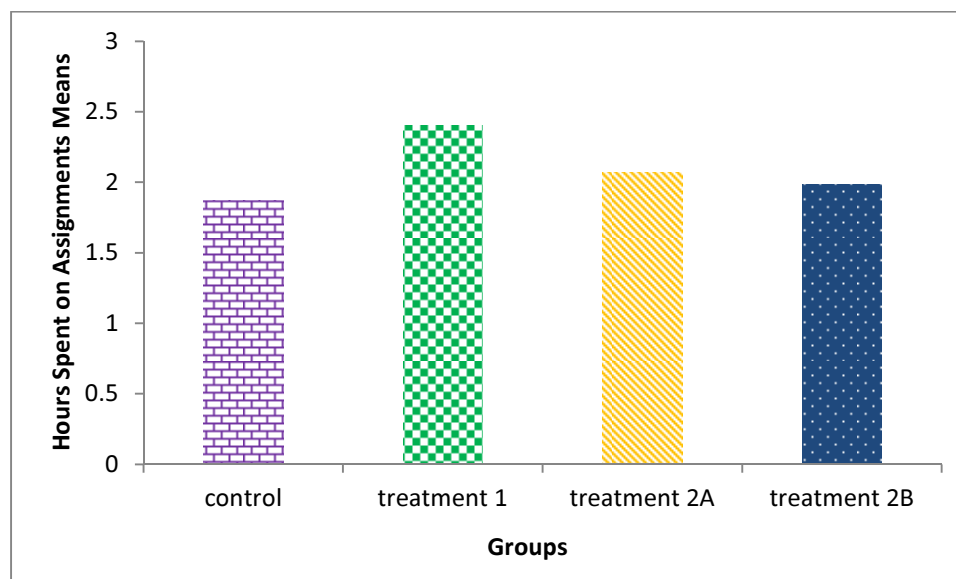
**Table 24** Hours spent on assignments mean scores

<b>Control, n=64</b>	<b>Treatment 1, n=32</b>	<b>Treatment 2A, n=103</b>	<b>Treatment 2B, n=79</b>
M=1.875, SD=0.655	M=2.406, SD=0.837	M=2.068, SD=0.731	M=1.987, SD=0.809

The results indicated a statistically significant difference of hours spent on assignments at the  $p < 0.05$  level for the treatment groups,  $F(2,211)=3.385$ ,  $p=0.036$ , partial eta squared=0.031. Due to the significant difference between the treatment groups' hours spent on assignments, univariate ANOVA using contrast coefficients was analyzed to compare the treatment groups' reported hours spent on assignments to the control group. The results indicated a significant difference of hours spent on assignments at the  $p < 0.05$  level for the four groups,  $F(3,274)=3.751$ ,  $p=0.011$ , partial eta squared=0.039. Post hoc



comparisons using the Scheffe test condition indicated that the mean score for the control group ( $M=1.875$ ,  $SD=0.655$ ) was significantly different than the mean score for the treatment 1 group ( $M=2.406$ ,  $SD=0.837$ ) with a mean difference of  $\Delta=-0.531$ . However, both treatment 2 groups' mean scores ( $M=2.068$ ,  $SD=0.731$ ) and ( $M=1.987$ ,  $SD=0.809$ ) did not significantly differ from the control and treatment 1 groups. Figure 12 shows the mean hours spent on assignments for the each group.



**Figure 12.**Mean hours spent on assignments comparison

### **Attitudes towards Creonto Software and Log-in Data**

Students in both the treatment 2 groups were required to use the Creonto software to assist them in composing their descriptive phrases and to visually represent how concepts were related to construct their concept maps. Each student was able to log into the Creonto software using their school's email address and ID that directly navigated them to the "Intro Chemistry" ontology book located in the Creonto software. In order to determine students' attitudes towards using the Creonto software, the post-survey included items that assessed the students in both treatment 2 groups' attitudes towards the

software. The post-survey was administered to all students in the treatment 2 groups at the end of the semester.

Due to there being only one treatment group who used the Creonto software, frequency analysis was conducted to determine the actual number of students' reported opinions towards their attitudes of the Creonto software on the 5-point Likert scale ranging from strongly disagree, disagree, neutral, agree, to strongly agree. Frequency distributions of n=103 students for the treatment 2A group resulted in a mean of 3.379 and standard deviation of 1.238. Frequency distributions of n=79 students for the treatment 2B group resulted in a mean of 3.494 and standard deviation of 1.048. The following frequency Table 22 shows the actual number of students' reported opinions towards their attitudes of the Creonto software. Based on the frequency results, the majority of students in the treatment 2 groups rated neutrally to in agreement for using the Creonto software in the introductory chemistry course.

**Table 25:** Attitudes towards Creonto frequency table

<b>Rating</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>Total</b>
Treatment 2A Frequency	13	8	28	35	19	103
Treatment 2B Frequency	4	7	28	26	14	79

**Creonto “Intro Chemistry” Log-in:** Frequency analysis was also conducted to determine the actual number of students who logged into the Creonto “Intro Chemistry” software during the semester. Table 23 shows the number of log-ins during the semester for the months of September, October, November, and December.

**Table 26:** Creonto “Intro Chemistry” log-in data

	<b>September</b>	<b>October</b>	<b>November</b>	<b>December</b>
<b>Total log-ins</b>	130	121	115	9
<b>Treatment 2A</b>	79	72	73	5
<b>Treatment 2B</b>	51	49	42	4

The results indicated that over 70% and 50% of the students in treatment 2A and 2B groups respectively logged into the Creonto “Intro Chemistry” software during the months of September, October, and November. The low log-ins for the month of December was likely due to all assignments being completed and it being the end of the school term.

## **CHAPTER 8**

### **DISCUSSION, LIMITATIONS, CONTRIBUTIONS, AND FUTURE WORK**

#### **Discussion**

The purpose of this study was to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course. The goals were to (1) develop a concept exploration based learning methodology using concept maps as study/learning tools for learning of chemistry concepts, (2) develop an ontology-based interactive platform in which relevant information to a course can be sought, and (3) measure student outcomes through the use of examinations and surveys to assess changes in metacognition and attitudes towards chemistry. Additionally this study sought to examine students' attitudes towards creating concept maps for learning and using the Creonto "Intro Chemistry" software in the introductory chemistry course. This chapter reviews the findings of this study and discusses the research limitations.

#### **Attitudes Towards Chemistry Results Discussion**

Attitudes towards chemistry were measured using pre- and post- surveys administered at the beginning and end of the semester. In order to analyze the attitude portion of the pre- and post-surveys, each group's mean attitude scores were calculated. These pre- and post- attitude mean scores were then compared to obtain a mean difference score to determine the students' attitude changes throughout a semester.

In regards to answering the research question: **“How do students’ attitudes change throughout a semester?”** The results indicated that for students in the control group, attitudes towards chemistry did not statistically significantly change throughout the semester. The control group’s attitudes towards chemistry remained in the neutral range from the beginning to end of the semester. The same results were also shown for the treatment 1 and treatment 2 groups even with the concept mapping and Creonto software implementation into the course. The treatment groups’ attitudes towards chemistry did not statistically significantly change throughout the semester and remained in the neutral range from the beginning to end of the semester. These results reflect trends that are in line with previous studies that have assessed students in a general chemistry courses on their changes in attitudes towards science over the semester for non-science major students and resulted in pre- and post- surveys indicating no significant differences in attitudes (Walczak & Walczak, 2009). While in other studies examining non-science major student attitudes towards chemistry pre-survey resulted in higher ratings for anxiety and fear towards chemistry and on the post-survey a significant decrease in ratings for anxiety and fear towards chemistry (Bauer, 2008). In order to gain a better understanding of the factors that may have affected students’ attitudes towards chemistry in the groups, it is imperative to investigate those students who experienced large changes in attitudes towards chemistry from the beginning to end of the semester. This would agree with Berg (2005) who states that “to understand attitude change, which generally is a long-term process, it is informative to investigate those students in whom marked attitude change has occurred”.

In regards to answering the research question: **“How do students’ attitudes change from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?”** The results indicated there was not a statistically significant change in attitudes towards chemistry between the groups. Even though the attitudes towards chemistry mean scores suggest that the treatment 2 groups with the concept mapping and Creonto “Intro Chemistry” software implementation into the course rated their opinions towards chemistry slightly higher compared to the control and treatment 1 groups, there was no statistically significant differences in the scores. These results are supported in part by previous studies in which students’ who were nursing and other non-science majors attitudes towards chemistry did not statistically change throughout the semester (Walczak & Walczak, 2009). It is also important to note that although for students in the treatment 2 groups, attitudes towards chemistry were not significantly different than the other groups, these students did report a slightly higher attitude towards chemistry. These results support other studies in which students who used technology in conjunction with creating their concept maps compared to other students had a higher motivation for success. The authors stated that “the advantage of this technique is the use of technology; it motivates the students and helps increase their success” (Erdem, Yilmaz, & Ozyalcim, 2009).

### **Metacognitive Skills Results Discussion**

Metacognitive skills were assessed using the pre- and post- surveys administered at the beginning and end of the semester for all groups. In order to analyze the metacognitive portion of the pre- and post- surveys, each student’s mean metacognitive skills scores were calculated. These pre- and post- metacognitive skills mean scores were

then compared to obtain a mean difference score to determine the students' metacognitive skills changes throughout a semester.

In regards to answering the research question **“What are the changes in students' metacognitive skills throughout a semester?”** The results indicated that there were no significant differences in the pre-metacognitive skills means scores and post-metacognitive skills mean scores for the control and treatment 1 groups. However, both treatment 2 groups experienced significant differences in their pre-metacognitive skills and post-metacognitive skills mean scores. The results indicated that students in the treatment 2 groups rated their pre-metacognitive skills higher at the beginning of the semester before the implementation of the concept mapping assignments while also using the Creonto software. Alternatively by the end of the semester these same students rated their post-metacognitive skills lower after the implementation of the concept mapping assignments while using the Creonto software. I speculate that the combination of using both tools (concept maps and the Creonto software) contributed to the decrease in self-reported metacognitive skills for the treatment 2 groups. This may have arisen for students in the treatment 2 groups becoming overwhelmed with the requirement to use both tools in the introductory chemistry course. This would agree with Scott & Berman (2013) who state that one aspect of metacognition suggests that students are less accurate about their perceived metacognitive skills when they become overwhelmed in a course in which they perceive as difficult. The results also partly agree with Isaacson & Fujita (2006) who state that students overestimate their pre-metacognitive skills because they “do not recognize the implication of different levels of learning and varying levels of task difficulty”.

In regards to answering the research question, **“What are the changes in students’ metacognitive skills from the interaction with the alternative learning aids (concept maps, ontology) compared to other students?”** The results indicated a significant statistical difference between the treatment groups’ metacognitive skills mean scores with the treatment 2B metacognitive skills decreasing by the end of the semester compared to the control, treatment 1, and treatment 2A. The results suggest that students in the treatment 2 groups did rate their metacognitive skills slightly higher than the control and treatment 1 groups at the beginning of the semester. By the end of the semester, the results suggest that students in only the treatment 2B group rated their metacognitive skills statistically lower than the control, treatment 1, and treatment 2A groups. There were no differences in post-metacognitive mean scores between the control, treatment 1, and treatment 2A groups. These results are supported in part by Rahman, Jumani, Chaudry, Chisti, & Abbasi (2010) who concluded that students who are more aware of their metacognitive skills rate their skills higher while ones who are less aware of their metacognitive skills rate them lower. As stated previously, these results may have occurred due to students overestimating their pre-metacognitive skills in the beginning of their studies. If this is true, then analyzing students’ metacognitive skills during the middle of the semester may give a better insight into factors that may have affected these students’ metacognitive skills. It may also be essential to measure the students’ metacognitive skills separately for each category of metacognition (planning, monitoring, and evaluating) in order to obtain a better understanding of the students’ perceived metacognition. This may reveal which categories of metacognition the students improved or decreased on during the course of the study.



## Concept Mapping Assignments Results Discussion

Four concept mapping assignments based on the central topics: “Energy”, “Electronegativity”, “Chemical Reactions”, and “Chemical Potential Energy” were administered to students during each unit for the treatment 1 and treatment 2 groups. The treatment 1 group was instructed to use any resources of choice to complete their concept maps using the list of key terms provided. The treatment 2 groups were instructed to use the Creonto software “Intro Chemistry” ontology to assist them in constructing their concept maps using the list of key terms provided.

In regards to answering the research question, **“How does the interaction with the alternative learning aids (concept maps, ontology) affect students’ ability to explain connections between key concepts?”** The results suggest there was no significant statistical difference in students’ abilities to use the keywords to construct their concept maps for the assignments. This was not unexpected due to students being instructed to use all terms provided to create their concept maps. However there was a statistically significant difference in students’ abilities to explain connections between the key concepts for the assignments. The results suggested that students in the treatment 2 groups were able to explain more connections for concept maps 3 and 4. This supports the results from the treatment 2 groups mean scores indicating use of more keywords to construct their concept maps for assignments 3 and 4, even though there were no differences in keywords for assignments 1 and 2 compared to treatment 1. In other words, the treatment 2 groups who used the Creonto “Intro Chemistry” software to assist them in constructing their concept maps were able to explain more connections for those assignments compared to the treatment 1 group who used resources of choices to create

their concept maps. These results are in line with other studies in which students that used computers to help them create their concept maps were able to construct a greater number of correct relationships between concepts compared to students who created their concept maps without the use of the computer (Erdem, Yilmaz, & Ozyalcim, 2009; Royer & Royer, 2004). With the aid of computers in creating these concept maps, the students in the treatment 2 groups were able to visually represent how the chemistry concepts were related which agrees with Erdogan (2009) who states that the aid of computers in creating these concept maps may encourage students to be more involved in their learning process by facilitating visual thinking.

### **Attitudes Towards Concept Maps Results Discussion**

Each student in the treatment 1 and both treatment 2 groups were administered survey items on the post-survey to assess their opinions towards constructing concept maps in the introductory chemistry course. In regards to answering the research question: **“What are students’ attitudes towards creating concept maps in the chemistry course?”** The results indicated no statistically significant differences in attitude towards creating concept maps for treatment 1 and both treatment 2 groups. The results suggest that the students in the treatment 1 and both treatment 2 groups had similar attitudes towards creating concept maps in the chemistry course. These results in part agree with Royer & Royer (2004) in which students who created concept maps without the use of computers were still able to understand the concepts better, remember more things, find relationships, and organize their thoughts. While for the students in the treatment 1 and both treatment 2 groups’ attitudes towards creating concept maps in the chemistry course remained neutral. I speculate that the results may have arisen from the students not fully

understanding the full picture of why they were creating concept maps in the chemistry course. This agrees in part with Pernaa & Aksela (2008) whose participants stated that “there were too much concept maps. I did not get the whole picture”. It is interesting to note as well that for the treatment 1 and both treatment 2 groups, 75% of the students did rate their attitudes towards creating concepts maps in the chemistry course as neutral to strongly agree. These findings suggest that although the mean attitudes towards creating concept maps were neutral that students still had a positive trend towards concept mapping in the chemistry course.

### **Examinations Comparison Results Discussion**

Four examinations based around the central topics of the concept maps were administered after each unit for all groups. In regards to answer the research question, **“How does the interaction with alternative learning aids (concept maps, ontology) affect students’ abilities to answer exam questions about key concepts?”** The results indicated a statistically significant difference between the groups’ exam 1 multiple choice mean scores, with the control group scoring statistically significantly lower than treatment 2B. There were no statistically significant differences between the control and treatment 1 and treatment 2A on exam 1. While on exam 3 multiple choice scores, the treatment 1 group scored statistically significant lower than treatment 2B. There were no statistically significant differences between treatment 2A and 2B on exam 3. The results also revealed that there were no statistically significant differences in exam 3 multiple choice scores for the treatment 1 and treatment 2A groups. It was also noticed that all groups’ exam multiple choice scores decreased by exam 4 however there were no statistically significant differences between group mean scores.

The results suggest that students in the treatment 2 groups scored higher on exams 1 and 3 compared to students in the control and treatment 1 groups. This indicates that students who created concept maps using the Creonto “Intro Chemistry” software were able to answer more exam questions correctly than the groups who did not create concept maps or use computers to assist them in creating their concept maps.

As for the short answer questions, the results indicated that the treatment 2 groups’ ability to answer the short answer exam questions increased significantly between all exams. The results agree with other studies in which students who used computers to assist them in creating concept maps were able to outperform students who created traditional concept mapping without use of computer assistance (Chou, Chen, & Dwyer, 2011; Erdem, Yilmaz, & Ozyalcim, 2009). In regards to all groups scoring lower on exam 4, I speculate that since that exam was considered the final exam for the course students may have become overwhelmed with other course final exams being taken during the same time. Consistent with Markow & Lonning (1998) the construction of concept maps may play an active role in students’ learning process by providing them with a way to connect concepts and visually see how these concepts relate to one another.

### **Time Completing Assignments Results Discussion**

Additional information was gathered to determine the average amount of time spent by constructing concept maps using resources of choice and constructing concept maps using the Creonto “Intro Chemistry” software compared to completing quizzes for homework assignments. The frequency results indicated that approximately 65% of the control, 53% of the treatment 1, 64% of the treatment 2A, and 54% of the treatment 2B groups spent on average 2-3 hours completing the homework assignments. However,

there was a significant difference in hours spent on assignments mean scores in which the control group reported hours spent on assignments was lower than the treatment 1 group. There were no differences in hours spent on assignments for both treatment 2 and the control groups.

These results suggest that the treatment 1 group reported spending more time on average completing assignments. I speculate the treatment 1 group which constructed concept maps using resources of choice reported spending more time on assignments every week due to the implementation of the study occurring during the summer semester. These students may have felt that the shorter time schedule during the summer semester led to a higher workload, which resulted in reporting that it took them longer to complete assignments.

### **Attitudes towards Creonto Software Results Discussion**

Both treatment 2 groups had access to use the Creonto “Intro Chemistry” software to assist them in constructing their concept mapping assignments. In order to answer the research question, **“What are students’ attitudes towards using the Creonto software?”** The results indicated that the majority of students in both treatment 2 groups rated neutrally and in agreement for using the Creonto “Intro Chemistry” software in the introductory chemistry course. In support of the students’ attitudes towards using the Creonto software, it was also imperative to determine if the students in the treatment 2 groups actually used the software. The results indicated that over 70% and 50% of students in treatment 2A and 2B groups respectively logged into the Creonto “Intro Chemistry” software during the semester. These results suggest that students in the introductory chemistry course were willing to use the software in the course to complete

assignments. While there are several studies in the literature on the use of ontologies, the researcher is unaware of any that have explored the use of ontologies for chemistry learning. Existing studies have been based on literature reviews (Allert, Markkanen, & Richter, 2006; Cassin, Eliot, Lesser, Rawlins, & Woolf, 2003; Fok & Shing, 2007; Sosnovsky, 2009) or overview studies introducing the ontologies without any noteworthy results of its use (Kadivar & Lee, 2010; Chu, Lee, & Tsai, 2011). While these studies have included the benefits of using ontologies for classroom learning, it does not address the effects of ontologies for science related courses. This study, however, was able to analyze students' attitudes towards using a domain specific "chemistry" ontology, measure student's abilities to complete assignments using the ontology, determine changes in metacognitive skills and answer exam questions about key concepts in an introductory chemistry course. This study agrees with He, Peng, Mao, and Wu (2010) that e-learning technology with the use of ontologies may enhance students' learning performance and become an extension to traditional instructional methods.

### **Limitations of Study**

Although the purpose of this study was to compare the effects of students using alternative learning aids (concept maps, ontology) to traditional learning aids used in an introductory chemistry course, there are limitations of the study that need to be addressed. The first limitation was the response rate. This was a limitation because data analysis was only obtained from students in the introductory chemistry course who completed the pre- and post- surveys. Therefore students who completed only one survey (either the pre- or post- survey) were eliminated from the study even if they had completed homework assignments and exams. Also, a decrease in the response rate was

due to the result of students dropping or withdrawing from the course.

Another limitation deals with selection bias. Since the study focuses on a quasi-experimental approach which involves participants from an undergraduate introductory chemistry course, the students in each course may not be equivalent and represent other students in other settings. In order to minimize the effects of a quasi-experimental approach, students would need to be randomly assigned into groups. However, in educational settings, the ability to assign students randomly may not be applicable which causes selection-bias. Therefore in this study we were not able to control participants' age, majors, gender, race, retention, college classification, or other factors that may have affected the results in the study. Another option in minimizing the effects of a quasi-experimental approach is to evaluate participants at the beginning of the study through equivalency measurements. In this study, the groups' equivalency was measured from their pre-calculus scores to determine statistically no differences existed between the groups at the beginning of the study. Therefore based on the equivalency measurements, the learning outcomes of the study were attributed to the learning aids provided to the treatment groups.

Additionally, since concept mapping was integrated as homework assignments and not as an integral teaching method in the course, some students may have felt the purpose of concept mapping to be irrelevant in a chemistry course. In this study, students were neutral concerning their attitudes of constructing concept maps in the introductory chemistry course. It was also observed from the concept mapping workshops that students had a lack of prior exposure to concept mapping and constructing them for learning. Since students only used concept mapping on a few homework assignments, it

may be beneficial to incorporate general maps before each unit of learning to allow students to become more familiar with the importance of concept mapping in the course. Instructors presenting general maps before each unit in the introductory chemistry course may give students a better sense of ways to organize their course materials and see the bigger picture of chemistry concepts for their learning.

Another limitation was the log-in tool incorporated into the Creonto software. The log-in tool only recorded a time stamp of when a student logged into the system. This time stamp did not affect results of this study but for future references it may be of benefit to instructors to also have a log-in system that recorded how long a student actually used the system. Also the “related keywords” tag cloud required the related keywords to be manually resized to reflect the linkages in the master concept maps for each chapter. It would be beneficial for future studies to have the “related keywords” tag clouds to automatically generate and resize based on the relevancy to the central terms that are reflected in the linkages of the master concept maps for each chapter.

Finally, using a closed-ended survey questionnaire to probe students’ attitudes towards chemistry, metacognitive skills, attitudes towards creating concept maps, and attitudes towards using the Creonto “Intro Chemistry” software may have been another limitation. An open-ended survey or interviews may have given further explanations of the results for this study and this may be conducted in future studies.

### **Contributions**

This research study accomplished the following goals: 1) to develop a concept exploration based learning methodology using concept maps as study/learning tools for learning chemistry concepts, 2) to develop an ontology-based interactive platform in



which relevant information to a course can be sought, and 3) to measure student outcomes through the use of examinations, homework assignments, and surveys to assess changes in exam scores, metacognition, attitudes towards chemistry, concept maps, and the ontology. This study was a quantitative study design with a control and two experimental groups and involved incorporating aspects of chemistry, engineering, and education for the purpose of technological advancements and education related to chemistry.

The first step in developing the concept exploration based learning methodology curriculum included the incorporation of the concept map workshop's curriculum to introduce students to the importance of relationships between concepts in the chemistry course. This workshop allowed students to become familiar with the idea of thinking about how concepts are related and the purpose of having these metacognitive skills in an introductory chemistry course. Additionally, concept mapping was introduced into the current chemistry curriculum which was not a component in the course before the study. This study also indicated that concept mapping was well received as homework assignments in the introductory chemistry course and may foster learning and become an integral part of traditional teaching methods.

Secondly, an ontology was developed from the Creonto software which included the development of a course specific ontology platform called "Intro Chemistry". This Creonto software supplied an authoring tool in which I was able to develop the "Intro Chemistry" web-based tool. The authoring tool allows for instructors to create course specific learning materials that include descriptions of concepts, images, web-links, videos, and a tag-cloud with related concepts. All of these learning materials can be

edited to suit the instructors' and courses' needs.

Finally, the study involved the creation of assessments including the surveys and concept map grading rubrics. The grading rubric was developed to score students' concept maps. In order to ensure that the grading rubric was reliable, inter-rater reliability was performed before being implemented as a measure to score concept maps. The grading rubric consisted of two sections: keywords and connections. Each concept map was worth possible score of 8 points. Pre- and post- surveys were also developed to measure students' attitudes towards chemistry and metacognitive skills. Post-surveys were also developed for the treatment groups to include sections to measure students' attitudes towards constructing concept maps and using the Creonto "Intro Chemistry" software in the introductory chemistry course. All surveys went through validity and reliability testing before being implemented into the course. All test measures proved to be reliable instruments for assessments for this study.

This study was able to fill a gap in the literature on the use of ontologies for e-learning in the sciences. As evidence from the previous literature ontologies for e-learning have been utilized in disciplines such as computer science but are limited for the use in the sciences. Therefore, this study was able to add to the knowledge base of existing literature to promote this alternative learning aid in science education. The ontology would also provide an alternative means of organizing and sharing course materials for several disciplines that can be used not only by students, but tutors and teachers as well. This study also expanded the knowledge on the use of concept mapping and computers in chemistry as a study/learning tool and identified further research possibilities that may pinpoint ways to improve students' attitudes towards chemistry,

conceptual understanding of chemical concepts, and metacognitive skills.

This study's significant contribution lies on the fact that there are limited studies which focus on the use of ontologies for learning in the sciences especially for chemistry education. Also, most of the studies on the use of concept mapping in chemistry are used to assess students and not used as an integral part of the curriculum. This research will hopefully add to the knowledge base on the use of concept mapping and technology in chemistry courses and promote the use of alternative learning aids for students.

### **Future Work**

This research study was able to introduce a concept exploration based teaching methodology using concept maps and a chemistry ontology that was not present within the introductory chemistry curriculum before this study. It accomplished its goals of examining the effects of these alternative learning aids on student learning outcomes, however, there is a need for more investigations on the factors they may have influenced these changes.

In future studies the ability to use open-ended surveys, focus groups, or interviews to gauge student's attitudes towards chemistry, creating concept maps, and use of the Creonto "Intro Chemistry" software may give a better insight into factors that may affect students in the course. By obtaining qualitative data from students, it may assist in identifying reasons students rated their opinions in a specific manner. This type of analysis incorporated with a quantitative approach would allow for a deeper insight into the students' way of thinking.

The Creonto software is also a tool that may be utilized to assist instructors in creating numerous learning materials to suit various courses such as engineering, biology,

physics, computer science, and much more. With the Creonto software, instructors may have the ability to control the direct information needed to ensure learning for their students by also incorporating their own PowerPoint teaching slides as well into the software. The system may also allow instructors to have a more domain-specific teaching platform that caters to the needs of their students. With the incorporation of the proper log-in system to record not only when students log into the software but also for how long, this may give instructors a better insight into monitoring students' progress in the course.

Additionally researchers and educators interested in concept mapping should not only focus on incorporating concept mapping as an assessment tool, but also as an integral resource in the curriculum. Previous studies in the literature focus on incorporating concept mapping as assessment tools, curriculum development, teacher aids, or study/learning tools. This study involved the incorporation of concept maps only for homework assignments in the course. In future studies, students may be more acceptable to creating concept maps in chemistry if they were also incorporated as an integral resource in the curriculum. I speculate that this may be done by instructors introducing general maps before each unit to show an overview of how chemistry concepts may be arranged and related to other concepts before assigning more specific concept maps for homework assignments. This approach may assist students to become more familiar with the importance of concept mapping in the chemistry course. Additionally, it may also give instructors and educators a better insight into the benefits of using concept mapping in the curriculum. Furthermore evaluation of the use of concept mapping and ontology systems over a longer period of time may also give

educators a more in-depth understanding of the advantages of using these alternative learning tools in the educational system.

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## APPENDIX A

### IRB APPROVAL & STUDENT SURVEY



#### Form 4: IRB Approval Form Identification and Certification of Research Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The Assurance number is FWA00005960 and it expires on January 24, 2017. The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56.

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Principal Investigator: MCCLURE, CRAIG P  
Co-Investigator(s): GRAY, NICOLE D  
Protocol Number: **X121108004**  
Protocol Title: *Development of a Concept Exploration Based Teaching Methodology of Undergraduate Chemistry Education*

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The IRB reviewed and approved the above named project on 11-9-12. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 11-9-12

Date IRB Approval Issued: 11-9-12

A handwritten signature in blue ink, reading "Marilyn Doss".

Marilyn Doss, M.A.  
Vice Chair of the Institutional Review  
Board for Human Use (IRB)

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#### Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

## Student Pre-Survey

Please read the following statements carefully and indicate your level of agreement by placing a check mark in the appropriate box. All responses will be kept confidential.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Attitude</b>					
I am interested in learning chemistry					
I am confident that I can understand chemistry concepts.					
I am confident in my ability to solve chemistry problems in this course.					
Chemistry understanding is necessary for me to reach my career goals.					

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Metacognitive Skills</b>					
I know I understand concepts when I can see how they relate to one another.					
Before solving a problem, I make a plan (steps) on how to solve it.					
When solving problems, I check my work before submitting it.					
The ability to connect new concepts with prior knowledge is a challenge for me.					
If I don't understand how to answer a problem, I use concepts I do understand to guess at the best way to proceed.					
I try to visualize a problem before attempting to solve it.					
When I have difficulty understanding a problem, I skip it.					
Checking my work on assignments is unproductive.					
When learning chemistry memorizing the concepts is all I need to know.					
For me, the ability to organize concepts is important for problem solving.					
When I don't understand a concept, I try to connect it to concepts I already know.					

## Student Post-Survey

Please read the following statements carefully and indicate your level of agreement by placing a check mark in the appropriate box. All responses will be kept confidential.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Attitude</b>					
I am interested in learning chemistry					
I am confident that I can understand chemistry concepts.					
I am confident in my ability to solve chemistry problems in this course.					
Chemistry understanding is necessary for me to reach my career goals.					

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Metacognitive Skills</b>					
I know I understand concepts when I can see how they relate to one another.					
Before solving a problem, I make a plan (steps) on how to solve it.					
When solving problems, I check my work before submitting it.					
The ability to connect new concepts with prior knowledge is a challenge for me.					
If I don't understand how to answer a problem, I use concepts I do understand to guess at the best way to proceed.					
I try to visualize a problem before attempting to solve it.					
When I have difficulty understanding a problem, I skip it.					
Checking my work on assignments is unproductive.					
When learning chemistry memorizing the concepts is all I need to know.					
For me, the ability to organize concepts is important for problem solving.					
When I don't understand a concept, I try to connect it to concepts I already know.					

On average, how many hours each week have you spent completing homework assignments (quizzes, concept maps) for this course?

*Check only one:*

- ☐ 0-1 hour  
☐ 2-3 hours  
☐ 4-5 hours  
☐ 5 or more hours

(Additional section of post-survey administered to treatment 1 and treatment 2)

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Learning Resource Items</b>					
I have used concept mapping to help organize course concepts					
I am confident in my ability to construct concept maps for learning					
Concept mapping has helped me to see links between concepts					
Concept mapping is helpful because it shows me what I know and what I need to learn					

(Additional section of post-survey administered to treatment 2)

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>Learning Resource Items</b>					
The Creonto software helped me to better understand the concepts taught in this course					
The Creonto software was beneficial to my learning in this course					



## APPENDIX B

### EXAMS

#### CH 105-Exam 1

**Choose the one best answer for each multiple-choice question.**

- 1) Which of the following is an exothermic process?  
A. Melting    B. boiling    C. sublimation    D. condensation    E. evaporation
- 2) What unit correctly completes the statement:  $2.34 \text{ km} = 23400 \underline{\hspace{1cm}}$   
A. m    B. cm    C. Mm    D. dm    E. mm
- 3) What is the SI unit of temperature?  
A. Joules    B. calories    C. Kelvin    D. degrees Celsius    E. degrees Fahrenheit
- 4) What characteristic differs between isotopes?  
A. the number of protons in each  
B. the number of neutrons in each  
C. their melting points  
D. their electron configurations  
E. their placement on the periodic table
- 5) When expressed in scientific notation, a large negative number would have  
A. a negative coefficient and a positive exponent  
B. a positive coefficient and a negative exponent  
C. a negative base and a positive exponent  
D. a positive coefficient and a positive base  
E. a negative coefficient and a negative base

**Using complete sentences and proper grammar, answer each of the questions below.**

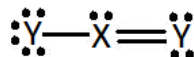
- A) Nickel has a larger specific heat than titanium. If the same amount of heat energy is added to equal masses of nickel and titanium starting at the same temperature, how would their final temperatures differ, and why

- B) The temperature of nickel is recorded in degrees Celsius before and after the heat is added, If the temperature was measured in Kelvin instead, how would the temperature change differ, and why?
- C) What can you say about the heat energy needed for melting nickel and titanium from the data presented? What additional information, if any, would need to be given?

### CH 105-Exam 2

Choose the one best answer for each multiple-choice question.

- What is the chemical symbol for an element with 25 protons, 27 neutrons, and 23 electrons?  
 A.  $\text{Mn}^{2-}$       B.  $\text{Co}^{2+}$       **C.  $\text{Mn}^{2+}$**       D.  $\text{V}^{2+}$       E.  $\text{Co}^{2-}$
- Which of the following is a monoatomic anion?  
 A. silver (I) ion      B. nitrate ion      C. lithium ion  
 D. sulfite ion      **E. oxide ion**
- Why does neon not tend to form bonds with other elements?  
**A. neon does not need to share electrons to satisfy the octet rule**  
 B. neon has a very high electronegativity, so pulls electrons so strongly it won't form bonds  
 C. neon only exists as homodiatomic molecule  
 D. neon has a very low ionization energy, so easily gives up electrons to other elements  
 E. neon only exists as a gas, so it won't get close enough to other atoms to form bonds
- What is the name for the compound with the chemical formula  $\text{SiF}_2$  ?  
 A. silver (I) fluoride      **B. silicon difluoride**      C. silver difluoride  
 D. silicon (II) fluoride      E. silver (II) fluoride
- What would be the molecular geometry of the compound represented here?  
 A. Square planar  
 B. B. linear  
 C. C. trigonal planar  
**D. bent**



E. tetrahedral

6) How many electrons would be expected to be in bonds in a molecule of carbon monoxide?

- A. zero                      B. two                      C. four                      **D. six**                      E. eight

**Using complete sentences and proper grammar, answer each of the questions below.**

You are studying with your friend Fred for your chemistry exam, and Fred states, "Chlorine has electronegativity value of 3.0, since that is greater than 1.8, it will always form an ionic compound."

- 1) What part of Fred's statements is correct?
  
  
  
  
  
  
  
  
  
  
- 2) What part of Fred's statement is incorrect, and why?
  
  
  
  
  
  
  
  
  
  
- 3) Will chlorine ever form a pure covalent compound? Explain why or why not.

### **CH 105-Exam 3**

**Choose the one best answer for each multiple-choice question.**

- 1) When following a chemical formula, what does (aq) mean?  
**A. The substance is dissolved in water**  
B. The substance is unstable, and likely to go through further reactions  
C. The substance is an ionic compound  
D. The substance has gained or lost electrons in a reaction

- E. The substance is in multiple states of matter
- 2) How many moles of  $\text{CO}_2$  are present in a sample containing 38.08 grams of that substance?
- A. 0.74 moles                      **B. 0.87 moles**                      C. 1.16 moles  
D. 1.27 moles                      E. 1.36 moles
- 3) What does the subscript communicate about the compound in  $\text{SeO}_2$ ?
- A. the mass ratio of selenium to oxygen is 1:2  
**B. the atom ratio of selenium to oxygen is 1:2**  
C. the proton ratio of selenium to oxygen is 1:2  
D. the density ratio of selenium to oxygen is 1:2  
E. the charge ratio of selenium to oxygen is 1:2
- 4) Two identical cylinders are held at the same temperature, one containing 100 grams of oxygen and the other containing 100 grams of helium. Which of the following statements and explanations is true about the comparative pressure in these cylinders?
- A. 100 grams of oxygen will have a greater pressure than 100 grams of helium, because the particles have more mass  
B. 100 grams of oxygen will have a greater pressure than 100 grams of helium, because there are two atoms of oxygen in an oxygen molecule, and helium atoms are monoatomic.  
**C. 100 grams of helium will have a greater pressure, because there are more gas particles in that cylinder**  
D. 100 grams of helium will have a greater pressure, because the particles have more kinetic energy  
E. The two cylinders will have the same pressure, because they have the same amount of gases
- 5) How many molecules are present in 0.081 moles of  $\text{S}_2\text{O}_4$ ?
- A.  $2.4 \times 10^{22}$  molecules                      B.  $3.7 \times 10^{-18}$  molecules                      **C.  $4.9 \times 10^{22}$  molecules**  
**molecules**                      D.  $6.3 \times 10^{-4}$  molecules                      E.  $8.1 \times 10^{21}$  molecules
- 6) What is the coefficient in front of the product in the reaction shown here?
- \_\_\_\_\_  $\text{Al}(s) +$  \_\_\_\_\_  $\text{Br}_2(g) \rightarrow$  \_\_\_\_\_  $\text{AlBr}_3(s)$
- A. 1                      **B. 2**                      C. 3                      D. 4                      E. 5

Using complete sentences and proper grammar, answer each of the questions below.

Compare a single-replacement reaction with a double-replacement reaction. Explain how these types of reactions are similar to one another.

Contrast a single-replacement reaction with a double-replacement reaction. Explain how these types of reactions are different from one another.

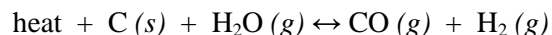
One of these types of reactions is usually a redox reaction, while the other one is usually not. Identify which reaction has each of these characteristics, and explain why that is the case.

#### CH 105-Exam 4

Choose the one best answer for each multiple-choice question.

- 1) A compound is dissolved in pure water to form a solution. After the compound dissolves fully, cations, anions, and molecules all exist as solute particles. Which of the following best describes this compound?  
A. **weak electrolyte**      B. base      C. nonelectrolyte  
D. indicator      E. strong electrolyte
- 2) A solution of HBr with a volume of 230 mL is titrated with a 1.32 M NaOH solution. If the equivalence point is reached after the addition of 39 mL of the basic solution, what was the concentration of the HBr solution?  
A. 0.051 M    **B. 0.22 M**    C. 0.41 M    D. 0.78 M    E. 4.5 M
- 3) Which of the following is not a property of a base?  
A. turns litmus blue  
B. neutralizes acids  
**C. tastes sour**  
D. forms a precipitate with  $\text{Zn}^{2+}$  ions  
E. has a slippery feel

- 4) Which of the following changes *would not* shift the equilibrium of the reaction shown to the right?



- A. **increasing the pressure in the container**
  - B. increasing the amount of water vapor in the container
  - C. decreasing the amount of carbon monoxide in the container
  - D. warming up the reaction mixture
  - E. decreasing the amount of hydrogen in the container
- 5) A dental amalgam, sometimes used for fillings, is a homogeneous mixture of 14% tin, 8% copper, 32% silver, and 54% mercury. What is the term that best describes mercury in this mixture?
- A. solution    **B. solvent**    C. colloid    D. binder    E. solute

**For each of the following statements, tell whether it is true or false. If false, use complete sentences and proper grammar to explain what parts of the statement make it false, and why.**

- 1) In an exothermic reaction, the reactants have only potential energy, and the products have only kinetic energy.
- 2) In a reversible reaction, the activation energy is larger in the endothermic direction than the exothermic direction.
- 3) Catalysts increase the rate of a chemical reaction by decreasing its heat of reaction.

## APPENDIX C

### CONCEPT MAP WORKSHOP HANDOUTS

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

A concept map is a graphical representation tool to help students visually organize key concepts, their relationships and connections about a topic.

It includes concept terms (provided from the list of key concept terms), one-way arrows (which connect two concept terms), and descriptive phrases (meaningful phrases to show relationship between a pair of concepts).

#### **Purpose of Concept Mapping**

In this course you will learn chemistry facts, chemistry concepts, and how these concepts relate to one another. Concept mapping assignments will be used as a way for you to illustrate how these concepts learned during the semester are related.

#### **Steps to Creating a Concept Map**

**Step 1:** Begin with the general topic at the top or center of the map in a single oval

**\*The general topic will be provided to you**

**Step 2:** Connect the general topic to relevant concepts with one-way arrows using the list of key concept terms provided

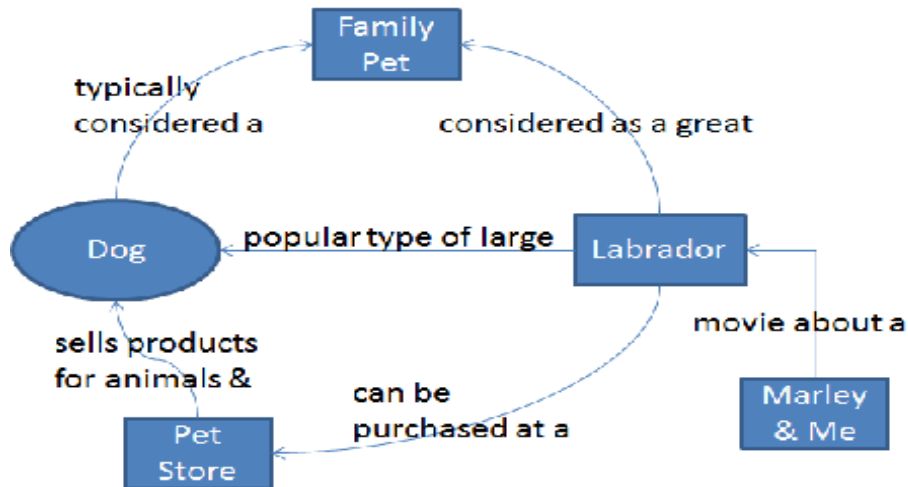
**Step 3:** Continue to connect concepts with arrows and identify connections between them until you have used all key concept terms provided

**Step 4:** Use all and only the terms in the list of key concepts provided to create your concept map

**Step 5:** Use a concept term only once when creating your map

**Step 6:** Write descriptive phrases above all arrows between concepts to show relationships among them

### Example Concept Map

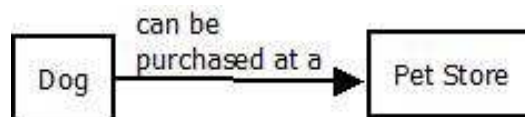


### Descriptive phrases:

Descriptive phrases should represent a meaningful and complete relationship between two relevant concepts and show a clear understanding of the relationships among them.

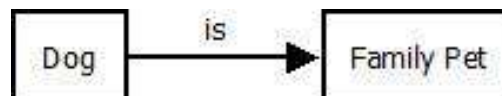
**A good example of how a descriptive phrase should be represented in your concept map is below:**

- Meaningful and complete descriptive phrase example



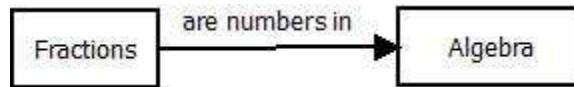
**The following examples below show a lack of understanding of the relationships between the two concepts and should be avoided when creating your concept maps:**

- Correct but general descriptive phrase example

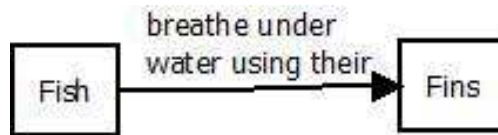




- Partially correct but incomplete descriptive phrase example



- Incorrect descriptive phrase example



### **Concept Map Grading Rubric** Possible Total Points of 8

#### **Concepts and Terminology**

4 points	Uses all and only the terms (100%) provided in the list of key concepts to create concept map
3 points	Uses a majority of the terms (99-75%) provided in the list of key concepts to create concept map
2 points	Uses some of the terms (74-50%) provided in the list of key concepts to create concept map
1 point	Uses only a few of the terms (49-1%) provided in the list of key concepts to create concept map
0 points	Fails to use terms (0%) provided in the list of key concepts to create concept map

#### **Knowledge of the Relationships among Concepts**

4 points for each	Meaningful and complete descriptive phrase between relevant concepts and shows a clear understanding of the relationships among them
3 points for each	Correct but general descriptive phrase between relevant concepts and shows a good understanding of the relationships among them
2 points for each	Partially correct but incomplete descriptive phrase between relevant concepts and shows a few misunderstandings of the relationships among them
1 point for each	Incorrect/Irrelevant descriptive phrase between relevant concepts and shows a lack of understanding of the relationships among them
0 points for each	Linkage with no descriptive phrases between concepts

### Knowledge of the Relationships among Concepts Scoring

Meaningful and Complete Phrases	_____ X (4) = _____
Correct but General Phrases	_____ X (3) = _____
Partially Correct but Incomplete Phrases	_____ X (2) = _____
Incorrect Phrase	_____ X (1) = _____
No Phrase	_____ X (0) = _____

Total Score = \_\_\_\_\_

- The total possible points for the knowledge of the relationships among concepts section will be (4) times the number of meaningful and complete descriptive phrases identified by the instructor on the master map.
- However, since each map will not have the same number of descriptive phrases, the final score possible for this section will be converted to a 1-4 scale with a maximum score of 4 points total for this section.

For example, if the master map includes 6 meaningful and complete descriptive phrases, the maximum total score would be 24 points (6 meaningful phrases X 4) for this section. If a student total score for the section is:

Meaningful and Complete Phrases	<u>2</u> X (4) = 8
Correct but General Phrases	<u>1</u> X (3) = 3
Partially Correct but Incomplete Phrases	<u>3</u> X (2) = 6
Incorrect/Irrelevant Phrase	<u>0</u> X (1) = 0
No Phrase	<u>0</u> X (0) = 0

Total Score = 17 points

The student's total score is 17 points for descriptive phrases out of a total possible points of 24. By dividing  $17/24 = .708333333$  and multiplying that by the maximum scale total of 4 ( $.70833333 \times 4 = 2.8333 \cong 3$  points). The student's score for that section will be 3 points.

## Concept Mapping Workshop Assignment

**Instructions:** As a group construct a concept map on a separate sheet of paper showing how the terms listed below are related. Your map should be constructed around the central concept: **Flower**

### Concept Term List:

- **Flower**
- Rose
- Fragrance
- Love
- Florist
- Feeling

**\*Check for the following after constructing your map:**

- ✓ **Your names are included on the top of your map**
- ✓ **You have included all and only the terms provided in the list above to create your map**
- ✓ **All lines connecting your concepts are one-way arrows**
- ✓ **You have included descriptive phrases on all one-way arrows connecting your concepts**
- ✓ **Your map shows what you know about the central topic: Flower**

## APPENDIX D

### CREONTO “INTRO CHEMISTRY” INSTRUCTIONAL SHEET

#### Instructional Sheet for using Creonto Software

In this course, concept mapping assignments will be used as a way for you to illustrate how chemistry concepts learned during the semester are related. The Creonto software will be used as a supplementary learning tool to help you as a student visually see how these chemistry concepts are related to one another.

You will be using this Creonto “Intro Chemistry” software as a tool to assist you in creating these concept mapping assignments.

1) Use the following link to access the Creonto software:

[http://books.creonto.com/login\\_uab.php](http://books.creonto.com/login_uab.php)

2) You will then be brought to the following webpage

Creonto BETA

Please login with your UAB email id with your Banner ID as the password.

**UAB**

**LOGIN**

Email

Password

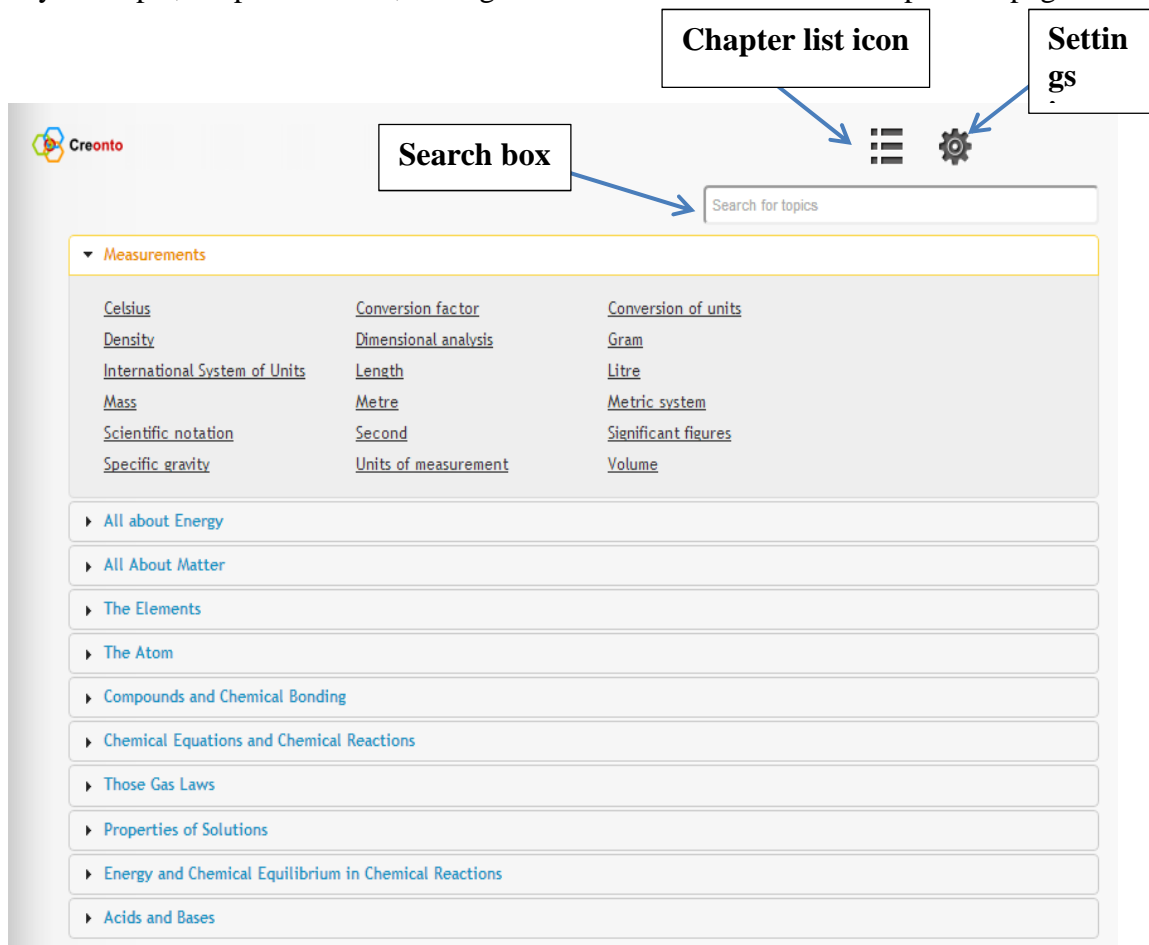
Login

Please contact [ndgray@uab.edu](mailto:ndgray@uab.edu) in case you face any problems or need further help.

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3) Login using your **UAB email** and **Banner ID/B00 number as password**

4) After opening the “Intro Chemistry” book, you will see the table of content list with key concepts, chapter list icon, settings icon and a search box at the top of the page.



5) To find key concepts, type the key term into the search box or click on the key term in the table of content list.

Using the table of content list to find key terms:

For example, if you are looking for the key term “state of matter”:

- Click “All About Matter” chapter in the table of content list. A list of key terms for that chapter will appear. Then click on the “state of matter” key term. You will then be directed to a page with descriptions, images, videos, external links, and related concepts for “state of matter”. Also the powerpoint notes for the course is located at the top of the page for reference.

All About Matter

Search for topics

Chemical change

Chemical compound

Chemical element

Chemical property

Chemical substance

Energy

Enthalpy of fusion

Enthalpy of vaporization

Gas

Homogeneity and heterogeneity

Liquid

Matter

Melting point

Mixture

Physical change

Physical property

Solid

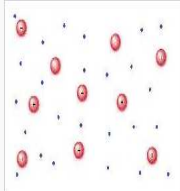

State of matter

Sublimation

PowerPoint notes icon

State of matter

States of matter are the distinct forms that different phases of matter take on. Solid, liquid and gas are the most common states of matter on Earth. Historically, the distinction is made based on qualitative differences in bulk properties. Solid is the state in which matter maintains a fixed volume and shape; liquid is the state in which matter maintains a fixed volume but adapts to the shape of its container; and gas is the state in which matter expands to occupy whatever volume is available.

External Content:

1. State of matter - Wikipedia, the free encyclopedia

Videos:

1. Bill Nye: Phases of Matter  
2. States of Matter  
3. States of Matter

Related Concepts for State of matter

Chemical compound   Chemical element   Chemical property   Chemical substance   Energy   Enthalpy of fusion   Enthalpy of vaporization   Gas   Homogeneity and heterogeneity   Liquid   Matter   Melting point   Mixture   Physical change   Physical property   Solid

Videos, external links, and the powerpoint notes will show up in another tab. To navigate back to the book, click on the Creonto-Intro Chemistry tab in your web browser.

6) In the related concepts box, the larger the concept the more related the concept is to the term. The smaller the concept represents that it has a smaller relationship to the term.

Related Concepts for State of matter

Chemical compound   Chemical element   Chemical property   Chemical substance   Energy   Enthalpy of fusion   Enthalpy of vaporization   Gas   Homogeneity and heterogeneity   Liquid   Matter   Melting point   Mixture   Physical change   Physical property   Solid

Videos, external links, and the PowerPoint notes will show up in another tab. To navigate back to the book, click on the Creonto-Intro Chemistry tab at the top of the browser window.

6) In the related concepts box, the larger the font, the more closely related the concept is to the term that the page is currently on. The smaller fonts represent that the concepts have a more distant relationship to them.

169

#### Related Concepts for State of matter

Chemical compound Chemical element Chemical property Chemical substance Energy Enthalpy of fusion Enthalpy of vaporization Gas Homogeneity and heterogeneity Liquid Matter Melting point Mixture Physical change Physical property Solid

Using the search box to find key terms:

For example, if you are looking for the key term “state of matter”:

- Type “state of matter” into the search box. Click on the “state of matter” term. You will be directed to the same page shown above.

7) Log-out of Creonto software by clicking on the settings icon at the top of the page and click “log out”.

The screenshot shows the Creonto software interface. At the top left is the Creonto logo. The main heading is "State of matter". Below it is a paragraph of text: "States of matter are the distinct forms that different phases of matter take on. States of matter of solid, liquid, and gas. Energy can be reflected in states of matter by the motion of particles. day life in the forms of solid, liquid, and gas. Energy can be reflected in states of matter by the motion of particles. ent is extremely slow while liquid particles move at a moderate pace. A gas particle as well has movement at an extremely fast pace. The energetic's of particle movements are one example of distinct characteristics between the sates of matter. States of matter can also change between different phases by the addition or loss of heat measured by temperature." At the top right, there is a settings icon (gear) and a menu icon (three horizontal lines). A callout box with the text "Click 'Logout'" has an arrow pointing to the "Logout" option in the settings menu. The menu also includes "My Library" and "Feedback".

## APPENDIX E

### EXPERT PANEL VALIDITY & RELIABILITY INSTRUCTIONS

#### **Information and Instructions for Expert Review Panel Qualitative Review**

The purpose of this survey instrument is to monitor changes in students' opinions about their metacognitive skills and attitudes toward chemistry and the sciences over the course term. Additionally the surveys will be used to assess how standard assignments and regular classroom activities impact students' opinions about chemistry. The survey will be administered to students enrolled in the introductory chemistry course at the beginning and end of the semester.

The instrument contains 38 statements on a 5-point Likert scale and is divided into three categories: attitude, metacognitive skills, and learning process. Attitudes towards the sciences statements are related to students' positive or negative feelings and their perceived self-efficacy about science. The metacognitive skills statements are related to students' planning, monitoring, and evaluating skills in learning and completing assignments. While the learning process statements are related to standard assignments and regular classroom activities.

Specifically, the statements under the metacognitive section are divided into three categories of metacognition which are planning, monitoring, and evaluation. The planning statements are intended to probe students' organizational skills. The monitoring and evaluating statements are intended to probe students' awareness of their own learning and assessment skills. The statements under the attitude section are divided into two categories: self-efficacy about science and chemistry and perceived usefulness of chemistry in particular. The self-efficacy statements are intended to probe students' perceived confidence and ability to do science and chemistry. The applicability section is intended to probe students' perceived usefulness of science not only in academia settings but to real world scenarios as well. Finally, the learning process statements are intended to probe students' opinions about standard assignments and regular classroom activities such as concept maps and computer activities.

You are being asked for the qualitative review to provide feedback regarding the directions, instrument items, and overall instrument. Please feel free to write your comments in the textboxes provided or use additional paper as needed.



**Directions**

- Are the directions for the survey instrument concise? If no, please explain.
- Are the directions for the survey instrument clear? If no, please explain.
- Are the directions for the survey instrument complete? If no, please explain.

**Instrument Items**

- Are the items appropriate? If no, please explain.
- Are the items clear? If no, please explain.
- Would you revise any item? If yes, please explain.
- Would you recommend deleting an item(s)? If yes, please explain.
- Do you recommend adding additional items? If yes, please explain.
- Additional comments?

**Information and Instructions for Expert Review Panel  
Quantitative Review**

The purpose of this survey instrument is to monitor changes in students' opinions about their metacognitive skills and attitudes toward chemistry and the sciences over the course term. Additionally the surveys will be used to assess how standard assignments and regular classroom activities impact students' opinions about science and chemistry in particular. The survey will be administered to students enrolled in the introductory chemistry course at the beginning and end of the semester.

The instrument contains 36 statements on a 5-point Likert scale and is divided into three categories: attitude, metacognitive skills, and learning process. Attitudes towards chemistry statements are related to students' positive or negative feelings and their perceived self-efficacy about chemistry. The metacognitive skills statements are related to students' planning, monitoring, and evaluating skills in learning and completing assignments. While the learning process statements are related to standard assignments and regular classroom activities encountered in the introductory chemistry course.

Specifically, the statements under the metacognitive section are divided into three categories of metacognition which are planning, monitoring, and evaluation. The planning statements are intended to probe students' organizational skills. The monitoring and evaluating statements are intended to probe students' awareness of their own learning and assessment skills. The statements under the attitude section are divided into two categories: self-efficacy about chemistry and perceived usefulness of chemistry in particular. The self-efficacy statements are intended to probe students' perceived confidence and ability to do chemistry. The applicability section is intended to probe students' perceived usefulness of chemistry not only in academia settings but to real world scenarios as well. Finally, the learning process statements are intended to probe students' opinions about standard assignments and regular classroom activities such as

lectures, instructional/study notes, concept maps, and computer activities encountered in the introductory chemistry course.

You are being asked for the quantitative review process to rate how essential each item is for monitoring changes in students' opinions about their metacognitive skills, attitudes towards chemistry, and learning resources over the course term.

**Directions**

Please rate each item as essential, useful but not essential, or not necessary based on the item's ability in monitoring changes in students' metacognitive skills and attitudes towards chemistry. Additionally, please provide additional comments in the text boxes provided.

## APPENDIX F

### CONCEPT MAPPING ASSIGNMENTS

# Concept Mapping Assignment #1

**Due Date: (at the beginning of class)**

(Instructions for Treatment 1 group)

**Instructions:** Construct a concept map on a separate sheet white/copy paper showing how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Energy**

(Instructions for Treatment 2 groups)

**Instructions:** Construct a concept map on a separate sheet of white/copy paper using the Creonto software as an assistance tool to show how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Energy**

#### Concept Term List:

- **Energy**
- Work
- Heat
- Specific Heat
- Temperature
- Celsius
- Fahrenheit
- Kelvin
- Heat of Vaporization
- Heat of Fusion
- Melting Point
- States of Matter

**\*Check for the following after constructing your map:**

- ✓ **Your name is included on the top of your map**
- ✓ **You have included all and only the terms provided in the list above to create your map**
- ✓ **All lines connecting your concepts have an arrow**
- ✓ **You have included descriptive phrases on all arrows connecting your concepts**
- ✓ **Your map shows what you know about the central topic: **Energy****

## Concept Mapping Assignment #2

### Due Date: (at the beginning of class)

#### (Instructions for Treatment 1 group)

**Instructions:** Construct a concept map on a separate sheet white/copy paper showing how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Electronegativity**

#### (Instructions for Treatment 2 groups)

**Instructions:** Construct a concept map on a separate sheet of white/copy paper using the Creonto software as an assistance tool to show how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Electronegativity**

#### Concept Term List:

- **Electronegativity**
- Covalent Compounds
- Ionic Compounds
- Electrons
- Pure Covalent Compounds
- Polar Covalent Compounds
- Metals
- Nonmetals
- Dipole
- Noble Gases

#### \*Check for the following after constructing your map:

- ✓ Your name is included on the top of your map
- ✓ You have included all and only the terms provided in the list above to create your map
- ✓ All lines connecting your concepts have an arrow
- ✓ You have included descriptive phrases on all arrows connecting your concepts
- ✓ Your map shows what you know about the central topic: **Electronegativity**

## Concept Mapping Assignment #3

### Due Date: (at the beginning of class)

#### (Instructions for Treatment 1 group)

**Instructions:** Construct a concept map on a separate sheet white/copy paper showing how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Chemical Reaction**

#### (Instructions for Treatment 2 groups)

**Instructions:** Construct a concept map on a separate sheet of white/copy paper using the Creonto software as an assistance tool to show how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Chemical Reaction**

#### Concept Term List:

- **Chemical Reaction**
- Double Replacement Reaction
- Chemical Change
- Products
- Reactants
- Chemical Equation
- Decomposition Reaction
- Combination Reaction
- Single Replacement Reaction

**\*Check for the following after constructing your map:**

- ✓ **Your name is included on the top of your map**
- ✓ **You have included all and only the terms provided in the list above to create your map**
- ✓ **All lines connecting your concepts have an arrow**
- ✓ **You have included descriptive phrases on all arrows connecting your concepts**
- ✓ **Your map shows what you know about the central topic: Chemical Reaction**

## **Concept Mapping Assignment #4**

### **Due Date: (at the beginning of class)**

#### **(Instructions for Treatment 1 group)**

**Instructions:** Construct a concept map on a separate sheet white/copy paper showing how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Chemical Potential Energy**

#### **(Instructions for Treatment 2 groups)**

**Instructions:** Construct a concept map on a separate sheet of white/copy paper using the Creonto software as an assistance tool to show how the terms listed below are related. Please write your name on the top of the paper used to construct your concept map to receive credit for this assignment. Your map should be constructed around the central concept: **Chemical Potential Energy**

#### **Concept Term List:**

- **Chemical Potential Energy**
- Chemical Reaction
- Law of Conservation of Energy
- Catalyst
- Rate of Reaction
- Activation Energy
- Heat of Reaction
- Endothermic Reaction
- Exothermic Reaction

#### **\*Check for the following after constructing your map:**

- ✓ **Your name is included on the top of your map**
- ✓ **You have included all and only the terms provided in the list above to create your map**
- ✓ **All lines connecting your concepts have an arrow**
- ✓ **You have included descriptive phrases on all arrows connecting your concepts**
- ✓ **Your map shows what you know about the central topic: Chemical Potential Energy**