5-1-2010

Organic chemistry preconceptions and their correlation to student success

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The Graduate School

ORGANIC CHEMISTRY PRECONCEPTIONS AND THEIR CORRELATION TO STUDENT SUCCESS

A Dissertation Submitted in partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

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May, 2010

This Dissertation by: Jodie T. Wasacz

Entitled: Organic Chemistry Preconceptions and their Correlation to Student Success

has been approved as meeting the requirement for the Degree of Doctor of Philosophy in College of Natural and Health Sciences in School of Chemistry and Biochemistry, Program of Chemical Education

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ABSTRACT

Wasacz, Jodie T. *Organic Chemistry Preconceptions and their Correlation to Student Success.* Published Doctorate of Philosophy Dissertation. University of Northern Colorado, 2010.

When general chemistry students register for organic chemistry, they often have a negative connotation associated with the topic. It has been observed that students talk as if they are experts in what organic chemistry is and exactly how hard it is when many of them have had very little background on the subject. Some students do not even know what topics organic chemistry encompasses. By establishing a framework of where their preconceptions come from and what they are, instructors, will have a better understanding of how to address preconceptions when beginning an organic chemistry course, or perhaps even before. Furthermore, relationships can be investigated between students' preconceptions and their success in organic chemistry. This mixed methods study was designed to investigate what preconceptions were found surrounding organic chemistry, the source of the preconceptions, and the association with student success. Results of this study indicate there are no significant correlations between students' preconceptions and their success in organic chemistry. There may however, be other underlying factors bridging their preconceptions and success. In addition to the qualitative results, quantitative chi-square and regression statistics will be discussed and presented.

ACKNOWLEDGEMENTS

The following project would not have been possible or completed without the help of many people. This project has taken the past three years to reach completion and I would like to thank those who have made it possible along the way.

First, I would like to thank all the student participants and faculty participants in this research project; without them, there would be no project.

Secondly, I would like to thank my committee members, Dr. Mark A. Smith and Dr. Youngjin Song for their many proofs, edits, and comments that have allowed me to reach this final point in my project. Their help with organization and their time was very much appreciated along the way. In addition, the idea for this project would not have been possible without Mark, as it was his comment about organic chemistry that brought me to this topic. I would like to thank Richard M. Hyslop, another committee member for his service as well as volunteering to proofread many of the chapters, often multiple times. I have greatly appreciated all the help and advice I have received. I would also like to thank Dr. David Pringle, Tessa Johnson, and Cathy Bohannan for all their help with the technicalities, such as student incentives for participation, and all the other places where they helped out when necessary to get me through this project.

I am also very much appreciative of Dr. Jack Barbera. Though he was a late addition to my committee, his insight helped to shape this project. I appreciate the hours of time spent trying to figure out the statistics, and analyze the data to determine what it s

meant. I appreciate the time spend reading and re-reading the many edits. Without Jack's help I may never have gotten through all the statistical analysis that ensued.

I would also like to thank many of the UNC graduate students that have also helped me along the way. Special thanks go to Erica Costello, who has been a constant support throughout this project and has listened to my talks and seminars more times than anyone else. Also, Erica's help proofreading and teaching me what BPR's were, was invaluable. I appreciated having someone to talk to at home and get me through this. Also, Niwat Srisawadsi also provided constant support and is a great friend. Other students I would like to acknowledge are Jackie Fajardo, Corina Brown, Dave Patrick, David Wren, and Matt Freyer for their help with the inter-rater reliability. Also, the chemical education research group as well as the organic research group (past and present) have both helped me to amend my project at times during group meetings.

A few outside people also deserve recognition for their help with this project. My Mom, Enid, of course, is always a constant source of advice and un-wavering support. If it were not for her I would not be here today so this is for her. Also I would like to thank my three brothers, Eric, Chris, and Colin, for their support, constant encouragement, and help with typing. I would also like to thank my "brother" Matt for all his help as well. I would like to thank my Dad, Joe, who at the end was also very "instrumental" in supporting me. Without my family none of this would have been possible. They are always encouraging, supporting, and are always there for me. Thanks to Justine and Jolene for their support and friendship throughout this project. Also, I would like to thank Tomoko Creed and family for their constant support and cheerleading. At the

hardest times, Tomoko was a ray of light convincing me it would all work out. I love you all!

Lastly, and probably most importantly, I would like to thank Dr. Kimberly Pacheco. Dr. P was always and is always a source of support and advice, and always pushes me to achieve more. Even when times were hard for her, she was there to help me with this project, proofread something, or listen to a presentation again and again. Her time, talents, and support are something I will always strive to emulate in my own career. In addition, to being my major advisor, she was also a great friend. I do not think I would have made it all five years out in Colorado without Dr. P. She opened her family and her home up to me. We have shared fancy meals, hikes, walks, talks, and Caleb, among other things. Dr. P was the pat on the back, or the smile of encouragement that made keep working hard and striving to finish this project. Words can never express how grateful I am to Dr. Pacheco!

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CHAPTER I

INTRODUCTION

Statement of Problem

While teaching General Chemistry II laboratories, the researcher observed students discussing the next semester's organic chemistry class. During these observations there was often a negative connotation associated with organic chemistry and rarely were positive aspects mentioned about the course. When talking about organic chemistry, students spoke as if they were experts in organic chemistry. Additionally, students spoke as if they knew exactly how difficult it would be to learn the concepts. Students speak in this manner, despite having very little background in the subject. When these students were asked by the researcher if they knew what organic chemistry was, however, many students did not even know what topics organic chemistry encompasses. Where do these general chemistry students get their information? How do these preconceptions about organic chemistry form and/or what are the sources of the preconceptions? What are the most common preconceptions? Do these preconceptions affect a student's performance in organic chemistry class? These are some of the questions this research project addresses. The aim of this research was to establish both the source of the preconceptions, identify specific preconceptions, as well as correlate preconceptions with student success. In understanding the origins of these preconceptions, what they are, and how they affect student success, instructors will have

the opportunity to utilize this information to address preconceptions prior to the first day or on the first day of an organic chemistry course. With the knowledge of what the most prevalent preconceptions of students are and their sources, professors can alleviate students' concerns by giving them a new and different perspective concerning organic chemistry. Alleviating student's concerns can be done through in-class discussions addressing the course content and by introducing successful study habits students' may find useful.

Purpose of Study

The purpose of this phenomenological study was to determine the variables, and their sources, affecting student attitudes towards organic chemistry prior to taking Organic Chemistry I. Phenomenological research describes the meaning of the lived experiences for several individuals about a concept or a phenomenon[1] and was used in this research to investigate the phenomenon of the effect of student preconceptions on success. To investigate this phenomenon, existing preconceptions were first identified, followed by the sources of these preconceptions and student's feelings about their preconceptions. To accomplish the identification and classification of preconceptions, qualitative analysis was conducted. Upon identification of preconceptions, further investigation was conducted concerning how any of the preconceptions affect student success. To determine the existence of any correlations between the preconception variables and the success of the students in organic chemistry, quantitative analysis was conducted. Students' success was measured using both their four-week and final grades

[1] Creswell, J. (2008). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

in organic chemistry. Statistical analysis via ordinal regression, chi-square analysis, and bivariate correlations were conducted to determine relationships within the data.

Research Questions

Q1: What preconceptions exist for General Chemistry II students surrounding the organic chemistry lecture?

Q2: Where do students' preconceptions originate?

Q3: Are students able to define, in basic terms, organic chemistry?

Q4: Are the preconceptions identified by the students during interviews correlated significantly to their success in the course (as established by student grades)?

Q5: How do the students with identified preconceptions perform in the course when compared to those with minimal preconceptions, as assessed by students' final grades?

Related Studies

In an unpublished study done recently by the researcher and two organic chemistry professors[2], it was observed that the majority of students' final grades in an organic chemistry course could be predicted after the first four quiz grades (quizzes were given once a week) were obtained, typically within the first month of the semester. Student's four-week and final grades were obtained from both organic chemistry instructors from the previous five years. Upon statistical analysis, the results showed that about 65% of the students' final grades were accurately determined by the average of the students' first four quiz grades. The remaining 35% of students showed a change in their grade from their four-week average to their final grade. However, of the 35% who

[2] Wasacz, J. T., Pacheco, K. A. O., & Schreck, J. (2009). Are students grades in organic chemistry predictable. Unpublished Research Project. University of Northern Colorado.

displayed a change in their grade, only 5% of those students increased their grade. The remaining 30% of students decreased their grade. This study was based on a 4.0 grading scale where awarded grades were A-F, excluding the use of plusses and minuses.

Analysis illustrated that the majority of student's final grades were determined after just the first four weeks of quizzes, with most students achieving the same final grade or a lower final grade than their four-week average. Could this be an indication that by this four-week mark, students' study habits and their approach to the course are ingrained since their grades do not improve? If this is the case, then what is affecting the students' study habits and approach to organic chemistry? These questions served as the foundation for this research project. Preconceptions were thought to be a possible cause of why students approach the course in a particular manner, causing their final grades to be predicted by only the fourth week. Upon examination of the literature, however, preconceptions appeared to be very minimally studied.

Based on the experiences of the researcher, course preconceptions were thought to be prevalent throughout college campuses. Upon observation, when it was time to register for the following semester's courses, students tended to ask their peers, professors, or teaching assistants about their upcoming classes. It appeared that students had an innate curiosity about what the course or teacher was going to be like. Students were observed asking questions such as: Is the course hard? Is the homework manageable? How should I study? What is the hardest part? Many times it was observed that the answers given to the inquiring students concerning these questions seemed to relieve their stress and put them at ease about the course. However, at other times, students appeared to develop negative preconceived notions about the specific course

before they attended the first class. It was thought by the researcher that these preconceived notions may affect their performance and ultimate success in a course.

Rationale

A literature review on the topic of preconceptions proved to be more difficult than expected. Preconceptions were defined in a myriad of ways including the definition used in this research. Most often, preconceptions were defined as misconceptions: ideas that do not align with reality that are held by students. Misconceptions are traditionally discussed by the degree in which they align with the accepted view. For this study, preconceptions were defined by the researcher as any attitude or belief held by a student regarding organic chemistry lecture that is based on a) something they have heard from someone else, b) something they have read or c) something they have experienced. Using this definition, preconceptions are not right or wrong (as with misconceptions), but instead are seen as being either positive or negative. Studies involving student preconceptions have been reported, although are sparse. Preconception studies have been done using a variety of methods including investigating the preconceptions students have about the professor, course, or lab experience.[3] It is also reported in the literature that preconceptions are not grounded just in one subject area but instead are campus wide.[4,5,6]

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[3] Cooper, M.M. and Kerns, T.S. (2006). Changing the laboratory: Effects of a laboratory course on students' attitudes and perceptions. *Journal of Chemical Education*, *83*(9), 1356-1361.
[4] Powers, D., & Powers, D. (2000). Constructivist implications of preconceptions in computing.
[5] Smith, R. (2001). *Challenging your preconceptions: Thinking critically about psychology*. Wadsworth Publishing Company.

One study investigated the preconceptions held by accounting students.[7] In this study, student preconceptions surrounding their accounting courses affected their motivation towards the course. The study concluded that different preconceptions held by the students were directly linked to their conceptual understanding and overall learning in the course. The study demonstrated that preconceptions affect student motivation and, consequently, the students' success in a course. Preconceptions, therefore, appeared to be a topic worth further investigation. Another study investigated how students' attitudes regarding a course can be greatly shaped by how the first day of class unfolds. This study is a direct complement to the previous study that found the first day of class might set the tone and have long-term consequences on students and their grades.[8] With these two studies, it is important to consider that students may approach a course with preconceptions that may negatively influence them and affect their grade. There are ways to positively affect students' attitudes towards a course, such as a friendly attitude by a professor the first day and a non-overwhelming syllabus. These studies demonstrate that students can still be successful despite having pre-formed ideas about the course.

Other literature in the area of preconceptions is not as consistent with the preconception definition. In one study, preconceptions are viewed more as stereotypes that students bring into a course. Students bring these pre-constructed views of material

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[6] Yasuhara, K. (2005). *Work in progress–gender and preconceptions of undergraduate computer science.* Paper presented at the 35th ASEE/IEEE Frontiers in Education Conference, Indianapolis, IN.

[7] Lucas, U. and Meyer, J.H.F. (2004). Supporting student awareness: Understanding student preconceptions of their subject matter within introductory courses. *Innovations in Education and Teaching International*, *41*(4), 459 - 471.

[8] Wilson, J.H. and Wilson, S.B. (2007). Methods and techniques: The first day of class affects student motivation: An experimental study. *Teaching of Psychology*, *34*(4), 226-230.

with them to a course, which cause them to answer and understand the material based on stereotyped information.[9] Along with literature dealing with preconceptions more as stereotypes, there is also literature in which preconceptions are more accurately described as misconceptions. Though preconceptions are ideas that a student brings with them to the class either about the course itself or the required material, misconceptions are material that a student believes they understand even though they may be completely wrong.[10] As referred to in this study, these “inaccurate preconceptions”, more commonly known as misconceptions, were seen to affect student performance in a study involving biology students and the topic of evolution.[11] In this study, students were asked to explain the theory of evolution, and the inaccuracies in their responses were noted. The misconceptions students brought with them resulted in less understanding of the true theory and, thus, hindered learning. Preconceptions that are not addressed can become misconceptions, which inhibit a student’s success in the course.

Lastly, students may have preconceptions regarding variables other than just the course or its material. Students have preconceptions regarding their professors[12] and their upcoming experiences such as a practicum or a laboratory.[13] In the former study,

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[9] Richburg, R.W., et al. (1994). Jump-starting thinking: Challenging student preconceptions. *The Social Studies*, *85*(2), 66.

[10] Schmidt, H. (1997). Students’ misconceptions — looking for a pattern. *Science Education*, *81*, 123-135.

[11] Robbins, J.R. and Roy, P. (2007). The natural selection: Identifying & correcting non-science student preconceptions through an inquiry-based, critical approach to evolution. *The American Biology Teacher*, *69*(8), 460-466.

[12] Anderson, K.J. and Smith, G. (2005). Students' preconceptions of professors: Benefits and barriers according to ethnicity and gender. *Hispanic Journal of Behavioral Sciences*, *27*(2), 184-201.

[13] Leh, S.K. (2006). Baccalaureate student nurses' preconceptions of the community health clinical experience. [D.N.Sc. dissertation, Widener University School of Nursing, United States -- Pennsylvania].

students were observed to have different ideas about a course depending on the professors "warmth", gender, and ethnicity. The qualities of the professor affected student's ideas and feeling concerning the course. In the latter study, nursing students were asked about their preconceptions concerning their upcoming clinical experiences and practicum. These preconceptions were classified and used to assist nursing educators in creation of clinical preparatory strategies.

A major concern reported in the literature was the indication that most students' preconceptions contribute largely to a lack of motivation. This lack in motivation may affect other areas of student behavior such as poor attendance,[14] which adversely affects the student's grades and overall success in the course. In conclusion, according to the reviewed literature, preconceptions are present and have been related to varying levels of success and attitude in many aspects of education.

Although the effects of preconceptions in different areas of academics, have been reported in the literature, research concerning preconceptions in science, specifically chemistry, is limited. Although all the previous articles were useful and relevant to some aspect of the current research, the results of the following studies display preconceptions by the same definition used in the current research. In one such study, researchers undertook the task of determining the cause of negative preconceptions.[15] In this study, researchers used the term perceptions, although the definition was parallel to the working definition of preconceptions. Their study focused on why chemistry is perceived as being "hard". The findings of the study demonstrated that students' perceptions of chemistry

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[14] Gump, S.E. (2006). Guess who's (not) coming to class: Student attitudes as indicators of attendance. *Educational Studies*, *32*(1), 39-46.
[15] Carter, C.S. and Brickhouse, N.W. (1989). What makes chemistry difficult? *Journal of Chemical Education*, *66*(3), 223-225.

are correlated to their achievement in chemistry. This study concluded that each institution should survey their students to find out what specific perceptions (preconceptions) they hold.

Another study involved students' preconceptions of science classes and more specifically chemistry.[16] The study was conducted with a population of chemistry students, and the researchers found that preconceptions were often a result of complex words or terms associated with the material. This study indicated that for student learning to occur, teachers had to address each complex word or term first through simplifying and explaining it. By understanding the words or terms, students were able to progress through the material with better understanding of the underlying concepts. A further study dealt with students' difficulties in learning chemistry and focused on the students' pre-instructional conceptions.[17] The study was centered on general science and chemistry concepts and found that for more effective learning to occur in these areas, students' prior knowledge must be addressed and taken into consideration. By addressing student's prior knowledge, however, an expansion of issues being covered beyond chemistry may arise as students' may comment on both relevant and irrelevant topics. Even so, the students will become more engaged in their learning of chemistry.

Other work done on student's preconceptions or perceptions that is related to the current study, and provides background on the research topic, however, does not directly address the purpose of this study. For example, some studies have focused on changing

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[16] Bouma, J. and Brandt, L. (1990). Words as tools: A simple method for the teacher to obtain information on pupils' preconceptions *Journal of Chemical Education*, *67*(1), 24-25.
[17] Treagust, et al. (2000). Sources of students' difficulties in learning chemistry. *Educación Química*, *11*(2), 228-235.

students' attitudes and perceptions in an organic laboratory setting.[18] Due to their nature, the researcher believes that laboratory experiences may differ from lecture experiences. Other educational research in the field of chemistry either addresses techniques, which can be employed in a lecture setting to aid in student learning,[19,20] or identifies misconceptions in college chemistry courses.[21] Although these studies help to address many important aspects of student success that should be considered for the current research, there are many areas that are left uncovered.

Many gaps exist in the literature. First, the most apparent gap was the lack of recent research in the area of preconceptions. Most of the preconception research was performed almost twenty years ago. Although the dated research was highly relevant and informed some aspects of this research, additional research should be done since students, curricula, and teaching methods are more varied today than they were twenty years ago.[22] Present day preconceptions that exist among students should be investigated to determine their nature and potential effects on student success. Second, the majority of the previous research has been centered on general chemistry. Researchers in the past have dealt with topics covered only in general chemistry and chemistry as a whole. Research examining

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[18] Cooper, M.M. and Kerns, T.S. (2006). Changing the laboratory: Effects of a laboratory course on students' attitudes and perceptions. *Journal of Chemical Education*, *83*(9), 1356-1361.

[19] Tien, L.T., et al. (2002). Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. *Journal of Research in Science Teaching*, *39*(7), 606-632.

[20] Browne, L.M. and Blackburn, E.V. (1999). Teaching introductory organic chemistry: A problem-solving and collaborative-learning approach. *Journal of Chemical Education*, *76*(8), 1104-1107.

[21] Zoller, U. (1990). Students' misunderstandings and misconceptions in college freshman chemistry (general and organic). *Journal of Research in Science Teaching*, *27*(10), 1053-1065.

[22] Covington, M.V. and Beery, R. (1976). *The will to learn*. New York: Holt, Rinehart & Winston.

the preconceptions surrounding organic chemistry has been sporadic at best. Published studies primarily focus on organic chemistry in the laboratory setting; a very separate and different experience than the lecture. Because little research has been based on the organic chemistry lecture, this research was performed to determine what preconceptions exist with respect to the lecture portion of the course.

Delimitations

Participants: general chemistry students were chosen because preconceptions about organic chemistry class were of interest, and these preconceptions were only useful if the participant was not currently in organic chemistry or had not previously been enrolled in organic chemistry.

Surveys: initial surveys were given to determine the students' diversity in the general chemistry course and those students who planned to enroll in organic chemistry the following semester. From these surveys, the interviewees were specifically picked to give a representative sample (diversity in majors, grades, types of students, feelings concerning organic chemistry, and sources of information).

Interviews: interviews were chosen to provide the researcher a better understanding of students' attitudes and to learn what preconceptions existed and their origin.

Definition of Terms

Preconception: as defined in this research, by the researcher, is any attitude or belief held by a student regarding organic chemistry subject material that is based on a) something they have heard from someone else, b) something they have read, or c) something they have experienced. Using this definition, a preconception is not right or wrong but is seen as being either positive or negative (as stated by the participant).

Attitudes: defined here as the overall feelings students have towards organic chemistry. Feelings may be, for example, apprehension, fear, nervousness, or confidence.

General chemistry: a freshman-level undergraduate chemistry course offered by all institutions as a pre-requisite for organic chemistry. Material covered during this course is typically a broad overview of all the sub-disciplines of chemistry including chapters of inorganic, analytical, and organic chemistry. General chemistry is traditionally taught over the course of two consecutive semesters. For the current research, students in their second semester of general chemistry were of interest.

Organic chemistry: a sophomore level undergraduate chemistry course typically taken immediately after successful completion of general chemistry. For the current research, students in their first semester of organic chemistry were of interest.

Source: the person, place, or thing from which the students receive their information concerning organic chemistry.

Misconception: an attitude or belief held by a student regarding any topic that is inaccurate and not aligned with the accepted views on that particular topic in the specific field. A misconceptions is an idea or belief that is wrong or slightly flawed and is not viewed as being either positive or negative.

Perception: a particular idea or belief as viewed through a student's eyes.

Stereotype: an idea or view held by a group of individuals (instructors, students, etc.) about a particular subject or material relating to that subject. A stereotype is not necessarily based on fact and may prove to be false.

CHAPTER II

REVIEW OF LITERATURE

Overview

In this chapter, an overview of past and current literature that can be used to inform this study will be discussed. Throughout the literature, preconceptions are referenced by many different names such as, misconceptions, perceptions, and attitudes. However, in regards to the working definition provided for this research project, all the terms used in the literature are different but it is the belief of the researcher that they can all be used to inform the current research. Therefore, literature concerning misconceptions, perceptions, and attitudes will be included in this review of literature. The chapter will start by outlining the theoretical foundations that are used to ground this study. From there, factors affecting student success will be discussed, as it is surmised by the researcher that preconceptions may be one such factor responsible for affecting student success in a course. At this point, student's preconceptions will be addressed in terms of the existing literature relating to them. Much of the literature defines preconceptions in a different manner than used in this study. This is important to highlight to understand the difference between preconceptions and alternate terms that may be used concurrently (i.e. misconceptions). The findings of these studies may however inform research of student preconceptions. After this general introduction and

background, more specific research will be discussed relating to the field of chemistry. Factors specifically affecting chemistry student's success will be discussed as well as way to aid and the difficulties in causing students to achieving success in chemistry. These presented studies will display methods that helped students overcome the factors hindering them, as well as how instructors may overcome the challenges faced in achieving success. The methods displayed may lay the foundation for how to deal with student preconceptions allowing students to overcome their preconceptions and achieve success. Finally, once these factors have been outlined, research addressing general chemistry student's preconceptions and more specifically, organic preconceptions will be discussed. This research will display that student preconceptions about chemistry have the potential to affect student success in the course and should be taken into consideration when an instructor begins a course. This research provides a basis for the current research project.

Justification

Based on the researcher's prior experiences and anecdotal observations, it was thought that preconceptions were a common occurrence in many people. Through these observations while teaching, many students seem to have reservations about upcoming events that they may think will have one outcome when in reality the outcome turns out be the opposite of what was originally thought. These preconceptions that are shaped in their heads often appear to affect how they behave. Thus, it was theorized that student preconceptions play an important role in shaping their everyday lives. Despite preconceptions being so ubiquitous, there has been little research done on their effects,

especially in the field of education. In education it is thought that the presence of preconceptions can potentially affect the outcome of success in students in any discipline.[23] Though there are some research studies done in a myriad of fields, which will be discussed later in the chapter, there have been only a few studies done in the field of chemistry, particularly organic chemistry. In attempts to solve this problem, a thorough review of the literature was performed. Initially, to determine what research had been done in the past, SciFinder Scholar was used to do a preliminary search of the literature. The terms used for the search included but were not limited to, "student preconceptions," "student attitudes," "student beliefs," "student fears," and "factors affecting student success." After the use of this search engine, several other search engines, (ProQuest, ERIC, Google Scholar) were used to explore science and chemical education journals. Specific studies, which were of interest in student preconceptions, were studied and their effects were noted. In addition, studies relating to chemistry, why chemistry is difficult and the factors affecting student success in chemistry were also deemed relevant. Most of the cited literature came from journals such as *Journal of Chemical Education*, *International Journal of Science Education*, *Journal of Research and Science Teaching*, and *Science Education*. The obtained information was compiled and is presented here in an expanded review of the literature.

Theoretical Foundations

The main theoretical foundation for this research is based on constructivism. To begin, constructivism is the theory that people construct new knowledge and

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[23] Covington, M.V. and Beery, R. (1976). *The will to learn*. New York: Holt, Rinehart & Winston.

understanding based on what they already know and believe.[24,25,26] In line with the constructivist belief that new knowledge must be formed using prior knowledge, teachers and professors must be aware of misconceptions, alternative conceptions, incomplete comprehension, and preconceptions. Teachers must address these beliefs to achieve higher learning and understanding on behalf of the students. Failure to do so could result in student misaligned understanding and learning from what the teacher originally intended.[27] During the past two decades, constructivism has become more widespread in the teaching world and the resulting paradigm shift from objectivism to constructivism has caught the attention of many educational researchers. This idea has become the basis for many teaching programs as well as learning style approaches.[28] Before addressing where constructivism is going and its place in this research, it is important to know from where constructivism has come, its roots, and its origins.

The field of constructivism has many key theoreticians who have performed the most relevant research in the field. Jean Piaget, John Dewey, Immanuel Kant, Thomas Khun,[29] and Lev Vygotsky[4] are just some of the major constructivist theorists. These intellectuals have dissected the theory of constructivism into two main subcategories: cognitive and social constructivism. Jean Piaget set forth the first theory of cognitive

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[24] Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.
[25] Piaget, J. (1973a). *The child and reality: Problems of genetic pschology*. New York: Grossman.
[26] Piaget, J. (1973b). *The language and thought of the child*. London: Routledge and Kegan Paul.
[27] Bransford, J. (2003). *How people learn: Brain, mind, experience, and school*. National Academy Press.
[28] Tobin, K. (1993). *The practice of constructivism in science education*. Hillsdale, New Jersey: Lawrence Erlbaum Association.
[29] Phillips, D. (2007). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher*, *24*(7), 5-12.

constructivism. Piaget believed that each person has the cognitive ability to construct new material for themselves. In this theory there is little reliance on other people, and instead it is reliant only on oneself therefore, everyone must build their own knowledge for him/herself. The primary limitation to cognitive constructivism is the misunderstandings associated with terms in Piaget's research. Piaget used many terms whose meanings to him do not align with the common meanings to others, such as, truth and verification. This creates disequilibrium and has caused his work to be a source for many misunderstandings in the study of constructivism.[30]

Lev Vygotsky had ideas that better align the current research. Vygotsky's theory is that of social constructivism. The social constructivism belief is that a student interacts with other students (peers) and from this interaction and their prior knowledge/experiences, constructs the new information. Vygotsky's theory is centered around the zone of proximal development. He professes that when someone is in this zone, which is a small range of time, a knowledgeable person must share what they know with the novice. During this stage, or while in this zone, the novice is the most impressionable and vulnerable to learning new information.[31] This theoretical foundation of constructivism is therefore the basis for this research both cognitive and social. The idea that student construct knowledge independently (cognitive) as they proceed throughout their academic career shows that they incorporate new knowledge, or preconceptions they may have in their mental framework. It is important that students are constructing not only correct knowledge but knowledge that will allow them to

[30] von Glasersfeld, E. (1992). An interpretation of piaget's constructivism. *Jean Piaget: Critical Assessments*, *142*(3), 612-635.
[31] Vygotsky, L. (1978). Interaction between learning and development. *Mind in society: The development of higher psychological processes*, 79-91.

continue construction. Preconceptions may be formed and incorporated into a student's construction during social interactions however. Preconceptions heard from other students or teachers, may cause students construction (social) to become hindered, therefore, affecting their ability to successfully learn and understand new material. It is for these reasons that constructivism, both social and cognitive, is the theoretical framework for this research project.

Factors affecting success

Students experience all different levels of success when taking a course. Many students are very successful through the course receiving a grade of an "A" while others demonstrate their knowledge of the subject to be less and receive a "B" or "C". Then there are the few at the bottom end of the class who receive a mark of "D" or "F". This is a typical grading scale measuring the relative level of success in a course. Due to these varying levels there must be factors then contributing to the success of each student that may explain why the student's receive the grade they do. What factors influence student success?

A potential factor that may influence success may be motivation, either, intrinsic or extrinsic. Motivational factors are seen to affect student success in a course[32] and therefore, additional factors that may affect student motivation, such as preconceptions, are important to investigate. In research studies, it was discovered that the expectation of success appears to be related to an individual's behavioral choice. The expectation individuals have that they will successfully complete a task is a main factor in whether

[32] Atkinson, J. (1964). *An introduction to motivation*. Princeton, New Jersey: Van Nostrand.

they even attempt the task or not. This attempting of the task, is therefore based on student's personal beliefs about how they will perform in the task. If students feel that they will have little to no success, then they will be less likely to even attempt the task. Therefore, individuals tend to choose tasks that they expect to perform well in and achieve great success.[33,34,35,36] This does not completely answer the question of what contributes to student success. The question then becomes what causes students to believe they can successfully complete a task.

To tie into the research addressing student motivation, it is important to understand what variables affect student engagement. What makes students become engaged in material or subject matter? What factors allow students to be engaged for long periods of time rather than just short term? What factors influence intrinsic student motivation? Most of these questions cannot be addressed without first looking at student attendance in courses. For students to be motivated, they must first attend their classes and become engaged in those classes. In college courses, however, attendance is a large problem. With no one forcing the students to go to class, their attendance is based solely on how they feel about the class and whether they feel their attendance is necessary. Students, who feel their attendance in a class is necessary and feel that by attending a class they will get something out of it, are more likely to attend class and have a positive attitude towards the class. These attitudes were seen to be a direct result of students'

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[33] Edwards, W. (1954). The theory of decision making. *Psychological Bulletin*, *51*, 380-417.
[34] Feather, N.T. (1959). Subjective probability and decision under uncertainty. *Psychological Review*, *66*, 150-164.
[35] Kulka, A. (1978). *An attributional theory of choice* (Vol. 2). New York: Academic Press.
[36] Parson, J.E. (1983). *Expectancies, values, and academic behaviors*. San Francisco: W.H. Freeman.

previous experiences and preconceptions.[37] Students who are motivated are more likely to attend a class. Previous studies have determined that student attitudes correlate with attendance, and student attendance is correlated to success in the course.[38,39,40,41,42,43,44] Therefore, research has indicated that preconceptions must be addressed if for no other reason than to help form positive student attitudes contributing to student success.

Student's General Preconceptions

The answer to the previously stated question may lie in the preconceptions held by the students about a course or subject. What if students have a very positive view of a class, are they more likely to succeed and receive a higher grade than students who enter a class with a very negative view? Where do these preconceptions come from and what affects or causes them? In a study involving nursing students' preconceptions about an upcoming clinical experience, many factors were discovered that contributed to their preconceptions. These factors included insecurity, the risk involved, fear of the unknown, change, lack of self-confidence, and feelings of unpreparedness. From this

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[37] Gump, S.E. (2006). Guess who's (not) coming to class: Student attitudes as indicators of attendance. *Educational Studies*, *32*(1), 39-46.
[38] Van Blerdom, M.L. (1992). Class attendance in undergraduate courses. *The Journal of psychology*, *126*(5), 487-494.
[39] Wyatt, G. (1992). Skipping class: An analysis of absenteeism among first-year college students. *Teaching Sociology*, *20*(3), 201-207.
[40] Gunn, K. (1993). A correlation between attendance and grades in a first-year psychology class. *Canadian Psychology*, *34*, 201-201.
[41] Launius, M. (1997). College student attendance: Attitudes and academic performance. *College Student Journal 31*, 86-92.
[42] Friedman, P., et al. (2001). Why students do and do not attend classes: Myths and realities. *College Teaching*, *49*(4), 124-133.
[43] Clump, M., et al. (2003). To attend or not to attend: Is that a good question? *Journal of Instructional Psychology*, *30*(3), 220-225.
[44] Gump, S. (2005). The cost of cutting class: Attendance as a predictor of success. *College Teaching*, *53*(1), 21-26.

research, it was concluded that all of these preconceptions were formed and influenced by the students personal beliefs, values and past experiences.[45] This research provides a solid grounding for the current study. This research demonstrates on a constructivist level that students' preconceptions are formed from their previous experiences. Beyond that, these preconceptions impact their feelings and attitudes towards a new experience.[15]

There are other factors that may influence students' preconceptions towards new experiences, too. Most preconceptions about courses are typically formed prior to entering the classroom. However, some preconceptions have been identified that are a direct result of the first day of the course. In one study, it was found that the appearance, readability, and content of the course as outlined in the syllabus given out the first day of the course had an effect on student attitudes and perceptions of the course. These perceptions formed by reading through the syllabus shaped how the students approached the course.[46] This study, although done with minority groups, still demonstrates that preconceptions can affect students adversely. In addition to the syllabus and perhaps even more importantly is the tone set the first day of class. Students who formed negative perceptions of a course based on the tone set the first day showed decreased motivation, ultimately resulting in lower grades for those students. Conversely, students with positive perceptions of the first day showed higher levels of motivation and received

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[45] Leh, S.K. (2006). Baccalaureate student nurses' preconceptions of the community health clinical experience. [D.N.Sc. dissertation, Widener University School of Nursing, United States -- Pennsylvania].

[46] Anderson, K.J. and Smith, G. (2005). Students' preconceptions of professors: Benefits and barriers according to ethnicity and gender. *Hispanic Journal of Behavioral Sciences*, *27*(2), 184-201.

higher grades in the course. These perceptions were formed based on the gender, ethnicity, and overall warmth of the professor on the first day of the course.[47]

There is evidence to take preconceptions seriously and address them when teaching a course. Preconceptions have been shown to influence the success of students in courses, however, what specific effect on the students' minds do these preconceptions cause? One possible explanation is that these preconceptions influence the students' ability to move forward and learn new concepts or theories. In one study, it was demonstrated that teachers could captivate and challenge their students' subsequent thinking by posing problems yielding solutions running counter to students' perceptions. By posing a problem to the students that produced a result that was the opposite of their perception, it allowed the students to realize their perceptions were wrong or inaccurate and allowed them to begin the process of correcting them.[48] In this case, students' perceptions were more accurately labeled misconceptions. Misconceptions are beliefs a student holds that are not aligned with the accepted ideas and are often inaccurate or false. Misconceptions about a topic can cause even more problems for the student, and when the preconceptions are also the source of the misconceptions the task of fixing this problem becomes very difficult.

Another similar and more recent study uses the example of the theory of evolution. Students often have many preconceived notions about evolution. These notions are often a reflection of uncontrollable things such as religion and culture.

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[47] Wilson, J.H. and Wilson, S.B. (2007). Methods and techniques: The first day of class affects student motivation: An experimental study. *Teaching of Psychology*, *34*(4), 226-230.

[48] Richburg, R.W., et al. (1994). Jump-starting thinking: Challenging student preconceptions. *The Social Studies*, *85*(2), 66.

However, these preconceptions, despite their sources, influence a student's critical thinking about that particular topic. Students do not have to agree with a topic or concept, but they should be able to learn the basics, understand it, and be able to explain it. In one study, to overcome this preconception barrier, inquiry-based learning was implemented. In this particular case, the student's preconceptions led to further misconceptions. The inquiry-based approach challenged the student's preconceptions using evidence, which allowed them to synthesize new ideas using logical thinking.[49] This research is relevant on several levels. First, preconceptions must be addressed or they can turn into misconceptions, which can cause a larger problem later. Second, preconceptions may come from uncontrollable sources such as religion or culture, but the resulting preconceptions can be deconstructed to improve student learning. Lastly, to allow students to think and move beyond their preconceptions, inquiry-based learning is a worthwhile approach because it allows students to identify their preconceptions on their own and work towards fixing them.

Once these preconceptions are identified, they need to be addressed by the instructor to facilitate learning. In the previous studies, to deal with misconceptions instructors created a state of disequilibrium (students realize that their ideas do not make sense and have to reformulate them before they move). Though dealing with misconceptions, this research may have implications, and similar methods may prove useful when dealing with student's preconceptions. Most researchers realize the importance of addressing these preconceptions to promote conceptual change. In a study

[49] Robbins, J.R. and Roy, P. (2007). The natural selection: Identifying & correcting non-science student preconceptions through an inquiry-based, critical approach to evolution. *The American Biology Teacher*, *69*(8), 460-466.

on how to address these preconceptions, teachers developed instructions and lessons based on students' preconceptions. It was thought that it was essential for teachers to have an adequate comprehension of an individual student's past experiences, current understanding, and interest in the topics presented to understand their preconceptions to properly address the preconceptions.[50] The research, however, identified that the primary factors contributing to the student's preconceptions were based on previous experiences and cultural background. These preconceptions, in turn, had an effect on the student's learning. Beyond this, the specific source of the preconceptions was not identified but was assumed to be prior schooling.

This idea of causing conceptual change is an important one. One outcome of identifying any preconception is to cause conceptual change. The only way to promote this conceptual change is for students to be engaged in the material they are learning. In order to engage the students in the subject, student's preconceptions must be addressed. Studies have shown that students who are engaged in the subject have more intrinsic motivation to learn and understand the material. A student cannot be 100% engaged if there are preconceptions hindering them.[51] To engage students and increase their intrinsic motivation, any ideas and beliefs, or preconceptions that could potentially be hindering them, must be addressed.

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[50] Morrison, J. and Lederman, N. (2003). Science teachers' diagnosis and understanding of students' preconceptions. *Science Education*, *87*(6), 849-867.
[51] Lucas, U. and Meyer, J.H.F. (2004). Supporting student awareness: Understanding student preconceptions of their subject matter within introductory courses. *Innovations in Education and Teaching International*, *41*(4), 459 - 471.

Factors Affecting Student Success in Chemistry

Perhaps, Carter and Brickhouse did the most relevant research done on the topic of student success in chemistry, and the factors that influence it.[52] In their study, they addressed a crucial question that tends to surface more often than not, "What makes chemistry so hard?" This was an important study because it focused on students' perceptions of chemistry. The participants of the study were students currently enrolled in a General Chemistry II course at the Ohio State University. The findings indicated that students' perceptions of chemistry are important regarding what they actually will learn from the course, and though no generalizations were made, it is suggested that institutions survey their students to find out what specific perceptions exist among them.

Further research has studied predictors of student performance in college chemistry. The predictors were associated with two different factors: student demographics (background, culture, religion, etc.) and student prior experiences in high school. The former factor is not a variable that can be controlled. However, due to the latter factor, it was determined that there is a high level of correlation between student success in high school and the success of those same students in introductory college courses.[53]

Another study focused on students' preconceptions of science classes, and in particular, dealt with student perceptions of chemistry.[54] Results indicated that

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[52] Carter, C.S. and Brickhouse, N.W. (1989). What makes chemistry difficult? *Journal of Chemical Education*, *66*(3), 223-225.
[53] Tai, R., et al. (2005). Factors influencing success in introductory college chemistry. *Journal of Research and Science Teaching*, *42*(9), 987-1012.
[54] Bouma, J. and Brandt, L. (1990). Words as tools: A simple method for the teacher to obtain information on pupils' preconceptions *Journal of Chemical Education*, *67*(1), 24-25.

preconceptions often surround specific words or terms that are more complex in nature. The researchers worked in reverse and first had students learn complex words or terms out of the context, and then, when the students were more comfortable, put the word or term back into the appropriate context. The researchers found that it was important, if students were to learn, for the teacher to address each preconception by simplifying it and explaining it. The researchers also believed that both students and teachers should be made more word conscious and hopefully, through this, students' preconceptions will not pose problems, such as affecting their ability to understand and learn, in the latter part of the course.

Another study dealing with students' difficulties in learning chemistry focused on the students' pre-instructional conceptions (i.e. preconceptions).[55] The study was centered around general science and chemistry concepts. It was determined, that for more effective learning in general science and chemistry to occur, teachers need to take into consideration prior knowledge of students so that they can address that knowledge during teaching. Taking the student's prior knowledge into consideration however, may result in a broader range of issues than just the chemistry concepts being covered; however, the students will become better engaged in their learning of chemistry.

Another relevant study dealt with factors affecting student success in chemistry and used a unique approach. Students were asked a series of questions with definitive answers surrounding organic chemistry. From these data, the ideal organic chemistry student was determined by comparing the data given by students to the success measured by the grade of the students in the course. It was seen that students tend to do better in

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[55] Treagust, et al. (2000). Sources of students' difficulties in learning chemistry. *Educación Química*, *11*(2), 228-235.

organic chemistry, ironically, who have taken fewer previous math and chemistry courses at either the high school or college level. When students have taken many previous courses, they typically perform the same as they have in the past and do not adapt their cognitive skills for the new subject. Many of the cognitive skills used in general chemistry and math are not applicable in the realm of organic chemistry and, therefore, did not benefit the students in any way. Also, and more importantly, the students who received the highest grades in organic chemistry had better perceived notions surrounding organic chemistry and a more positive attitude towards the class.[56] This supports, that student attitudes and preconceptions about a course, specifically organic chemistry, have a strong influence on and seem to be highly correlated with student success in that particular course.

Methods of Achieving Chemistry Success

Like with any subject, there are many proposed approaches and methods to facilitate student success. For every subject, including chemistry, there are traditional as well as contemporary methods of presenting material to the students. Many studies have looked these various teaching methods to determine what effect if any they have on student success. One study investigated teacher perceptions and their corresponding approach to teaching the course. It was determined that the traditional instructional processes were seen to have reached their limits. The researchers concluded that a refined method for the approach of teaching and learning chemistry alike must be sought

[56] Steiner, R. and Sullivan, J. (1984). Variables correlating with student success in organic chemistry *Journal of Chemical Education*, *61*(12), 1072-1074.

and implemented.[57] The traditional method for teaching chemistry, as well as the majority of the sciences, is a lecture format. These large lecture courses are highly efficient for presenting large numbers of students, large amounts of information. The downfall of this method of teaching is that large lectures often do not promote a deep understanding of the material. In research studies done on the effectiveness of large lectures courses verses smaller lab/discussion type courses, a significant difference in student performance was observed between the two, with the lab/discussion type students outperforming the traditional lecture ones.[58] The crux of this research is that due to recent paradigm shifts, the traditional lecture is no longer the most effective method to present material, especially chemistry material. So the question then becomes, what are some of the effective ways professors should use when teaching a chemistry course? There is not just one correct answer to this ever-important question. Research has been done on many different methods in attempts of solving this problem. Probably the most common approach to this conundrum is the implementation of cooperative, or peer learning in the classroom. One such study looked at using a peer-led learning approach to problem solving. This approach involved a structured setting for guiding the student's learning in organic chemistry. The peer led learning approach put the students in small study groups and gave them problems on which they worked together to solve. The results of this study showed an increase in the student's overall performance as well as a significant increase in the positive attitudes of the students towards the course and the

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[57] Beasley, W. (1980). High school organic chemistry studies: Problems and prospects. *Journal of Chemical Education*, *57*(11), 807-809.
[58] Christianson, R.G. and Fisher, K.M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms. *International Journal of Science Education*, *21*(6), 687 - 698.

material.[59] By increasing student performance as well as student attitudes by the teaching method used in the course, student's attitudes and ideas can be influenced and affected after they are physically in the class. This shines some light on how to go about changing students' attitudes for the better despite their preconceptions, as well as a more effective method for teaching chemistry in the modern day classroom.

Another similar study compared two groups of general chemistry students. The control group consisted of students attending a traditional lecture course, while the treatment group was a cooperative learning classroom environment for the students. This study hoped to demonstrate that the students in the cooperative learning classrooms showed higher achievement than the students in the traditional lecture classrooms. However, this study, unlike the previous one, did not produce the intended results. Although there was no significant difference between the treatment and the control in this instance, it was hypothesized that the best method for teaching would be a combination of the two instead of one or the other.[60] Therefore, the answer to the question of what is the best method to teach chemistry may not be straightforward. The traditional lecture or cooperative/peer learning may not be answer when used exclusively but instead, the lecture and cooperative/peer learning may be complimentary when used together to promote increased student learning.

Teaching either via lecture or group learning may not be the entire answer to the problem of improving student success in chemistry courses. Other investigations have

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[59] Wamser, C.C. (2006). Peer-led team learning in organic chemistry: Effects on student performance, success, and persistence in the course. *Journal of Chemical Education*, *83*(10), 1562-1566.

[60] Banerjee, A. and Vidyapati, T. (1997). Effect of lecture and cooperative learning strategies on achievement in chemistry in undergraduate classes. *International Journal of Science Education*, *19*(8), 903-910.

yielded a myriad of other techniques that have proven successful. The SOLO (structure of observed learning outcomes) taxonomy instrument was adapted and used to identify points of difficulty and difficult concepts in organic chemistry. This instrument was used to reveal student difficulties with the material and was used both as a formative and summative assessment tool. By doing this assessment, it becomes possible to design interventions to address these difficult concepts or areas in organic chemistry. It was demonstrated that students' success hinged on understanding the material and understanding the goals the professor set forth. Those students who were more motivated to learn and understand the material (intrinsic) outperformed students were motivated only by their grade (extrinsic).[61] Therefore it becomes important to help students become more intrinsically motivated in addition to their extrinsic motivation, or their goal of a specific letter grade. By showing that student's motivation is important to their understanding, and therefore success in a course it is important to address factors influencing their motivation. With preconceptions being previous shown to affect student understanding, maybe they are a factor affecting student motivation?

Another issue dealing with organic chemistry is that typically the textbook used covers a lot of material in little depth. Students get more of a broad overview of organic chemistry, which lacks in the deeper understand of the subject. This limits how much they can therefore learn in the course. To address this problem, new textbooks have been written that condense what is typically in an organic chemistry textbook. This new format of textbook portrays the depth of the topics and not the breadth. Textbooks like

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[61] Hodges, L.C. and Harvey, L.C. (2003). Evaluation of student learning in organic chemistry using the solo taxonomy. *Journal of Chemical Education*, *80*(7), 785-787.

this are written to help prepare the students for learning organic chemistry.[62] Again it is seen that students with a positive attitude tend to outperform students with negative attitudes. Textbooks are just another instrument used in creating positive student attitudes.

In addition to the textbook helping the students, the structure of the course, organization, and teacher enthusiasm is also very important to student learning. In a recent study, it was determined that structure of the organic chemistry course is important and must be organized very linearly and presented clearly. In conjunction with this, the pedagogical content knowledge (PCK), or teacher's personal theories on how to teach specific topics as well as how students learn these concepts[63], drives success in the course. The teacher's enthusiasm and PCK influence not only the student's attitudes but also helps to facilitate the student's ability to convert the content into material they can understand, fostering student success.[64]

Another important study done relating to factors that affect student success in chemistry was one attempting to identify the ideal college chemistry student. Many variables were identified and studied by asking students directed questions and then correlating their answers with their grades. From the resulting correlations, it was determined that the most important factor in predicting student success in chemistry is a student's self-perceived ability. This self-perceived ability was dependent on the number

[62] Karthy, J. (2006). The nuts and bolts of organic chemistry: A student's guide to success. *Journal of Chemical Education*, *83*(11), 1603.
[63] Henze, I., et al. (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education*, *30*(10), 1321-1342.
[64] Green, G. and Rollnick, M. (2006). The role of structure of the discipline in improving student understanding: The case of organic chemistry. *Journal of Chemical Education*, *83*(9), 1376-1381.

of previous chemistry courses the student had taken as well as their interpretation of those courses, or what they learned from it. A student's self-perceived ability was seen to be a determining factor in the number of subsequent chemistry courses the student takes.[65] This is an important construct to the current research. Not only does it show that students have perceptions that they carry with them that are formed from previous courses but also that these perceptions can affect their success in future courses.

Another approach to facilitating student learning and improving the quality of chemistry teaching is for teachers to collaborate among themselves. A study done with chemistry teachers as a way to address the students' difficulties, focused on the lecturers' perceptions. All teachers are going to perceive things differently based on their current students' progress and how things are progressing in their respective classrooms. Though many teachers experience similarities in their classes, overall the experience is unique to the teacher. As a result not all teachers will have the experience and tools required to address problems they see in their classrooms. Research has shown a simple solution to this problem. Teachers should collaborate and talk openly about the specific perceived difficulties in their classroom. While communicating about these difficulties, teachers will be exposed to different views and many different problems, as well as the situations used by each teacher to address the problem. By openly discussing these problems and hearing different points of view, teachers will be able to integrate their thoughts and those of their colleagues to help them better address individual student problems.[66] This "support group" system allows for all teachers to freely discuss and collect ideas on how

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[65] Deboer, G.E. (1987). Predicting continued participation in college chemistry for men and women. *Journal of Research and Science Teaching*, *24*(6), 527-538.
[66] Kirkwood, V. and Symington, D. (1996). Lecturer perceptions of student difficulties in a first-year chemistry course. *Journal of Chemical Education*, *73*(4), 339-343.

to handle specific difficulties from a panel of other experts. The results will be more likelihood that teachers will be able to address their specific students' difficulties, contributing to higher success for the students.

Another method to overcome the problems in student learning in science and chemistry involves examining the methods teachers use for presenting the material. The primary place where this is relevant is in the order of topics set forth in the textbook used. If the order proposed in the text follows a logical one, then students will have an easier time comprehending the material and the overall success will also increase. If the textbook presents the material out of order or illogical to the teacher and the students, then it will be more difficult for students to achieve a deep understanding of the material. In addition to the order, the emphasis on certain material also plays a role. The cure for this problem is to use texts that have innovative material, student-centered activities, and use context to convey theories. This idea of contextual chemistry is becoming more popular to convey the same traditional concepts in a contemporary way thus increasing student understanding and success. A model for this idea is to visualize a spider web. At the center of the web is the real world context. Then radiating out from the center but still interconnected are things such as interdisciplinary connections, integrated laboratory exercises, group work and discussion, critical thinking exercises, etc. This is an example of context-based teaching that covers all the essential concepts but parallels student's learning patterns.[67]

Another approach to increasing student learning is to use student-generated questions to steer the course instead of using the textbooks to guide student learning and

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[67] Schwartz, A. (2006). Contextualized chemistry education: The american experience. *International Journal of Science Education*, *28*(9), 977-998.

class discussions. Using student questions is not only a way to run a class but also a way to measure student-learning interactions. In a research study, the number of student-generated questions measured the success of the classroom. The class used these student questions to prompt further discussion, and the more questions the students had, the greater their learning and interactions. This method was used to improve the quality of classroom interactions as well as the overall learning by the students. From this study, there was a positive correlation between the number of questions asked during the class and the resulting success of the classroom (indicated by student learning).[68] The researchers achieved higher student success by working on a curriculum that was more student-centered and allowed more interaction, participation, and increased student engagement. Student grades were then assessed. The methods implemented by teachers have shown to improve success in chemistry; however, there are still other factors, namely preconceptions, that can affect student success in chemistry that have yet to be thoroughly researched and addressed.

Difficulties Learning Science/Chemistry

Learning chemistry as a student poses many difficulties to those who undertake this task. There are many factors that make chemistry not only a difficult subject, but one that is difficult to understand. Students may be required to do a lot of work on their own

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[68] Teixeira-Dias, J., et al. (2005). Teaching for quality learning in chemistry. *International Journal of Science Education*, *27*(9), 1123-1137.

which can results in the formation of ideas concerning the course as preconceptions or misconceptions.

There may be potential to deal with preconceptions similarly to misconceptions (which are better documented and researched) the following literature is important to the scope of this study. The primary challenge in teaching chemistry is dealing with the misconceptions that students bring with them into a class. The constructivist theory on teaching relies on the fact that teachers are there merely to facilitate learning of the student. Constructivists believe that curriculum for a course is not a static body of knowledge. However, the curriculum from which teaching should occur is instead a group of activities, representing a dynamic body of knowledge. From this dynamic nature, students learn either through acquisition of the knowledge or by constructing new knowledge around their previous beliefs.[69] It is up to the student to take their previous experiences and prior knowledge when learning and amend it into new usable and accurate information. The process of teaching is thought to provoke conceptual change in the learner. Since new knowledge requires students to formulate it on their own using what they already know, misconceptions are often formed. These misconceptions play a large role in a student's future learning, and cause students to become resistant to conceptual changes needed for understanding.[70]

There are many ways to deal with misconceptions. The major focus of most current research deals with addressing misconceptions and techniques in ways that deconstruct these inaccurate ideas. The most common way to address misconceptions in

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[69] Driver, R. and Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science Education*, *13*, 105-122.
[70] Gil-Perez, D. and Carrascosa, J. (1990). What to do about science "misconceptions" *Science Education*, *74*(5), 531-540.

a classroom has been to induce a state of disequilibrium. The state of disequilibrium occurs when students are presented material or evidence that counters the misconception they hold. This induces a conceptual revolution in the students mind. One research study hypothesized that this idea of disequilibrium is essential in addressing students' misconceptions. They determined that students with misconceptions had difficulty with development of reasoning. It was revealed that students with misconceptions embedded within their knowledge of a topic, were not able to correctly learn a related topic. This caused the students to have a more difficult time succeeding in their chemistry course.[71] Therefore, inducing a state of disequilibrium may be one way to deal with student's preconceptions as well. For example, students approaching a course with preconceptions concerning the difficulty, might be given examples of where they course may be easier to understand.

Knowing what misconceptions are and how to "fix" them is one thing, but is it known that misconceptions even exist? Diagnosing misconceptions is another important part of learning chemistry. Without properly diagnosing and addressing misconceptions, it has been shown that conceptual change and, therefore, learning cannot take place. Diagnosing misconceptions is in reality quite easy. In one such study, a multiple-choice test was given to students. The distracters in the answers were all common misconceptions thought to be held by the students as well as some alternate conceptions (similar to misconceptions but not necessarily wrong in nature, just lacking in understanding or evidentiary support). Analysis of the test determined which

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[71] Hamza, K. and Wickman, P. (2007). Describing and analyzing learning in action: An empirical study of the importance of misconceptions in learning science. *Science Education*, *92*(1), 141-164.

misconceptions were actually most common to the students. Once these misconceptions were uncovered, it became important to look for the framework from which students get this information. The causes of these misconceptions are very hard to accurately pinpoint but by building a framework of student's sources of information and the misconceptions they have formed, a gap in knowledge will be seen. This gap is important to any teacher in any discipline including chemistry. If a professor is aware that his or her students have constructed their knowledge through a specific framework and they have certain misconceptions, then the professor will eventually be able to predict what alternate conceptions, or misconceptions, might be held by the students. Knowing initially what alternate or misconceptions exist in a classroom will allow the professor to address the most common conceptions while teaching.[72] By addressing these misconceptions and not remaining unwilling to acknowledge them with regard to their existence, teachers have a better chance of creating the state of disequilibrium allowing students to change their beliefs and develop conceptually. Students who are continually experiencing conceptual change, learn and have the most success in their chemistry course.

The next hurdle faced when learning science, besides misconceptions, are the student perceptions about certain factors. As defined by the researcher, students' perceptions are ideas, attitudes, and beliefs that the students form while taking a class. One such study dealing with student perceptions showed that students made decisions about their own learning, and these decisions were seen to be influenced by task related factors. Students approached the tasks differently depending on whether or not the students perceived the tasks to require a high cognitive demand and/or a high level of

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[72] Schmidt, H. (1997). Students' misconceptions — looking for a pattern. *Science Education*, *81*, 123-135.

motivation. Their willingness not only to do the task but to even take on the task was determined to be highly affected by their perception of personal challenge. Tasks thought to show high personal challenge to the students, were avoided and done less frequently than the tasks that were of little challenge. However, from this study some correlations were shown including the student's progress in years through schooling, the perceived challenge in learning science increases. In addition, the negative perceptions of the task at hand seem to increase, as students progress by year. Students in the latter years view the tasks as more work and therefore as requiring more conceptual thought, while students in the younger years were more satisfied with what they had to do because their tasks required little thought. Despite the increase in negative attitudes towards the task as the students progress in school, there was still hope. As the students progress in school, teachers can have a positive impact on students' attitudes, and, therefore, students are more likely to take on the task because the perceived challenge is no longer there. This finding is the most important aspect of this research.[73] The idea that teachers can take mainly negative student-formed attitudes and transform them into positive attitudes allowing them to willingly learn new material, applies to the current research at hand.

Another difficulty in learning science and chemistry concepts is in student's attitudes. It was thought that student's attitudes determine behavioral intentions, and the stronger a person's intention, the more they may put forth effort therefore increasing the likelihood they perform that behavior.[74] This shows a direct relationship between

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[73] Baird, J. and Penna, C. (1997). Perceptions of challenge in science learning. *International Journal of Science Education*, *19*(10), 1195-1209.
[74] Ajzen, I. and Madden, T. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of experimental social psychology*, *22*(5), 453-474.

student's attitudes and their behaviors towards performance. Students with more positive attitudes would have a different behavior towards a course and therefore, would put forth more effort resulting in a higher chance for success. In addition, student's expectations of a course, which are influenced by their attitudes, are significantly correlated to their learning outcomes.[75] Again, student attitudes are correlated to their success in a course and therefore are worth consideration. These attitudes about a course could be due to student's preconceptions. Further correlations show student's academic expectancies, a result of student motivation, were a significant predictor of achievement.[76] Lastly, in addition to student's attitudes student perceptions are another factor possibly related to success in a course. Student's perceptions were related to their motivation.[77] This research displays implications for student learning. The structure of the classroom is important for students to modify their experiences, which may facilitate student's achievement of goals and therefore success in a course. These research projects demonstrate that student attitudes are correlated with their success in a course. With attitudes being correlated, preconceptions may also have an affect on student success as part of the definition includes student's attitudes.

Difficulties Teaching Science/Chemistry

[75] Hume, D., et al. (2006). Chemistry is in the news: Assessment of student attitudes toward authentic news media-based learning activities. *Journal of Chemical Education*, *83*(4), 662.
[76] House, J. (1994). Student motivation and achievement in college chemistry. *International Journal of Instructional Media*, *21*(1), 1-11.
[77] Ames, C. and Archer, J. (1988). Achievement goals in the classroom: Students. *Journal of Educational Psychology*, *80*(3), 260-267.

Chemistry content, and even science content in general, presents teachers with many difficulties when deciding how to teach a course. Chemistry content is conceptually difficult to understand, and, therefore, results in a myriad of obstacles a professor must face to achieve success in his or her classroom. Preconceptions may be one such obstacle that instructors have to deal with in attempts of increasing their student's success rate.

Difficulties in teaching science or chemistry is a widespread issue in education: the idea of memorizing as opposed to understanding. Students across many disciplines tend to approach a course using memorization. They will memorize the necessary material in hopes of obtaining the desired grade and getting through the course. Memorization does require effort, but there is little actual learning that takes place. There have been studies focusing on methods to help students to actually learn and understand the material, instead of just merely memorizing it. One attempted study to address this problem, was done using different types of questions. Students were asked to answer not only verbal questions but also pictorial questions. It was thought that students who approach the questions from a strictly memorizing stance would regurgitate what they had memorized without thinking, in a verbal question. Verbal type questions do not necessarily display understanding. Pictorial type questions were then used to determine if students had to demonstrate more understanding to correctly answer the question by drawing a picture. Results showed no significant effect on learning when comparing the two types of questions. The authors, however, seem to indicate that there may be some

value to using the two types of questions together.[78] Therefore, using pictorial and verbal questions may force students to learn and understand the material on some level rather than just memorizing it to get through the course. Student's approach of memorizing is a problematic one and will hinder their success in the course. Helping students understand the material is a difficulty that many teachers experience when teaching, especially in the sciences and chemistry.

The idea of challenging material and student's reliance on memorization, instead of understanding, are both problems plaguing teachers. Another problem is the lack of readiness to understand and correctly use images presented to students. Many recent teaching methods are incorporating visualizations into the teaching process. Students are presented with visuals and are then asked to incorporate the visualizations into their understanding of the subject. The new paradigm is to not rely on the text to explain everything about a subject or topic, especially chemistry, but instead to integrate the text with pictures and images to enhance student learning and understanding. This Piagetian theory of visual learning starts long before students ever step into a classroom. From a young age students begin learning concepts through visualization and integrating what they have seen into their memory bank allowing them to form new concepts about the world around them. Science is viewed as merely a training tool to understand those visualizations that have been accumulated since childhood. One of the problems in teaching chemistry, however, is the student's inability to correctly use visualizations of molecules and spatial arrangement. Just seeing a visualization or 3-D representation does not ensure that any learning has occurred. Besides just observing these images, students

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[78] Halakova, Z. and Proksa, M. (2007). Two kinds of conceptual problems in chemistry teaching. *Journal of Chemical Education*, *84*(1), 172-174.

need to be ready and willing to correctly understand them, and incorporate the images to form new conceptual knowledge. If students are not "ready" to correctly use and thoroughly understand the images then the conceptual knowledge gained from these visualizations will be marginal.[79] Therefore, the student's inability to understand visualizations and molecular representation, and correctly use them, is another problem faced by teachers when teaching chemistry. This problem, along with the perceived challenge of a task, and the student's tendencies to memorize material rather than to deeply understand it, could all be evidence of insufficient intrinsic motivation of the students. This lack of motivation has become a widespread problem and will continue to increase if teachers do not actively work to develop methods to address it.

The previous sections have focused on some of the most difficult challenges when teaching a general science or chemistry course. This evidence has been presented from the view of the students and what they have highlighted in the research studies to be the cause of their unsuccessfulness in science or chemistry. However, in education there is always two sides, and the teacher's perspective is also just as valuable. Teachers may purposefully or inadvertently cause preconceptions. As teachers students may listen to the information shared with them and may view it differently than information they have heard from students. Therefore, the influence of teachers is worth consideration when discussing student preconceptions.

There are many factors that teachers contribute to the lack or limitation of learning in a classroom. The first factor to be discussed presents a hurdle in the science community. One study looked at science teachers' ideology. Science teachers progress

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[79] Mathewson, J. (2005). The visual core of science: Definition and applications to education. *International Journal of Science Education*, *27*(5), 529-548.

through the same process as the students. First, they are students themselves learning how to be teachers. During this phase in their education they are influenced by the ideology of their teacher(s). This is a crucial time in their development into teachers as they do not have a rigid set of beliefs thus they can be influenced. Once teachers finish taking classes in which they are learning how to be a teacher, they then venture out into the real world and complete their student teaching, again under a specific ideology. Basically, the ideology they were taught under becomes the ideology they adapt. The ideology runs so deep that trying to reform even a small part of it becomes very difficult and many teachers therefore are highly unlikely to embrace the change. Teachers therefore, are really just promoting the scientific community. This becomes a problem in the classroom because teachers will accept the curriculum and the delivery of the curriculum based on their ideology.[80] This factor of acceptance under certain ideologies can be problematic for student learning in a classroom, therefore hindering student success. Despite what this research concludes, if changes need to be made to the curriculum or the delivery method, teachers must be open and receptive to that change and incorporate it into their ideology instead of rejecting because it does not align with their current beliefs.

One problem pointed out by the teachers is the material covered in chemistry courses. General chemistry, as well as organic chemistry, covers a broad range of material and therefore has the breadth but has very little depth to the subject. In a study done with chemistry teachers, the teachers noted that too much material and theory is covered in one course. The teachers believed the saying “less is more”, and solutions to

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[80] Cross, R. (1997). Ideology and science teaching: Teachers' discourse. *International Journal of Science Education*, *19*(5), 607-616.

the problem of breadth but not depth were debated. It was found that the flaws with the typical breadth way of teaching is that there is not enough experimental opportunities for the students, there are very few methods for them to practice, and the amount of new and relevant chemistry is very small or non-existent. Despite this being a potential solution to the problem, it was determined in this research that there is no universal solution. It was concluded that it is the responsibility of each teacher individually to address the problem and create his or her own unique solution. Learning via the breadth method of teaching, students often do not develop a deep understanding of the material and are prime candidates for memorizing instead of truly learning.[81] This breadth method is more of a hindrance on learning than it is a promoter. Teaching certain topics in depth, instead, would help students to develop a deeper understanding of the material and close the gap between what students should be learning and what they actually are learning.

General Chemistry Preconceptions

Preconceptions in chemistry have not been studied in depth; there are only a few examples of research done on chemistry preconceptions. Student perceptions were found to come from a limited number of sources. In one instance, students from Europe, formed preconceptions about chemistry from reading case studies about industrial chemistry. This mixed methods research, demonstrated that the preconceptions formed from reading industrial case studies affected students ideas of chemistry and their future

[81] Ellis, J.W. (1994). How are we going to teach organic if the task force has its way? Some observations of an organic professor *Journal of Chemical Education*, *71*(5), 399-403.

in chemistry[82] Reading about a topic is one potential source of preconceptions that will be investigated in the current research. Other research on chemistry preconceptions deals with identifying the existence of the preconceptions. To identify preconceptions, one research group used an instrument in which high school students identified their views on science and technology. Once identified the preconceptions were used to develop the lesson plan. This instrument was useful as it allowed teachers to access directly the student's views on topics and epistemology of science and then incorporate that knowledge into their proposed plan of teaching.[83] Once the preconceptions have been identified, it is important to act on the knowledge of the preconceptions. One study determined that teachers are aware that preconceptions held by the student could adversely affect the ability to learn new chemistry concepts. Through qualitative methods the teachers identified and described student preconceptions and began attempts to induce conceptual change. [84] Once the preconceptions are identified, modifications can be made to the curriculum or teaching methods. Research concerning these potential modifications has yet to be done, however.

Organic Preconceptions

There has been very little research done regarding learning difficulties with organic chemistry, let alone preconceptions about organic chemistry. One research study dealing with organic chemistry and a student's success investigated how students

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[82] Kesner, M., et al. (1997). Student and teacher perceptions of industrial chemistry case studies. *International Journal of Science Education*, *19*(6), 725-738.
[83] Ryan, A.G. and Aikenhead, G.S. (1992). Students' preconceptions about the epistemology of science *Science Education*, *76*(6), 559-580.
[84] Hashweh, M. (1998). Descriptive studies of students' conceptions in science. *Journal of Research and Science Teaching*, *25*(2), 121-134.

construct knowledge. Student's construction of new knowledge is greatly influenced by their previous knowledge. The students' approach to organic chemistry is, therefore, governed by their previous experience and how they perceive organic chemistry. As the semester progresses, students' knowledge will increase, however, the question becomes will their conceptual knowledge increase and strengthen? If the students' knowledge does not increase and remains limited, then the students become more susceptible to constructing misconceptions.[85] This is important to acknowledge since preconceptions have a large impact in not only the success of the students, but also their acquisition and use of knowledge in organic chemistry. Beyond that, students build a mental framework to support the new knowledge they will acquire during the organic chemistry course. This mental framework is shown to be in place very early in the course.[86] Therefore, if students' mental frameworks are set early in the course, they approach the course with a near finished mental model. Preconceptions are thought to be the cause of this rigid and early-formed framework, and are of interest for further studies. To the extent of this literature review, specific research dealing strictly with organic chemistry preconceptions, their effects, and potential solutions to this problem has yet to be uncovered.

Further research has been done investigating students' preconceptions however, does not directly address the purpose of this study (identifying preconceptions). For

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[85] Taagerpera, M. and Noori, S. (2000). Mapping students' thinking patterns in learning organic chemistry by the use of knowledge space theory. *Journal of Chemical Education*, *77*(9), 1224-1229.

[86] Pungente, M.D. and Badger, R.A. (2003). Teaching introductory organic chemistry: 'blooming' beyond a simple taxonomy *Journal of Chemical Education*, *80*(7), 779-784.

example, Cooper and Kerns[87] focused on changing students' attitudes and perceptions in an organic laboratory. The study strictly examined students' perceptions of the laboratory setting. Although the field is still organic chemistry, a laboratory experience is different than a lecture experience. In an organic laboratory, instruction is focused mainly on laboratory techniques and not the theory behind the actual lab; whereas, in a lecture setting, theory is the focus and not the techniques. Beyond these points, most organic chemistry educational research involves either addressing techniques employable in a lecture setting to aid student learning[88,89] or identifying misconceptions in college chemistry courses.[90]

The lack of sufficient research in the area of chemistry preconceptions, and more specifically, organic chemistry preconceptions, displays a gap in knowledge. Since research has shown preconceptions to be one factor potentially affecting the success of students in college courses, they should be addressed and taken seriously. Research should be done to pinpoint the exact preconceptions existing as well as the sources of these preconceptions. Once the different preconceptions have been identified, correlations can be determined to see if the specific identified preconceptions affect the success of students in organic chemistry. If the correlation is positive, meaning

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[87] Cooper, M.M. and Kerns, T.S. (2006). Changing the laboratory: Effects of a laboratory course on students' attitudes and perceptions. *Journal of Chemical Education*, *83*(9), 1356-1361.
[88] Tien, L.T., et al. (2002). Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. *Journal of Research in Science Teaching*, *39*(7), 606-632.
[89] Browne, L.M. and Blackburn, E.V. (1999). Teaching introductory organic chemistry: A problem-solving and collaborative-learning approach. *Journal of Chemical Education*, *76*(8), 1104-1107.
[90] Zoller, U. (1990). Students' misunderstandings and misconceptions in college freshman chemistry (general and organic). *Journal of Research in Science Teaching*, *27*(10), 1053-1065.

preconceptions do affect student success in organic chemistry, then new methods and approaches can be constructed to help ease students fears and apprehensions, and help them modify their preconceptions. By successfully identifying preconceptions, allowing teachers to address and deconstruct any negative preconceptions, student success in organic chemistry is expected to increase.

CHAPTER III

METHODOLOGY

Overview

A mixed methods design was used to investigate what preconceptions students had about organic chemistry and the source of these preconceptions. Mixed methods research incorporates both qualitative and quantitative research techniques.[91] Mixed methods were employed to broaden understanding by incorporating quantitative research and using that approach to better understand and explain the results from a qualitative approach.[92] In this study, the qualitative approach yielded information concerning student's preconceptions, their sources, and the feelings associated with their preconceptions. These results were used to inform the quantitative approach and investigate the existence of correlations between the qualitatively identified variables and student's success in organic chemistry. This type of study is considered as a sequential exploratory mixed methods study, in that one approach was used first, and then the second approach was done to build the results of the first phase.[92] The quantitative data from this study was used to aid in the exploration of the preconception phenomena and the interpretation of the qualitative results.

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[91] Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative Research*, *6*(1), 97.
[92] Creswell, J. (2008). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

To determine what preconceptions students had, and the sources of the preconceptions, qualitative methods were used. Participants first completed a survey containing demographic information and open-ended questions. The open-ended questions allowed students to identify their preconceptions and sources. The information given by the participants in the survey was validated through member checks and inter-coder agreement, and further explored during interviews.

The study design initially called for purposeful sampling. Purposefully sampling is a strategy used to select interviewees from the target population, based on certain traits or characteristics important to the research purpose.[93] The research questions called for interviewees selected from a diverse group of majors, students with a wide range of first semester general chemistry grades, as well as current predicted grade in second semester, and a variety of preconceptions and sources. However, due to the voluntary nature of the interviews, participants' willingness to participate ultimately determined the interview population. Therefore, during the research process interviewee sampling became more of a convenience sampling rather than purposeful sampling. Convenience sampling is referred to as an availability sample as it relies on available subjects for the research project.[94] Through the use of open-ended surveys and interviews the first three research questions were addressed.

Identifying what preconceptions existed, what the sources of these preconceptions were, and whether the preconceptions were positive, negative, or both leaves further questions to be answered concerning this study. After qualitative analysis, quantitative

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[93] Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Sage Publications.

[94] Berg, B.L. (1989). *Qualitative research methods for the social sciences.* Allyn and Bacon Boston.

analysis was conducted to determine if the identified preconceptions contributed in any way to student success in organic chemistry. Statistical analysis was used in the form of ordinal regression to test if there were any significant correlations between preconceptions and student success. Further significant correlations between students four-week grade and their respective final grades was determined using a Spearman's rho bivariate correlation. Lastly, a chi-square analysis was done using the identified variables and whether or not students completed the organic chemistry course. The chi-squared analysis determined if any of the variables were significantly correlated with student success in the course, defined as completing or not completing, organic chemistry.

To explore all aspects of this research a mixed methods design was the best research approach for this project to answer all research questions. To answer the first three research questions, initial investigation in the form of open-ended questions either via survey or interviews were conducted. The qualitative approach was necessary to determine what information the students had obtained from other people or sources and how they had interpreted that information to help formulate their opinions of organic chemistry.

Once the presence of preconceptions and their sources were identified, further investigation was conducted to determine their nature. There was still no reason for instructors to have any concern about the presence of preconceptions. Further research was necessary to understand the potential implications of this study (if any) to be useful to professors of chemistry on college campuses throughout the country. The need to conduct quantitative research to confirm or deny the correlation (Ordinal regression)

between student preconceptions and student success in organic chemistry was essential to complete the full spectrum of this research.

The existence of preconceptions and their sources was identified. Preconception's potential to affect student performance in organic chemistry was investigated. Upon successful completion and publication of the research, professors will be more aware of preconceptions and their affects, therefore enabling professors to begin deconstructing these preconceptions and hopefully helping to improve student success.

Researcher Epistemology/Stance

Due to the nature of qualitative research, the investigator has qualities that may affect the results.[95] It is important in qualitative research to identify the researcher's subjectivities so that these qualities do not misconstrue or skew the data collection, analysis, and results.[93] For these above reasons, the researcher's epistemology is presented first, followed by the researcher's stance.

The epistemology of this research is that of both postpositive and social constructivism. The postpositive epistemology is one in which inquiry is viewed as a series of logically related steps, participants provide multiple perspectives rather than one reality, and supports rigorous methods of data collection and analysis.[96] It is the belief of the researcher, that students have multiple preconceptions concerning courses and these preconceptions may be affecting their performance. The social constructivism epistemology is the belief that individuals seek understanding of the world through

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[95] Peshkin, A. (1988). In search of subjectivity one's own. *Educational Researcher*, *17*(7), 17.
[96] Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Sage Publications.

interactions with others.[94] In social constructivism, theories are not discovered but rather, constructed.[97] The researcher has an initial theory about the research, that students have preconceptions, however, other theories or patterns may be identified through the data collected. It is also a belief that students construct these preconceptions through social interactions and use these interactions to form not only preconceptions but also attitudes and feelings towards a course. The researcher will thus approach this research from both a postpositive and social constructive epistemology. Post-positivism is a perspective largely used in quantitative research and refers to the search for an approximate to the truth, rather than aspiring to understand it in its entirety.[97] In contrast the epistemological perspective of constructivism is the central viewpoint used when examining the qualitative components of the study. Constructivism is a theory in which meaning is not discovered but constructed by human beings as they engage and interact with the world they are interpreting.[97]

I have had many experiences that have allowed me to conduct this research project. First, I was once in the same position as the students included in this study. I took organic chemistry as an undergraduate and was very intimidated and scared of the course due to hearing other student's negative comments. I formed preconceptions as to the difficulty of the course, and I believe those preconceptions hindered my success during the first semester of organic chemistry. I made things more difficult than they really were. I was convinced that organic chemistry was hard. It was not until I realized I had these preconceptions and chose to overcome and ignore them that I finally began to learn and understand the beauty that is organic chemistry. In this instance, I still was

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[97] Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage Publications Ltd.

involved in chemistry, however, for many others, it was observed, that they realized their preconceptions too late. It was observed that many students change their majors, after organic chemistry. Because of my personal experiences, I am very interested in the project as I want to learn more about it so I can help those like me who may lose touch with not only organic chemistry, but science as a whole.

When conducting this research, I was a TA for two Organic Chemistry II laboratory courses. I have also taught General Chemistry I and II laboratories, Organic Chemistry I and II laboratories, and an Organic Chemistry II lecture section. Watching and working with the same students from semester to semester has allowed me to get to know them, their struggles, their work ethic, their attitudes, etc. Because of this experience, I have heard the students talk about organic chemistry when they are realizing what course they need to register for in the next semester. I have heard many comments, mainly negative ones, about the course before they even enroll in it. Due to my experiences teaching students, my awareness of student comments concerning upcoming courses, as well as my awareness of the existence of preconceptions regarding courses, I feel I am able to completely conduct this research. Also, students have said that I am easy to talk to and that they can relate to me, which will be an asset when conducting interviews.

One assumption that must be considered is that there are preconceptions that exist (though this is based on hearing students speak), and second that based on my past experiences, the negative preconceptions will be more prominent than the positive. Because my goal is to teach organic chemistry to college students in the future, I am vested in this research and interested in its outcome so that I can use the results to my

benefit, as well as to the students' benefit, when I begin my career. Understanding what preconceptions exist before teaching a lecture, ensure that I address the preconceptions and hopefully alleviate some of the students' stress and fears about the class.

Setting

The universities chosen for conduction of the research were three western universities (University A, University B, and University C), one midwestern college (College D), and one northeastern college (College E). Three western universities were chosen because they all had a baccalaureate chemistry degree (therefore, they offer both general and organic chemistry) and have a wide diversity of students from all majors taking organic chemistry. Institutions were all medium-to large-sized, public universities. All three universities focus on liberal arts; however, they also support a variety of B.S., M.S., and Ph.D. degree programs. Typical lecture sections containing the target population of students consisted of four 50-minute lectures and one three-hour laboratory per week.

The two other institutions, College D and College E, are both small, private institutions. These schools were included to add diversity: both geographical and type of institution (public verses private). These institutions are small-sized, private universities. Both focused on liberal arts as the aforementioned western universities; however, they only support a small variety of B.S degree programs.

Participants

All students in General Chemistry II at each of the respective institutions were given a written survey (Appendix B). Participation was voluntary and those students wishing not to participate could return the survey blank. Therefore, the survey population consisted of the majority of students taking General Chemistry II in each school. The survey asked students to share their thoughts, feelings, and apprehensions about organic chemistry. All participants were given the survey near the end of General Chemistry II, after the majority of students had registered for the following semester. This timing ensured that the population used in this study was as close to the same population enrolled in organic chemistry the following semester. The desire was that students registered for the course may be less likely to drop it prior to the first day of class, and were more likely to make up the actual population. Although there was no guarantee, this was one step used to help reduce participant loss over the summer. From this population, students were chosen for interviews.

From the group of students participating in the survey, purposeful sampling was done to obtain a representative group of students to interview. Purposeful sampling is basically "hand-picking" participants that contain specific qualities important to the research.[98] This allowed the researcher to obtain a representative group of students. A representative group of students for this research was defined as students with diversity in majors, grades, types of students (i.e. Freshman, Sophomores, etc.), feelings concerning organic chemistry, and sources of information. Purposeful sampling was done because it is the idea that the subset population in some sense represents the population in which it

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[98] Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Sage Publications.

is desired to generalize.[99] These criteria were selected to identify a representative group of students from the general survey population. However, due to the nature of the research and the small number of students volunteering for the interviews, participants were more of a convenience sample. A convenience sample is done to save time, money, or effort, however, at the expense of information.[100] During this research, convenience sampling was not ideal, however, student's willing to participate in the interview all received an interview, and therefore, did not constitute a representative sample.

Initially, surveys were stratified by a representative sample to be interviewed. Initially, it was estimated to interview, 25 General Chemistry II students (five students per institution). However, due to convenience sampling only 16 students were interviewed. Interviews were conducted in person, allowing students to add further explanations and clarification to their written survey answers. Students were interviewed prior to actually taking organic chemistry (while they were enrolled in General Chemistry II). The professors, textbooks, and exams/quizzes did not have to be consistent throughout, as they were not the main focus of the current research and were assumed to play a negligible role in students' preconceptions. It was an assumption that student preconceptions existed independent of the above factors and were only indirectly and negligibly related to these factors.

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[99] Lincoln, Y. and Guba, E. (1985). *Naturalistic inquiry*. Newbury Park, California: Sage Publications Inc.
[100] Creswell, J. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Sage Publications.

Variables

For the quantitative part of this research, variables were identified from the qualitative interviews. After interviews were transcribed, interviews were listened to and surveys were read through to identify any preconceptions, factors contributing to their preconceptions, or sources of their preconceptions. Student identified preconceptions were documented in addition to their sources, feelings associated with the preconceptions, and the students primary cause their identified feelings. The type of coding done with the information was descriptive coding. Descriptive coding identifies the basic topics or ideas from the surveys using a word or short phrase directly from the student's interviews/surveys.[101] After this analysis was done on interview participant's surveys, a list of variables was compiled using the descriptive coding.

After the variables were identified, the variables had to be assigned a numerical code in order to use the data later in the statistical analysis. Specifically, for the type of statistics required for this data, dichotomous coding was utilized.[102] The use of dichotomous coding allows for rigid definition of variables and renders them immutable.[103] Once the variables were dichotomous they could be used in the regression and correlation analysis in the quantitative aspect of this study. This list of coded variables was then used to classify all the survey participants. All students who completed a survey had a unique coding of binary numbers representing their preconceptions, sources, feelings, and primary concern about organic chemistry. Once

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[101] Saldana, J. (2008). *The coding manual for qualitative researchers*. Sage Publications.
[102] Pallant, J. (2007). *Spss survival manual: A step by step guide to data analysis using spss* (3rd ed.). New York, NY: McGraw-Hill Education.
[103] Driscoll, D., et al. (2007). Merging qualitative and quantitative data in mixed methods research: How to and why not. *Ecological and Environmental Anthropology*, *3*(1), 19.

students were successfully coded, statistical regression analysis was done on the entire coded population to test the correlation between the identified preconceptions and students' current grades in the course.

Instruments

This study employed mixed research methods, qualitative and quantitative. The first part of the study focused around qualitative research while the second half focused on the quantitative aspects. Due to the polarity of the study it will be discussed as two different studies for the remainder of the dissertation.

Qualitative Study 1

The main instrument used in this research was a survey. A literature review was done to find previously validated surveys that could be amended for this research. All instruments found in the literature were not applicable to the current research, and therefore, could not be used. A survey was created for the specific purpose of this research. The developed survey was then assessed for both expert and novice face validity. Face validity involves having experts and/or novices examine the written surveys.[104] For expert face validity, a panel of chemical educators was asked to report on the readability and grammaticism of each question. The suggestions were incorporated and only minor grammatical changes occurred as a result. For novice face validity, student interviews were conducted. During the interviews, students were asked the same questions as on the survey and their responses were interpreted by the researcher and

[104] Gall, M.D., et al. (2003). *Educational research: An introduction* (7th ed.). New York: Pearson Education, Inc.

restated to the students. Student then could agree or disagree with the researcher's interpretation and could refine the interpretation if necessary. Both expert and novice face validity, establish trustworthiness in the research. The student survey can be seen in Appendix B. In addition to the survey instrument, qualitative data was obtained via student interviews. Interview questions were customized for each student based on their responses in the written survey. Due to the customization, specific survey questions cannot be included; however, general interview questions are included in Appendix C so that a general interview outline can be seen.

Quantitative Study 2

There are no instruments used in the quantitative part of this research. A statistical analysis software package (SPSS 10.0)[105], aided in the analysis of the quantitative part of this research including, ordinal regression, bivariate correlation, and chi-square.

Design

Qualitative Study 1

The research was designed to include a brief survey followed by voluntary interviews. The survey was designed to collect superficial information concerning student preconceptions, sources of the preconceptions, feeling associated with the preconceptions, and the primary cause of the identified feelings. Because the survey was to be administered during lecture time, the length of the survey was kept short and questions had the ability to be answered with brevity. The researcher gave students a

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[105] SPSS Inc. (2001). SPSS 10.0. 7 for Macintosh. Chicago, Illinois.

brief introduction to who they were as well as the purpose of the project. By establishing contact with the participants, it was anticipated the majority of surveys would be returned.[106]

To address the first two research questions in this study, surveys consisting of open-ended questions were given to the participants. Open-ended questions are when there are no predetermined answers and students can write any answer they choose. Open-ended questions are often used when the answers are in terms of opinions or beliefs.[106] For this research, the use of open-ended questions allowed students to identify any preconceptions they had freely with no constraints. Since the survey was designed to discover what preconceptions existed, using open-ended questions allowed students to identify anything, which they felt related to the topic/question. It was decided by the researcher, that open-ended questions were the best way to identify what preconceptions existed because students could identify anything they felt pertinent and were not limited to choosing from a pre-defined set of answers. Open-ended questioning allowed students to identify topics that may or may not have been something expected by the researcher and would have otherwise been overlooked. The surveys were administered by the researcher during lecture, at the convenience of the professor. Surveys were administered after students had registered for the following semester's courses. The exception to the researcher administering the surveys, were the two institutions across the country, in which case the instructor administered the questionnaire. The goal of the researcher was to administer as many surveys in person as was possible. Surveys given out in person have a higher likelihood to be completed and returned as students are then doing the

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[106] Gillham, B. (2007). *Developing a questionnaire* (2nd ed.). London: Continuum Intl Pub Group.

survey for you.[107] Students were given as much time as they required to complete the questionnaire (approximately 10 minutes).

This initial survey consisted of demographic type (major, class year, past and present chemistry grades) questions as well as the open-ended questions aimed at identifying what preconceptions students had and the source of these preconceptions. To add validity and further explanations to the first two research questions and to address the third research question, student interviews were conducted.

Prior to student interviews, the written surveys were analyzed for specific information. This allowed for the survey questions to be tailored specifically for each interviewee, depending on their survey responses. For example, if a student responded they heard preconceptions from a teacher, an interview question they were asked was what type of teacher: college or high school, or what course the person taught. The interviews, therefore, had a two-fold purpose. The first purpose was to establish novice face validity. Face validity was used to subjectively test the content of the questionnaire items to determine if students interpreted the questions the way the researcher had anticipated.[108] The second purpose of the interviews was to verify and expand on what participants had said in the written survey. By asking the same type of question during the interviews students could clarify and expand on their answers providing further details and explanations than received on the surveys. In addition, a ten-point Likert-type scale[109] was used for students to rate their feelings about organic chemistry: one

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[107] Gillham, B. (2007). *Developing a questionnaire* (2nd ed.). London: Continuum Intl Pub Group.
[108] Gall, M.D., et al. (2003). *Educational research: An introduction* (7th ed.). New York: Pearson Education, Inc.
[109] Likert, R. (1932). The likert-type scale. *Archives of Psychology*, *140*(55), 1-55.

indicating students feel ready to take organic chemistry to ten indicating students are considering changing their major to avoid taking organic chemistry. The scale was used to determine the strength of the student's responses concerning the affect of preconceptions to each student. The Likert-type scale question was asked again during the interview, allowing students' to explain the rationale behind their choice.

Conducted interviews lasted on average 15 minutes. Research has shown that there are conflicting views on the length of the interviews.[110] For the purposes of this study, interviews were not given a predetermined length and lasted various lengths depending on the interviewee's answers. Interviews were conducted at a time and place convenient to the student and were recorded using a digital recorder. Conducting interviews at the convenience of the participants allows them to choose a place in which they are comfortable and secure.[111] All interviews were conducted face to face with the exception of one, which was done over the phone due to the location of the student. Interviews conducted in-person is more effective,[110] and were therefore, the preferred method for this research. Interviews conducted over the phone were only done because in-person contact was not possible. Phone interviews limit the communication between the researcher and interviewee in that neither could read intentional or unintentional visual cues.[110]

Interviews were constructed in a semi-structured format. Semi-structured interviews allow for themes to be addressed, suggested questions to be answered, however, while allowing a flexibility to change of sequence and additional questions to

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[110] Berg, B.L. (1989). *Qualitative research methods for the social sciences*. Allyn and Bacon Boston.
[111] Seidman, I. (1991). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. Teachers College Press New York.

be used to respond to statements made during the interview.[112] For example, during interviews, students were asked specifics concerning certain questions and were asked to expand on their comments (Appendix C). For example, on the survey students may just have written "who" they heard this information from, such as a friend or teacher; however, in the interview, students were able to further explain whether or not the person identified had taken organic chemistry, or if they were successful in the course. These specifics allowed students to address further components of organic chemistry including, exams, concepts, homework, etc., that they may have heard information concerning. These specifics were important to identify as they may have influenced their preconceptions of the course. Details such as these were often not identified in the brief survey and allowed the researcher to gain all possible information from the participants for this research.

Quantitative Study 2

To address the fourth and fifth research questions, ordinal regression was used. Ordinal regression tests the predictive power of a set of variables of which at least one is ordinal (ordered) in nature.[113] This was done to see if there was a correlation between the preconceptions students had and their success in organic chemistry. To do this, all of the student responses identified in the written surveys were coded. Since all of the variables identified are categorical, the variables were grouped and then coded using numbers. For example, some of the groups observed were as follows: students who have heard that

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[112] Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing.* Sage Publications, Inc.
[113] Pallant, J. (2007). *Spss survival manual: A step by step guide to data analysis using spss* (3rd ed.). New York, NY: McGraw-Hill Education.

organic chemistry is hard in general, students who have heard organic chemistry is easy in general, and students who think organic chemistry is within their capabilities. To code the variables, every identified variable (i.e. individual sources of preconceptions or what feelings were associated with preconceptions) was dichotomously coded for use in the regression and chi-square analyses.[114] For example, if the students heard that organic chemistry was hard, they were designated by a "1" for that variable. Conversely, students who had not heard organic chemistry was hard, were designated with a "0". Using this coding system each variable identified, or not identified, resulted in each student having a certain code (list of numbers for each variable).

Student success in the course was measured by taking the student's average grade four weeks into the organic chemistry course. Because the goal of this research was to correlate student's preconceptions with their success in the course, it was thought prudent to obtain their grades early in the semester prior to external variables affecting their grades. The composition of the average is dependant upon each institution. Institutions participating in the research have stated there will be at least two grades from which the average is comprised. In addition, students' final averages for organic chemistry were also obtained and used in the ordinal regression.

Student's success was measured by obtaining an overall course average once they were four weeks into organic chemistry and again at the end of the semester after they obtained their final grades. Students' preconceptions were correlated with their four-week grades from organic chemistry using the regression analysis as described above. In

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[114] Pallant, J. (2007). *Spss survival manual: A step by step guide to data analysis using spss* (3rd ed.). New York, NY: McGraw-Hill Education.

addition, due to a previous study,[115] it was decided that correlations would be observed between students' four-week averages and final averages in organic chemistry. By correlating student preconceptions with their four-week grades, a determination of the correlation to overall success in organic chemistry was made. Student completion of organic chemistry was also considered. Chi-square analysis was ran to determine if any of the identified preconceptions could be used to predict whether or not students would complete organic chemistry. A chi-square test is used to compare an observed result with an expected result, or, how likely are the students to complete the course with a given set of variables.[116] It was thought by the researcher that, if students study habits were set by the fourth week, their initial approach to the course could greatly affect how they proceed throughout the semester. Student's progress through the semester, as well as their ability to complete the course, is of interest for this project and possibly correlated with preconceptions. The results of this project provided useful information for a parallel research project as well as laid the groundwork for future research projects. The results of the statistical analysis allowed the researcher to determine any significant correlations among student preconceptions, and other identified variables, with respect to the students' overall success in organic chemistry, as well as determined if there was any significant difference in student grades between four weeks into the semester and the end of the semester of organic chemistry.

Initial investigative research was done via qualitative analysis to determine what preconceptions existed and the sources of those preconceptions. Afterwards, correlating

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[115] Wasacz, J. T., Pacheco, K. A. O., & Schreck, J. (2009). Are students grades in organic chemistry predictable. Unpublished Research Project. University of Northern Colorado.
[116] Glass, G. and Hopkins, K. (1996). Statistical methods in education and psychology. *Needham Heights, Massachusetts*, 444–480.

students' preconceptions to their success in the course adds a quantitative aspect to the research. Through this mixed method project, all of the research questions for this particular study can be answered and addressed thoroughly.

Analysis

Qualitative Study 1

Surveys

Analysis of the data consisted of many parts. First, after giving the initial Student Questionnaire, the responses were analyzed to choose the participants best suited for this research project. The researcher did all questionnaire analysis and selected a representative sample of students to participate in interviews. Representative samples for this research were those having: a diversity of majors, grades, types of students (A students, C students, etc.), feelings concerning organic chemistry, and sources of information. Due to a low response rate for the interviews, all students volunteering for interviews, received and interview. The sample therefore, was more of a convenience sample and not a purposeful (representative) sampling. Additionally, only those students required to take organic chemistry were chosen for interviews and used in this research. Any student answering the questions on the survey and responding they needed at least one semester of organic chemistry were used in *Quantitative Study 2*. Students who were not anticipating enrolling in organic chemistry were initially thought to be of interest because their opinions could provide insight into student preconceptions and may be the reasons they are not taking the course. However, student's responding they required "0"

semesters of organic chemistry did not identify any preconceptions, causing their surveys to be disregarded.

Upon initial analysis of student surveys, they were grouped into four sections:

1.) Students willing to be interviewed and release their organic grades (interview - yes; grades - yes)

2.) Students willing to be interviewed but not willing to release their organic grades (interview - yes; grades - no)

3.) Students not willing to be interviewed but willing to release their organic grades (interview - no; grades - yes)

4.) Students not willing to be interviewed and not willing to release their organic grades (interview - no; grades - no).

Students belonging to Group 1 were then contacted via email or telephone based on their preference as stated on the survey. Eligible students were called or sent an email asking if they were willing to participate in a brief interview concerning their current feelings regarding organic chemistry. The information obtained in the initial survey was then further analyzed and coded using the variables identified during interviews (as previously described in the *Variables* section). The created variables were used to investigate further existing correlations in *Quantitative Study 2*.

Interviews

Interviews were audio recorded so they could be played back to aid in analysis. Listening to the interviews multiple times ensured the researcher was able to identify all key concepts addressed by the participants, such as: what their preconceptions are, and

what their current chemistry experience is like. After each interview was analyzed, the key concepts identified by each participant were coded (as previously described) and applied to their survey information. Using the information obtained in the interviews, all surveys were completely coded using a dichotomous coding system. Student responses aligning with the variable were coded as “1” while student responses not aligning with the variable were coded as “0”. In addition, patterns that were observed by multiple students were noted. These patterns or themes were further investigated in the quantitative study to determine if they affect student success in organic chemistry.

The coded information gained from student surveys and interviews were then analyzed via statistical analyses in the form of ordinal regression. From this information, correlation coefficients of the preconceptions and student’s four-week grades were examined to determine if there were any significant correlations between student preconceptions and their success in organic chemistry. This gave quantitative data to support the qualitative findings of this research. The findings from this research are useful because, prior to beginning the semester, a professor may be able to know (and therefore address) the most common, general apprehensions students have concerning organic chemistry. Being aware of the apprehensions that exist in their classroom and addressing them, professors can deconstruct and alleviate some of these fears before beginning the course.

Study Rigor

Qualitative Study 1

For the first part of this research project, the qualitative analysis aspect, the trustworthiness of the study must be taken into consideration. The justification of this study may be subject to attacks on its trustworthiness and a poorly defined study may open the research up to much scrutiny. Trustworthiness of a study pertains to how the researcher can persuade the target audience that the results of the research are noteworthy.[117] In qualitative research, trustworthiness encompasses the credibility, dependability, confirmability, and transferability of a study.

First, the credibility of a study involves establishing that the results of the study are believable from the participant's perspective.[118] To ensure the credibility of the study during interviews, the researcher summarized answers and restated them back to the students. This method provided a form of peer checking.[118] Students were then able to agree or disagree with the interpretation of their answers as given by the interviewer. This ensured that students' responses were understood and used correctly during this research project.

During the analysis of the interviews, themes were identified in the student responses. These same themes were applied to all student surveys. If the same themes

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[117] Lincoln, Y. and Guba, E. (1985). *Naturalistic inquiry*. Newbury Park, California: Sage Publications Inc.
[118] Merriam, S.B. (1998). *Qualitative research and case study applications in education. Revised and expanded from" Case study research in education."*. San Francisco: Jossey-Bass Publishers.

were present in both, student interviews and surveys, further credibility was established through this form of triangulation (using multiple sources to confirm themes).[119]

Second, the dependability of a study involves accounting for the dynamic nature of qualitative research and the ability of the researcher to describe the effects of these changes on the study.[120] To address the dependability of the study, the students and their position (class year, current grade, prior experiences) were noted either in the interview or in the written survey. All students participating in this study have different backgrounds and may be affected by different experiences, both of which they could use to formulate their opinions on organic chemistry. Also demographic information was obtained about each participant including class year and major, as well as past and previous grades in general chemistry. To obtain a holistic picture of each student and their feelings about organic chemistry, they were asked to talk about their previous experiences in general chemistry during the interview. By consistently asking open-ended questions and allowing students to talk about their experiences, the researcher hopes to account for the ever-changing environment of qualitative analysis.

Third, the confirmability of a study involves the degree to which the results can be corroborated by others.[121] To specifically address the issue of trustworthiness, inter-coder agreement (inter-observer reliability) was utilized. Inter-coder agreement is based on

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[119] Creswell, J. (2008). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
[120] Lincoln, Y. and Guba, E. (1985). *Naturalistic inquiry*. Newbury Park, California: Sage Publications Inc.
[121] Lincoln, Y. and Guba, E. (1985). *Naturalistic inquiry*. Newbury Park, California: Sage Publications Inc.

whether additional coders agree on with codes obtained by the researcher.[122] In quantitative analysis, inter-coder agreement is measured using a Kappa measure of agreement.[123]

Lastly, the transferability of the study involves the degree to which the obtained results can be transferred to another setting.[122] Transferability is a significant aspect of this research. First, not all students who filled out a written survey participated in the interview portion of this research. However, all survey data was carried over and used in *Quantitative Study 2*. Since the coding that was used as the variables in *Quantitative Study 2* came directly from student interview data, but indirectly from student surveys, transferability issues could have arisen. Once themes were identified from student interviews, it was important for those themes to be outlined in a clear, descriptive manner. This allowed for the themes to be transferred back to the survey data. Any themes that were vague and not descriptive enough were not transferred back to student surveys, and therefore were not used.

In addition to all of the above four threats to trustworthiness, the researcher's stance was also disclosed and discussed as part of the research. By including a subjectivity statement, the neutrality of the researcher can be further confirmed. By being aware of, and taking into consideration these four aspects: credibility, dependability, confirmability, and transferability, the researcher hopes to prove that this dissertation meets the requirements for trustworthiness.

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[122] Creswell, J. (2008). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
[123] Pallant, J. (2007). *Spss survival manual: A step by step guide to data analysis using spss* (3rd ed.). New York, NY: McGraw-Hill Education.

Quantitative Study 2

For the second study done in this research project, the primary focus was quantitative analysis. Quantitative analysis is subject to different criteria for judging than the aforementioned qualitative research. The major components to be addressed in quantitative research are validity (both internal and external), reliability, and objectivity.

The first threat to be accessed is validity. Validity is composed of two different parts: internal and external validity. Internal validity is any experience of the participants that threatens the researcher's ability to draw correct inferences from the data about the population. [124] The following were potential threats to internal validity as well as how they were dealt with during this research.

- Effects of history[125]- this is any event that occurs after the start of the study that can alter the outcome. This potential threat to internal validity cannot be controlled and was not observed to occur in this project.
- Experimental mortality[125]- this happens when participants are lost during the lifetime of the research. To minimize this affect, students were interviewed very quickly after they had taken the survey. In addition, student consent to obtain organic chemistry grades was obtained during the initial survey. In this way, the permission was pre-obtained for the information needed at the end of the research. Student's role in the research is then limited to only the time between when they took the initial survey until they were interviewed. This left very little time for participants to withdraw from the research, leaving only involuntary withdrawal of students from the research. Some students did

[124] Creswell, J. (2008). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

not take organic chemistry (35) the following semester for one reason or another. Also, some students who started organic chemistry were forced to withdraw from the course (11). Both of these cases resulted in a loss of research participants.

- Selection[125]- Students were selected for the interviews based on certain criteria, therefore, preventing randomization. Instead, purposeful sampling was done. To minimize this threat to validity, the chosen sample contained diversity in major, class year, and past and present chemistry grades. This ensured all areas were represented and no one criterion skewed the results. The population however, was a convenience sample, and therefore did not constitute a purposeful sample.
- Subject effects[125]- this could happen if the participants know or think they are supposed to answer one way. If participants think the researcher is only concerned about those with preconceptions, they may state they have preconceptions when in reality they do not. To minimize this threat, the initial surveys were given. Since the surveys were anonymous and there was little detail given about the entire research project, it was anticipated that students would answer the survey questions honestly if they chose to participate. Beyond that, their interviews confirmed what was written on the surveys. Students whose interview was entirely different from their written survey, and who could not justify the change, were not used for this research.

[125] Gall, M.D., et al. (2003). *Educational research: An introduction* (7th ed.). New York: Pearson Education, Inc.

- Experimenter effect[126]- this occurs when an experimenter's biases get in the way of collecting and/or analyzing the research data. To minimize this threat, all researcher biases were set forth prior to commencing the research.

External validity, on the other hand, is the extent to which we can generalize the results beyond the participants tested.[127] In this research there is one potential threat to external validity. The following explains the threat, as well as how it was dealt with during this research.

- Experimenter effect[128]- occurs when the researcher enters an environment and reforms an experiment, which may change the culture of the environment. This threat was minimal, however, because the researcher went into the classroom to talk about the research and distribute surveys. Students may suddenly think about preconceptions or their feelings about chemistry more in depth since attention is being brought to them. This may have skewed some of the survey data. To minimize the effects of this threat, there was a survey question asking about the origins of student's preconceptions. Those students answering, "the researcher," were not used in the research. In addition, interviews were done allowing students to explain more in depth where their preconceptions originated from, as well as their feelings.

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[126] Peshkin, A. (1988). In search of subjectivity one's own. *Educational Researcher*, *17*(7), 17.
[127] Lincoln, Y. and Guba, E. (1985). *Naturalistic inquiry*. Newbury Park, California: Sage Publications Inc.
[128] Gall, M.D., et al. (2003). *Educational research: An introduction* (7th ed.). New York: Pearson Education, Inc.

The next important topic to assess during the quantitative aspect of this research is study reliability. Reliability is in brief, the repeatability of the study.[129] To account for this, multiple universities from across the nation were used in this study. This ensures diversity in the research participants and increases the potential of repeatability. Surveys were obtained from the following:

- Western University #1 - public school containing approximately 10,000 undergraduates; 62% female, 38% male, 23% minority; over 100 majors
- Western University #2 - public school containing approximately 8,000 undergraduates; 53% female, 47% male, 15% minority; over 100 majors; average age 27
- Western University #3 - public commuter school containing approximately 21,000 undergraduates; female: male ratio unknown, large percentage minority; 53 majors; median age 23
- Midwestern College #4 - private school containing approximately 2,000 undergraduates; 54% female, 46% male; 33 majors
- Northeastern College #5 - private school containing approximately 1,500 undergraduates; 57% female, 43% male, 15% minority

Lastly, objectivity is important to address in any research. To address the objectivity of the study, peer checks were used as well.[130] All results were looked over by

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[129] Merriam, S.B. (1998). *Qualitative research and case study applications in education. Revised and expanded from" Case study research in education."*. San Francisco: Jossey-Bass Publishers.
[130] Merriam, S.B. (1998). *Qualitative research and case study applications in education. Revised and expanded from" Case study research in education."*. San Francisco: Jossey-Bass Publishers.

the research advisor to ensure that the results were plausible and that no researcher biases were present. In addition, a researcher stance, including the researcher's biases, was included.

All other matters, including ethical issues, were previously addressed and were also addressed in the IRB (Internal Review Board). An IRB is necessary to assure informed consent of the participants in the research.[131] The approved IRB is shown in Appendix A. Student names were not used and numbers were used to refer to students. Student interviews were transcribed, names were not used, and the interview transcriptions were kept in a locked filing cabinet separate from their consent form (recordings were deleted after transcription). Any other ethical questions arising during the research were addressed.

[131] Berg, B.L. (1989). *Qualitative research methods for the social sciences.* Allyn and Bacon Boston.

CHAPTER IV

RESULTS

The purpose of this study was to investigate general chemistry students' preconceptions concerning organic chemistry and correlate the identified preconceptions with each student's success in organic chemistry. Participants were surveyed during lecture with follow-up interviews conducted outside of class at the students' convenience. Data were collected and coded prior to performing statistical analysis to identify any significant correlations that exist. The data include participants' answers to survey questions, participants' answers during the interviews, and the results of the chosen method of statistical analysis. In Chapter V, these data are analyzed with respect to the five research questions.

Overview of Results

Qualitative Study 1

In this section, data from *Qualitative Study 1* are presented. First, an overview of the students' written survey data is presented. Next, an overview of student interviews will be discussed. An outline of the proposed coding of interviewee's surveys will be presented as well as the intended information to be gained from student surveys. A brief overview of the validation of student surveys using these interviews will be discussed. After the initial overview of both the surveys and the interviews, additional results will be

discussed in the following manner. Since the interviews were designed to validate the student surveys, the results of the student interviews will be presented first, followed by the results of the student surveys. *Qualitative Study 1* will present data obtained from the surveys and interviews and *Quantitative Study 2* will present the statistical analysis done on the information obtained in the first study.

Survey Overview

The student survey can be seen in Appendix B. To generate the survey questions, an informative pilot study was done. During the pilot study, open-ended interviews were conducted allowing students to identify any information they felt pertinent concerning organic chemistry. From the results of this pilot study, questions were generated for use in the Student Questionnaire (referred to as the "survey"). The survey contained a few demographic questions including: major, class year, and previous, as well as, current chemistry grades, in addition to questions regarding preconceptions.

The survey was evaluated for construct validity with a panel of chemical educators (expert face validity) having various levels of expertise. Questions were analyzed by the panel to ensure not only the ease of readability and to ensure all topics of interest for this project were addressed but to also show that the survey could gauge what preconceptions a student might hold regarding organic chemistry. Questions were minimally refined for grammar prior to administration to the target population.

After participants completed the survey, surveys were analyzed. In addition to the survey, each student completed an informed consent document, which contained two spaces for signatures. The first was permission to use the students' data from the written

surveys, and the second was permission to access the students' future organic chemistry grades. Additionally, the last question on the written survey asked students if they would be willing to participate in a brief interview and, if so, asked them to leave contact information for the researcher.

To allow the researcher to contact volunteers for the interview portion of the research, surveys were sorted into four categories: 1) Students consenting to the survey, obtaining grades, and participation in an interview, 2) Students consenting to the survey and obtaining grades, but not to participation in an interview, 3) Students consenting to the survey and participation in an interview, but not to obtaining grades, and 4) Students consenting only to the survey, and not to obtaining grades or participation in an interview. The participants in each category are listed in Table 1.

Table 1. *Classification of Participants' Survey Consents*

Classification of Survey Consents (N = 301)	
Students consenting to the survey, obtaining grades, and participation in an interview	N = 69
Students consenting to the survey and obtaining grades, but not to participation in an interview	N = 77
Students consenting to the survey and participation in an interview, but not to obtaining grade	N = 17
Students consenting only to the survey, and not to obtaining grades or participation in an interview	N = 138

The ideal population for this research was the participants within the first two categories in Table 1. The population used in this research therefore was limited to a maximum of 146 students.

Student participants that indicated they would not be taking organic chemistry the following semester were removed from the set of surveys (N = 16). This was done because the target population was general chemistry students taking organic chemistry the following semester. All remaining surveys (N = 130) were then sorted by institution; the number of students participating from each institution can be seen in Table 2.

Table 2. *Classification of Participants by School*

Classification of Participants by School (N = 130)	
Large Public Western State University	N = 53
Small Public Western University	N = 10
Medium/Large Public Western State University	N = 41
Small Private Midwestern College	N = 11
Small Private Northeastern College	N = 15

Upon identifying participants within the first two categories, and after conducting student interviews, surveys were coded using predetermined categories (derived from the student interviews). During survey coding, student responses aligning with a category were given a “1”, whereas student responses not aligning with a category were given a “0”. For example, students having negative feelings towards organic chemistry would be coded as a “1”, while participants with positive feelings would have “0” coding. All participants’ surveys were coded in this fashion for each category. Therefore, based on the responses of each survey, every student had a unique set of zeros and ones corresponding to their survey answers.

In addition, demographic information was also coded. Due to the varying depth (more than just two ways to answer) in each demographic category, the above-described coding scale was not used to code the demographic information. Within demographic categories, all possible answers were coded using different numbers. For example, the category of major was coded as: "1" = chemistry, "2" = biology, "3" = sports and exercise science, etc… All demographic coding and general survey coding was compiled into one large spreadsheet containing all participants in the study.

The reliability of the coding scheme, was evaluated using peer checks (inter-coder agreement). Inter-coder agreement was conducted with other experts in the field of chemical education. Randomly selected surveys were given to experts with instructions on how to code the surveys (categories were provided). The proposed coding of each expert was then compared with the coding of the researcher to ensure the reliability of the coding.

Interview Overview

Interviews were semi-structured and a guide of general interview questions (Appendix C) was generated, however, questions were tailored for each participant based on their written surveys responses and verbal interview responses. Therefore, every interview was unique and questions were tailored to each participant individually. This allowed the researcher to add further construct validity (novice face) to student surveys. By asking students to re-answer and clarify their written survey answers during the interview, the researcher could understand exactly what students meant in their written surveys. This clarification provided validity to the researcher's coding scheme used to

evaluate all survey responses. By establishing novice face validity, through the use of student interviews, the researcher was able to accurately interpret the remaining surveys and code them for identified variables.

Participants for the interviews were chosen from the population of students participating in the written surveys. Interview participation had two phases: first, agreeing to be contacted to arrange for a brief interview, and second, arranging to meet with the researcher to actually be interviewed. Due to the voluntary nature of the interviews, participants could not be randomly chosen. In attempts to maximize participation, interviews were also conducted at the student's choice of location and at their convenience. A total of 87 students were willing to be interviewed; however, only 16 interviews were conducted. It was anticipated that the number of students volunteering to be interviewed would be larger than the number of interviews required for this research; however, due to the timing of the research, student's agreeing to participate in the interviews were minimal; therefore, all participants were interviewed. The resulting demographics of the interview population were: 69% upperclassmen, 69% biology majors, 25% chemistry majors, 6% sports and exercise science majors, 75% of student reported themselves as being "A" or "B" students, and 88% of student required two semesters of organic chemistry. The population was therefore, a convenience sample and does not reflect a representative sample of the target population.

Once the interviews were conducted, they were transcribed. To preserve anonymity, the audio recordings were deleted after transcription. The transcriptions were then analyzed for themes. These themes were used to create the categories used for coding the students' written surveys.

Interview Results

Upon analysis of the interviews, there appeared to be four major categories students addressed concerning their preconceptions. These categories and an explanation of each category can be seen in Table 3. In addition, a student quote representing each category is also displayed. These quotes highlight answers students provided on the survey regarding each of the four categories.

Table 3. *Identified categories from student interviews.*

Categories	**Explanation of Category**
Sources	Students responding that they had preconceptions about organic chemistry were asked to identify the source of these preconceptions. Sources fell into two main categories: people and other classes. 109231: "My cousin who has taken it"
Information	Students responding that they had preconceptions were asked to identify what specific information they had heard. Information included difficulty of the course, the conceptual nature of the course and the content of the course. 109103: "I have heard that the organic chemistry course is very difficult"
Feelings	Students identifying what preconceptions they had and their sources often had a feeling they associated with organic chemistry class. Feelings were either negative, neutral , or positive. 109099: "Concern because, I will fail and have to take it over or that I will spend all my time on that and will do poorly in other courses"
Cause of Feelings	Once students identified their feelings, they typically had some category that was the direct cause of those feelings. The identified causes of feelings ranged from other people, other classes, reputation, and difficulty. 109255: "What I have heard from so many people"

Within each of these identified categories there were many variables students identified. During analysis of the student interviews, each new variable was recorded and a formed a list of all the identified variables in each category. Often many students commented on the same variable, while some students identified additional interesting variables. After analysis, there were a total of 28 variables identified, all falling into one of four categories as presented in Table 4. These were the initial individual variables that were to be used in quantitative analysis. It was expected that some of the variables may correlate to student success in organic chemistry.

Table 4. *List of variables within each category.*

Category	**Identified Variables**
Sources	Professor
	TA
	Other Class
	Advisor
	General Peers and Family
Information	Organic is hard
	Organic is easy
	Organic is passable
	Organic is memorizing
	Organic is no math
	Organic is conceptual
Feelings	Scared
	Nervous, Anxious
	Excitement
	Looking forward to it
	Do not know what to expect

Category	**Identified Variables**
Cause of Feelings	Previous Chemistry
	Previous Understanding
	Confidence
	Professor
	Other Students
	Reputation
	Difficulty
	Workload
	Fear of unknown

Sources

A.) *Professor*- Students identifying this variable defined this as either a past or present professor of theirs. Many students described this as their current professor in their general chemistry course, while for others it was the professor of a GOB (General-Organic-Biological) chemistry course. This professor was always the instructor of record for a course in which the students were enrolled. An example of this was a student commenting the source of their information was:

109051: “Orgo teacher.” and, 109109: “Proffesor [sic].”

B.) *TA*- Students identifying this variable defined this as either a past or present TA of theirs. For example an student said they heard the information from:

109090: “TA and chemistry lab coordinator.”

C.) *Other Class*- Students identifying this variable defined this as either a past or present course in which they were enrolled. In this course, they were exposed to

some aspect of organic chemistry from which they formed an opinion or gained a preconception about organic chemistry. Examples of these courses are GOB chemistry, general chemistry, or a biology course. For example:

109026: "I briefly touched on organic chemistry in high school in both my IB [sic] bio and IB [sic] chem. class."

D.) *Advisor*- Students identifying this variable defined this as the professor with whom they specifically talk to about course registration and plans of study. The identified advisor did not necessarily teach a course in which the student's were enrolled. For example, one student said they heard the information from:

109288: "Advisor, and other students."

E.) *General peers and family*- This variable was a conglomeration of people, mainly non-academic. Student's friends, peers or classmates, and family members were the main contributors to this variable. The friends, peers, and classmates have an unknown background in chemistry and/or more specifically organic chemistry. Due to this reason, they were combined into this variable and considered non-academic sources. For example, one student commented when asked from whom they heard the information from:

109041: "Family/Friends (Chemistry/Biology majors/minors)."

From the above definitions, it is evident that there is overlap between many of the variables. Due to the many overlapping variables, the researcher decided to combine the individual variables into a set of group variables. Group variables were formed using systematic and statistical analysis. By only grouping variables that were similar, and

often hard to distinguish from one another (i.e. Professor, TA, and Advisor), the new group variables remained independent from each other.

The source variables that were thought to systematically group were professor, TA, advisor, and other classes. Initially, factor analysis was used in attempts to group the variables statistically. However, due to the low response rate per variable, factor analysis was unable to produce statistically grouped variables. In addition to factor analysis, an examination of the correlations between variables was analyzed. It was determined that the correlations between each of these variables was <0.1, however, the student response rate in each individual variables was very low with an average of 7.5 students per category, a minimum of 1 student and a maximum of 19 students. Despite the lack of statistical significance, these variables were systematically combined. Since many students did not explain in depth what they meant by professor or TA, for example, it was determined that it was unknown if there was any difference between the above mentioned variables. In addition, the response rate per variable increased as a result of the new combinations.

The new group variables can be seen in Table 5 along with a brief description of the new category. The other variable, General Peers and Family was not significantly correlated with any of the other variables so due to the nature of this source was kept as a separate group variable. Students responding their information originated from family members and general peers did not consistently identify if this person had any background in organic chemistry. By having an unknown background in organic chemistry, as well as, and unknown academic background, the variable General Peers and Family was used as a separate variable from other academic sources.

Table 5. *Combined categories for sources of student preconceptions.*

Sources		Description
Old Variables	**New Variables**	
Professor TA Other Class Advisor	Academic Sources	The sources of student preconceptions are from some academic aspect.
General Peers and Family	Non-academic sources	The sources of student preconceptions are from other sources (non-academic). This could be family, friends, or just other general peers.

Information

A.) *Organic is hard*- Students responded that the information they had heard was that organic chemistry was a very difficult/hard class. For example:

109003: "I heard a lot about ochem and how hard and horrible it is. I've heard it's the hardest and most time consuming course there is."

B.) *Organic is easy*- Students responded that the information they had heard was that organic chemistry was an easy class. An example of a student commenting they heard organic chemistry was easy mentioned:

109258: "They said its hard for some and easy for others, you either get it or you don't."

C.) *Organic is passable*- Students responded that the information they had heard was that organic chemistry could be done, and done successfully, if students studied and worked hard in the class. A student commented that:

109017: "I believe if I study extra hard, I should get at least a B."

D.) *Organic is memorizing*- Students responded that the information they had heard was that organic chemistry required memorization. Students commented only that the materials needed to be memorized mentioning nothing about the difficulty of the task. For example:

109085: " Organic chemistry is very difficult… and that it is a lot of memorization."

E.) *Organic is no math*- Students responded that the information they had heard was that organic chemistry contained minimal to no math. For example one participant said:

109023: "I actually feel it will be easier than Chemistry because there is less math."

F.) *Organic is lots of work*- Students responded that the information they had heard was that organic chemistry was a lot of work. Typically, students responding about the workload commented on the difficulty of the course as well and associated it with the workload. No students interviewed, however, knew any specific information concerning why it was a lot of work or what contributed to the large workload they had heard about. For example a student had heard that:

109018: "It is very hard and a lot of work."

G.) *Organic is dependent on general chemistry*- Interestingly, there was a small subset of students responding that that the information they had heard was highly dependent on their success in general chemistry. However, success in general chemistry and their future success in organic chemistry were identified as being inversely related. For example, students hear that if they did well in general

chemistry they would not do well in organic chemistry, and visa versa. For example:

109228: “I have heard only that generally those that don’t necessarily do well in general chemistry have a tendency to do well in organic chemistry.”

H.) *Organic is conceptual*- Students responded that organic chemistry was mainly a conceptual course from what they had heard. This information was not elaborated upon. The only comment students had who responded that organic was conceptual was also about the abstract nature of the course. For example:

109130: “Organic chemistry is more conceptual than calculatory.”

It can be seen that the above information given by the students has noticeable overlap. The ideal situation was to combine the individual variables into group variables. Again the number of responses per variable was relatively low. The method for grouping the variables was similar to that outlined in “*Sources”* where variables were group statistically and systematically.

Grouping variables that were similar, into new variables that were independent from each other, allowed for more of a distinction to be made between variables. The new combination of variables can be seen in Table 6 along with a brief description of the new categories. Again, the response rate per variable increased as a result of the new combinations. Lastly, there were two variables that had a very low response (one or no people responded) and were very weakly correlated (<0.05).

Table 6. *Combined categories for information given by students concerning their preconceptions.*

Information		Description
Old Variables	**New Variables**	
Organic is hard	Organic is hard info	Students have heard that organic is hard in nature.
Organic is easy Organic is passable	Organic is passable info	Student have heard that organic is a course within their capabilities.
Organic is memorizing Organic is no math Lots of work	Content based info	Students have heard something about organic that is content based such as there is a lot of memorizing, it is a lot of work, it is no math, or something of that aspect.

The extremely low response of *organic chemistry is conceptual* and *dependent on general chemistry* caused those variables to be dropped from the data set. This occurred due to experimental mortality, or the withdrawing of some student's from this study throughout the duration of the project. After the variables were identified, students commenting on that variable withdrew from the study leaving very low responses if any.

Feelings

A.) Concern- Students commented that their current feelings about the following semester's organic chemistry course were those of concern. Students were not more specific in this instance and merely stated they had concerns. No students with concerns talked about them with a positive attitude. For example, one student mentioned about their feelings:

109197: "I am little bit concerned."

B.) Scared- Students commented that their current feelings about organic chemistry were that of fear, or being scared. Students were scared about the course mainly because of the negative things they had heard about the course. The feeling of being scared was always negatively associated with the course. A student asked about their current feelings concerning organic chemistry commented they were:

109179: "Scared crapless!"

C.) Nervous/Anxious- Students relayed a feeling of nervousness or anxiety about the upcoming organic chemistry course. Again, student's nervousness was always negatively associated with the course. For example, one student commented they were:

109002: Just a little nervous about not doing well."

D.) Excitement- Students responding in this manner were excited about the upcoming organic chemistry course. Although there were very few responses in this category, the student's feelings were always positive when talking about organic chemistry. Typically, students responding in this method had heard minimal to no negative information. An example of this would be a student saying:

109124: "I am very excited to take it."

E.) Looking forward to organic- Students commented that they were looking forward to taking organic chemistry. Their reasons for looking forward to organic were always associated with their abilities and previous grades rather than information they had heard. One student commented that the feeling they had concerning organic chemistry were that they were:

109120: "Looking forward to it."

F.) Do not know what to expect- Students commented they did not know what to expect concerning organic chemistry because they did not know what it was or what it entailed. These students responded that they had neutral feelings concerning the course. For example, when asked what concerns the student had they mentioned:

109113: "I am not sure what to expect."

As with the sources and the information, there was visible overlap with the feelings reported by the students. Grouping the variables in a statistical and logical manner was again the decided course of action to increase response within the variable categories and diminish the overlap. The new group variables for student's feelings concerning organic chemistry can be seen in Table 7.

Table 7. *Combined categories for feelings students had concerning their preconceptions.*

Feelings		**Description**
Old Variables	**New Variables**	
Concern Scared Nervous, Anxious	Negative Feelings	Students have very negative feelings associated with organic chemistry.
Excitement Looking forward to it	Positive Feelings	Students have positive feelings associated with organic chemistry.

The combination of variables for student's feelings as seen in Table 7 are accompanied by a brief description of the new category. There was one variable (*Do not know what to expect*) that had a very low response within the feelings category (less than five people responded), which was dropped from the data set.

Primary Cause of Feelings

A.) *Previous chemistry*- Students commented that the primary cause of their expressed feelings about organic chemistry were in large part due to a previous chemistry course they may have had. This course was typically either general chemistry or GOB (General-Organic-Biological) chemistry. For example, when asked what the primary factor contributing to their feelings was one student said:

109062: "I'm not good with chemistry, don't enjoy it."

B.) *Previous understanding*- Students commented that the primary cause of their feelings was due to their previous understanding of chemistry. This previous understanding typically came from a course they had taken in which they felt they understood or did not understand the material clearly. For example a student commented:

109071: "Having enough gen. chem. knowledge to be successful."

C.) *Confidence*- Students commented that the primary cause of their feelings was their personal level of confidence. Students did not necessarily comment if the confidence contributed to feeling negatively or positively, just that their confidence did play a role. The source of the confidence was also not disclosed by the students in every interview. For example, the primary factor contributing to a student's identified feelings was:

109101: "My own insecurity" and, 109280: "My success thus far."

D.) *Professor*- Students commented that the primary cause of their feelings was something a professor had said to them. The information obtained from the professor could have been either negative or positive; however, hearing

information from a professor was noted as a primary cause of many of the identified feelings. For example when asked what the primary factor contributing to their feelings was one student said:

109008: “My current chem. teacher.”

E.) *Other students*- Students hearing information from other students was identified as a primary cause of their feelings. There was no specification as to who these other students were or what background in chemistry they had. Students commenting that this was the primary source of their feelings always commented they had negative feelings. For example when asked what the primary factor contributing to their feelings was one student said:

109019: “Other people’s reaction when I mention ochem”

F.) *Reputation*- Students commented that the primary cause of their feelings was the reputation that the organic chemistry course had. Again, students did not specify the source of the reputation they heard about the course. However, students responding that the reputation was a primary cause always associated it with negative feelings. For example one student commented when asked what contributes to their feelings:

109134: General student rumors. No one seems to have anything good to say about it.”

G.) *Difficulty*- Students commenting that the difficulty was a primary cause of their feelings responded they had negative feelings as well. The difficulty was merely

an anticipated difficulty since students had no prior experience with organic chemistry. A student's primary cause of their identified feeling was:

109288: "The difficulty of the course."

H.) *Workload*- Similarly to above, students commented that the workload of organic chemistry was the primary cause of their feelings. Workload was always viewed negatively. When asked what the primary factor contributing to their feelings was one student said:

109027: "The workload of the class."

I.) *Fear of the unknown*- When asked what the primary cause of their identified feelings were, students commented that it was really a fear of the unknown that contributed to their feelings. For example, when asked what the primary factor contributing to their feelings was one student said:

109234: " Don't have any idea about it."

As with the other categories, the responses students gave for the cause of their reported feelings appeared to overlap. Again, it was decided, to group similar variables into new variables to create more of a distinction and increase the responses within variables. The combination of variables within the category *Cause of Feelings* can be seen in Table 8 also with a brief description of each of the new categories.

For this category, a statistical and logical grouping of variables was also done while considering the feelings associated. For example, those categories that were always associated with negative feelings were grouped together (correlation > 0.150), while those associated with mixed feelings were grouped together. There was one

variable in this category that, similarly to the variables in other categories, had a very low response and was not correlated with the other variables (two people responded). The cause of feelings being stated as *the fear of the unknown* was dropped from the data set.

Table 8. *Combined categories for cause of feelings students had about organic chemistry.*

Primary Cause of Feelings		**Description**
Old Variables	**New Variables**	
Previous Chemistry Previous Understanding Confidence	Prior experience caused feeling	Students expressed feelings were caused by their prior experiences. These feelings were either negative or positive.
Professor Other Students Reputation	Person caused feelings	Students expressed feelings were caused by a person. These people were either professors or other students. The reputation of the course weighed heavily into these feelings. Feelings were either positive or negative
Difficulty Workload	Difficulty caused feelings	Students expressed feelings were caused by the difficulty of the course.

Survey Results

After student interviews were conducted, and the variables identified, student surveys were then coded using the ensemble of variables identified. A total of 130 surveys were coded using the above, predefined, variables. However, upon obtaining students 4-week grades the following semester 19 students never enrolled in organic chemistry and were therefore dropped from the population. The new population then became 111 students. Upon obtainment of student's final organic chemistry grades, it was observed that 11 additional students had withdrawn from the course prior to

completion. Because of these students withdrawing, the total population of N = 100 will be used and reported from here forward.

Demographic information was also obtained from the surveys. The demographics of interest included the following variables: class year, major, self-reported first semester general chemistry grade, a prediction of their second semester general chemistry grade, and a scale of apprehensions towards organic chemistry. The results, accompanied by a brief description of each variable follow.

A.) *Class year:* Students were given the option of freshman, sophomore, junior, senior, and higher than a senior (in the event they were a graduate student or fifth year senior). Because General Chemistry I is traditionally taken as a freshman, it was decided to combine class year into two categories: traditional (freshman) verses non-traditional (upperclassmen). Traditional students were those who were enrolled in general chemistry as a freshman and who would later be enrolled in organic chemistry as a sophomore. Non-traditional students were those who were enrolled in general chemistry as at least a sophomore and therefore would be juniors or higher while enrolled in organic chemistry. The discrimination of students into each of the categories is seen in Table 9.

Table 9. *Categorization of students by class year.*

Class year	**Number of students (N = 100)**
Traditional (Freshman)	47
Non-traditional (Sophomore, Junior, Seniors, 5^{th} year Seniors, or Graduates)	53

B.) *Major:* Students were given the option of chemistry, biochemistry, biology, sports and exercise science, and other. The question was a 'circle the answer' question however, many of the students responding "other" wrote in their respective major, which aided in later categorization of majors. During coding it was noted there were nine categories of majors. Many of the majors were very similar however, and were therefore grouped into five categories as seen below in Table 10.

Table 10. *Categorization of students by major.*

Students major	**Number of students (N = 100)**
Chemistry/Biochemistry	13
Biology	65
Sports and Exercise Science	6
Health Sciences (Pre-med, Pharmacy)	5
Other	11

The recombined categories for majors were: chemistry/biochemistry, biology, sports and exercise science, and health sciences (including pre-med, pharmacy, etc…).

C.) *First semester general chemistry grade:* Students were asked to circle the final grade they received in first semester general chemistry. The students were given the choice of A, B, C, D, or F. However, since surveys were given in second semester general chemistry, it was assumed that no students with an F grade would be present in the population. This was confirmed by student's answers. Importantly, these grades were reported by students only and were not verified

(due to IRB regulations) with their respective first semester general chemistry instructors. The number of students reporting each type of grade can be seen in Table 11. These reported grades represent all general chemistry students participating in this study from all five participating schools.

Table 11. *Categorization of student reported first semester general chemistry grades.*

Grades	**Number of students (N = 100)**
A	38
B	35
C	25
D	2
F	0

D.) *Second semester general chemistry grade prediction:* Similar to the first semester general chemistry grade, students were asked to circle the final grade they anticipated receiving at the end of second semester general chemistry. Again, the students were given the choice of A, B, C, D, or F. The reported grades were again not verified and are seen in Table 12 below. Initially, these two questions (first semester and second semester grades) were included on the survey for interest purposes. Prior to deciding on convenience sampling, the researcher was interested in student's reported grade for use as a discriminator in obtaining a representative interview population. Additionally, in retrospect, these self-report and predicted grades were an interesting variable in themselves that was worth

further investigation. After analysis of the statistical correlations, the self-reported and predicted grades were correlated with both students' four-week and final grades in organic chemistry (to be discussed later in this chapter). Future investigation would investigate this correlation with verified students grades instead of self-reported and predicted grades.

Table 12. *Categorization of student predicted second semester general chemistry grades.*

Grades	**Number of students (N = 100)**
A	40
B	41
C	18
D	1
F	0

In this case, since students were currently enrolled in second semester general chemistry, the grades students reported were only a prediction. Thus, the validity of these grades could not be verified and were merely left to the students' truthfulness when answering the questions.

E.) *Scale of apprehensions:* On the survey, the last question asked students to rank their apprehensions towards organic chemistry on a scale of 1 to 10, where 1 meant: "students were totally prepared to take organic chemistry and had no apprehensions" and 10 meant "students were considering changing their major so

they did not have to take the course". In addition, the same question was asked during the interviews and students were asked to elaborate on why they chose the ranking they had. A histogram of the rankings given by students on the written surveys can be seen in Figure 1. Upon analysis it was observed that a student chose not to respond to this survey and therefore the population answering this question was only 99 students out of the original 100 students. Additionally, one student chose not to circle the provided choices (1 – 10), and instead wrote in their own number (2.5).

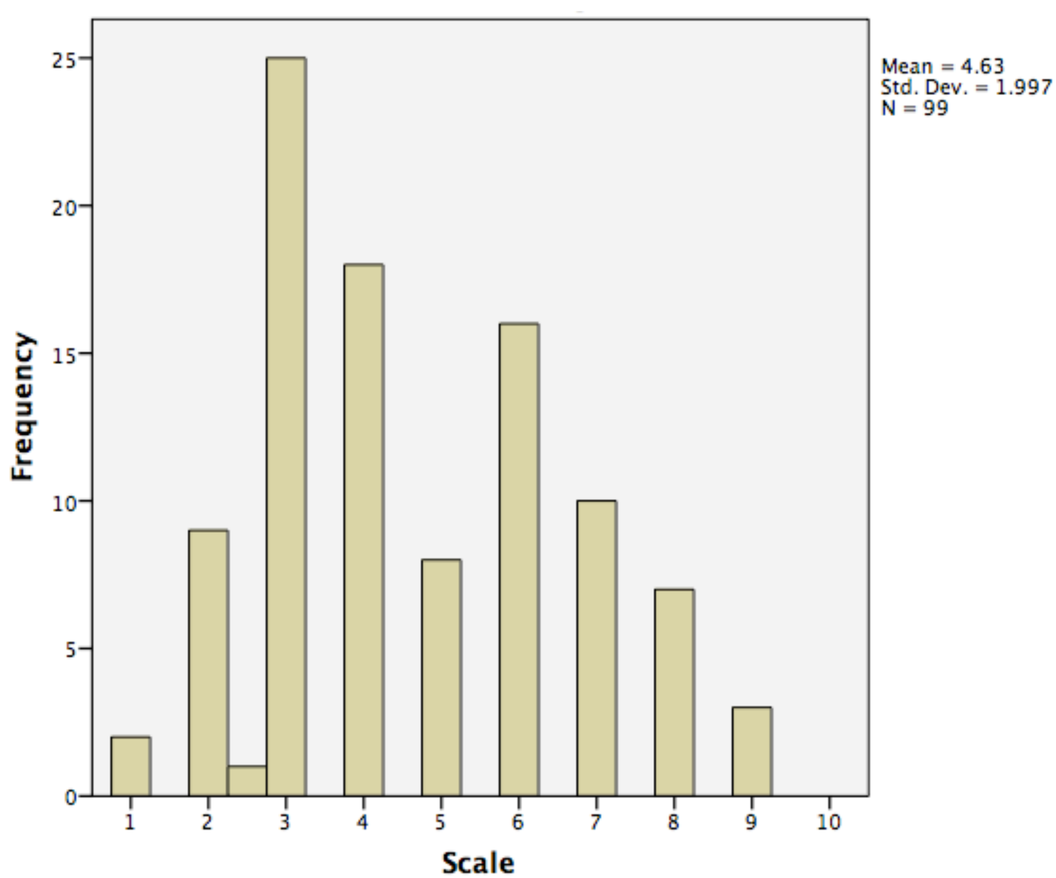

Figure 1. *Students' apprehensions ranked on a scale 1-10.*

Lastly, the surveys were subjected to an inter-coder agreement to test to determine the confirmability of the researcher's coding. One survey was randomly selected for this analysis and given to four different chemical education experts. A Kappa statistic was used because it is a measure of the agreement against what might be expected by chance. The inter-coder agreement for the evaluators was found to have a Kappa = 0.800 ($p < 0.05$), 95% CI (0.435, 1.165). This value displays a high level of agreement between the raters and the researcher for the coding scheme used.

Quantitative Study 2

In this section, data from *Quantitative Study 2* are presented. First, an overview of the statistics used is presented. Each successive statistical analysis and the results will be presented. The group variables identified and defined in *Qualitative Study 1* were the same variables that were used during the statistical analysis in *Quantitative Study 2*. Throughout the duration of this section various correlation coefficients and significance values will be discussed. Correlation coefficients will be discussed in terms of being strong (≥ 0.6), moderate (0.4 – 0.6), weak (0.2 – 0.4), or very weak (≤ 0.2). A perfect correlation would be a value of 1.0, and will only occur if the two variables being correlated are the same variable. The given values for characterization of correlation coefficients were those used by the statistical analysis software package (SPSS) also. In addition to correlation coefficients, an accepted significance value, or p-value, for this research was set at 0.05, meaning, that is the minimum number accepted in order to be considered statistically significant.

Ordinal Regression

The first part of the statistical analysis was to investigate if there was a relationship between the identified variables and students' four-week grade. To accomplish this task, an ordinal regression was chosen. Regression analysis is used to test the predictive power of a set of variables.[132] In this research, a set of identified variables was used to determine their predictability and correlations to student's four-week and final organic chemistry grades. Due to the nature of the variables: grade (ordinal) and the identified variables (categorical), an ordinal regression was determined to be the optimal method to obtain the most statistically significant results.[133] One way of determining if the chosen statistical model fits with the observed values is by computing a chi-square goodness-of-fit. For the observed data (student-identified variables) the goodness-of-fit analysis is presented in Table 13. A significance (sig.) value > 0.05 indicates that the chosen statistical model is a good "fit" for the observed data. A Pearson chi-square test was used to determine goodness-of-fit and resulted in a significance value of 0.172.

Table 13. *Goodness-of-fit analysis.*

Goodness-of-Fit		
	Chi-Square	Sig.
Pearson	271.034	0.172

After determining that ordinal regression was the appropriate statistical analysis to use, the significance of each variable with students' four-week grade was analyzed. The

[132] Pallant, J. (2007). *Spss survival manual: A step by step guide to data analysis using spss* (3rd ed.). New York, NY: McGraw-Hill Education.
[133] Tabachnick, B. and Fidell, L. (2001). *Using multivariate statistics*. Allyn & Bacon.

statistical results (Table 14) displays a significance value for each variable in addition to the upper and lower bounds of the significance value at a 95% confidence interval. Significance (sig.) values < 0.05 indicates that the correlation between that specific variable and the students' four-week grade is statistically significant. The sig. values presented in Table 14 indicate if the variable is statistically significant when compared with student's four-week grades. These values do not indicate a correlation between the variable and four-week grade. Correlation coefficients must be calculated to determine if any of the variables are significantly correlated with student's four-week grade.

Upon analyzing the ordinal regression results, it was determined that the only variable shown to have statistical significance when compared to four-week grade was that of student's prior experience being the primary cause of their identified feelings (sig. = 0.018). Beyond prior experience, none of the other variables were statistically significant. All the resulting significance values for each identified variable are presented in Table 14.

A significance value of 0.018 for prior experiences being the cause of student's feelings indicates that there may be a correlation to their four-week grade. The actual correlation coefficient was determined to be -0.192 thus displaying a very weak correlation with student's four-week grades.

It is also important to note that the correlation between student's prior experiences being a cause of their feelings towards organic chemistry and their four-week grade was observed to be negative. A negative correlation means that student's prior experiences are inversely related to their success in the course (four-week grade), that is to say that, the more prior experiences a student commented they had, the lower their four-week

grade. The ramifications of these findings will be further discussed in Chapter V. After analysis of the ordinal regression, it was necessary to obtain correlation coefficients of each variable (Table 15).

Table 14. *SPSS ordinal regression results for variables vs. four-week grade.*

		95% Confidence Interval	
Variables	**Sig.**	Lower Bound	Upper Bound
Academic sources	0.132	-1.49	0.195
Non-academic sources	0.515	-0.772	1.541
Organic is Hard info	0.198	-1.913	0.397
Organic is passable info	0.808	-1.428	1.832
Content based info	0.77	-0.738	0.997
Negative Feelings	0.616	-0.727	1.227
Positive Feelings	0.37	-1.331	0.496
Prior exp. caused feeling	0.018	-1.949	-0.183
Difficulty caused feeling	0.575	-0.657	1.183
Person caused feeling	0.073	-1.647	0.073

Correlation coefficients allow the researcher to quantify the relationship, and significance, among each variable with students' four-week grade. From the values seen in Table 15, a few correlations were denoted as being significant. The correlation coefficients with one star (*) are significant at a 0.05 level, while those with two stars (**), are significant at a 0.01 level. The correlations significant at a 0.01 p-value are as follows: organic is hard information with non-academic sources (0.583), organic is hard information with prior experiences caused the feeling (-0.301), negative feelings with organic is hard information (0.274), and non-academic sources with prior experiences caused the feeling (-0.273).

Table 15. *Correlation coefficients between variables.*

	4-Week Grade	**Academic sources**	**Non-academic sources**	**Organic is Hard**	**Organic is Doable**	**Content Based Info**	**Negative Feelings**	**Positive Feelings**	**Prior Experience Caused Feeling**	**Difficulty Caused Feeling**	**Person Caused Feeling**
4-Week Grade	1	-0.168	0.041	-0.065	0.005	0.037	0.016	-0.111	-0.192	0.129	-0.100
Academic sources	-0.168	1	-0.243*	0.053	0.079	-0.021	0.053	0.120	0.198*	0.120	-0.174
Non-academic	0.041	-0.243*	1	0.583**	0.064	0.229*	0.138	-0.072	-0.273**	-0.223*	0.210*
Organic is Hard	-0.065	0.053	0.583**	1	-0.210*	-0.008	0.274**	-0.108	-0.301**	-0.108	0.230*
Organic is Doable	0.005	0.079	0.064	-0.210*	1	0.131	-0.138	0.131	0.002	-0.059	0.005
Content Based Info	0.037	-0.021	0.229*	-0.008	0.131	1	0.001	0.188	0.004	0.087	-0.010
Negative Feelings	0.016	0.053	0.138	0.274**	-0.138	0.001	1	-0.410**	-0.069	0.104	0.262**
Positive Feelings	-0.111	0.120	-0.072	-0.108	0.131	0.188	-0.410**	1	0.148	-0.015	-0.146
Prior Experience Caused Feeling	-0.192	0.198*	-0.273**	-0.301**	0.002	0.004	-0.069	0.148	1	-0.044	-0.305**
Difficulty Caused Feeling	0.129	0.120	-0.223*	-0.108	-0.059	0.087	0.104	-0.015	-0.044	1	-0.326**
Person Caused	-0.100	-0.174	0.210*	0.230*	0.005	-0.010	0.262**	-0.146	-0.305**	-0.326**	1

The correlation between organic is hard information with non-academic sources was a moderate (0.4 – 0.6) and direct correlation. Students commenting that they heard information from non-academic sources were likely to comment that the information was concerning the difficulty of the course. For example, student 109074 commented they heard the information from: "Friends" and also commented that: "Organic is very hard requires a lot of time and effort… impossible to get higher than a C at best." This is possibly due to students (possibly those who have not successfully completed the course) spreading rumors about organic chemistry and its difficulty.

As for the correlation between organic is hard information with prior experiences caused the feeling, it was observed to be an inverse, but weak, (0.2 – 0.4) correlation. Students commenting that they heard information concerning the difficulty of the course were less likely to comment that their prior experiences were a cause of their feelings about organic chemistry. An example of a student who did comment on the difficulty and their prior experiences was student 109131 who mentioned: "For the most part, they've said it's really hard, a lot to remember" and also mentioned their primary factors contributing to their feelings were: "Taking organic chem. in high school." Students with more prior experiences possibly view the course based on their abilities and therefore, may be less likely to view the course as being difficult.

The correlation between negative feelings with organic is hard information was a weak, but direct, correlation. Students with negative feelings were, therefore, more likely to comment they had heard information concerning the difficulty of organic chemistry. Student 109031 commented: "I am very scared" as well as: "I heard that it is a very difficult and time consuming class." A possibility for this correlation is that students

hearing information that organic chemistry is very difficult will more likely to have negative feelings towards the course because they will be scared, apprehensive, and nervous about the material.

Lastly, the correlation between non-academic sources with prior experiences caused the feeling was observed to be an inverse, but weak, (0.2 – 0.4) correlation. Students hearing information from non-academic sources were less likely to comment that their prior experiences were a cause of their feelings about organic chemistry. An example of a student who did mention they heard information from non-academic sources and their prior experiences caused their feelings was student 109062, who said they heard their information from: “Friend” and also said their primary factor contributing to their feelings was: “I’m not good with chemistry.” Students hearing information from friends may be less likely to consider this information if they have prior experiences and higher confidence.

The correlation coefficients in Table 15 with one star (*) are significant at a 0.05 level. The correlations significant at a 0.05 p-value are as follows: organic is hard information with organic is doable (-0.210), organic is hard information with a person caused the feeling (0.230), non-academic sources with content based information (0.229), non-academic sources with difficulty caused the feeling (-0.223), non-academic sources with person caused the feeling (-0.223), non-academic sources with academic sources (-0.243), and academic sources with prior experiences caused the feeling (0.198).

All of the correlations significant at a 0.05 level were observed to be weak, (0.2 – 0.4). The correlation between organic is hard information with organic is doable and academic with non-academic sources were observed to both be inverse correlations.

These correlations were expected to be inverse in nature because each variable in a pair represent opposite ends of the spectrum in respect to organic chemistry.

The correlation between organic is hard information with a person being the primary cause their feelings was observed to be direct. Because the sources were always from a person, student's hearing organic chemistry was hard often commented the person identified as their source was the primary cause of their feelings. For example, student 109104 commented: "They told me it would be lots of hard work" and then commented that the primary cause of their feelings was due to: "Information from friends." The result displays that students hearing information concerning the difficulty from others were likely to weigh this information heavily when considering their feelings.

The correlation between non-academic sources with content-based information was also observed to be direct. Students hearing information from non-academic sources, mainly friends or family, were more likely to comment they heard content-based information. Student 109113 responded they had heard information from: "Another student" and the information they head was: "I have heard it is a lot of diagrams and how chemical bonds and chemical structure come together." Possibly, students who have previous taken the course, regardless of their success, spread information concerning some of the content of the course to future students.

The correlation between non-academic sources with difficulty being the cause of student's feelings was observed to be inverse. Students hearing information from non-academic sources were less likely to comment that the difficulty was a primary cause of their feelings. An example of a student who did mention they heard information from a non-academic source and the difficulty was a primary cause of their feelings was student

109302, who commented their non-academic source was: “Many sources” and then proceeded to write that their primary factor influencing their feelings was: “The course difficulty.” Beyond this students hearing information from other students may have the primary cause of their feelings be the reputation they have heard from these sources instead of the difficulty of the course.

The correlation between academic sources with prior experiences being the primary cause their feelings was observed to be inverse. Students hearing information from academic sources were less likely to comment that their prior experiences were the primary cause of their feelings. An example of a student who did mention they heard information from an academic source and their prior experiences was the primary cause of their feelings was student 109134, who mentioned they had heard information from: “Teacher” and also mentioned “Gen chem. doesn’t seem to click with me so hopefully Ochem will” as being the primary cause of their feelings. Students hearing information from teachers may not consider their prior experiences and focus only on the information obtained from the teacher as being the primary cause of their feelings.

The correlation between non-academic sources with person being the primary cause student’s feelings was observed to be direct. When students mentioned they heard information from a non-academic source they were more likely to comment that people were the primary cause of their identified feelings. Student 109257 mentioned their source as being: “Friend” and then commented that the primary cause of their feelings was: “I have heard stories of people flunking out of organic.” Students hearing information from friends or family potentially greatly affect their feelings. All other correlations were very weak (≤ 0.2) and not statistically significant, and therefore, they

will not be further discussed.

Lastly, a test of parallel lines (Table 16) was done on the data. This test displays if there is a difference across the categories.[134] In this instance the null hypothesis states that the coefficients of the slope are the same across the categories (and lines of the same slope are parallel). Since the data consists of different and unique categories the same coefficient for the slope should not be obtained, therefore, the lines should not be parallel. Ideally, there should be a difference and the parameters should not be the same, therefore, rejecting the null hypothesis.

Table 16. *SPSS results for the Test of Parallel Lines.*

Test of Parallel Lines		
	Chi-Square	Sig.
General	53.118	0.006

The data presented in Table 16 displays a significance value of 0.006. This p-value is less than 0.05 and therefore it is determined that the null hypothesis (the parameters are the same across the category) can be rejected. This further ensures that the above chosen statistical models were correct for the given data set.

Spearman's Rho Correlation

Upon determination of the correlations between variables and student's four-week grades, correlations between student's four-week and final organic chemistry grade were investigated. It was theorized that any variable significantly correlated with four-week

[134] Tabachnick, B. and Fidell, L. (2001). *Using multivariate statistics*. Allyn & Bacon.

grade would also be significantly correlated to final grade. This would be considered true only if four-week grade was significantly correlated to final grade in organic chemistry. To accomplish the grade-to-grade relationship, a bivariate correlation was done.[135] The Spearman's rho correlation is reported in Table 17.

Table 17. *Bivariate correlation between student's four-week grades and their final grades.*

Spearman's Rho Correlation	
	Final Grade
4 Week Grade	0.718**

The data in Table 17, displays that the student's four-week grade is strongly correlated (0.718) to their final grade. The double star (**) indicates that this value is significant at a 0.01 significance level.

Chi-Square Analysis

During analysis of the data it was observed that 11 students withdrew from organic chemistry prior to completing the course. These students did, however, receive a four-week grade. Despite only 11 students withdrawing, these students who failed to complete the course, were thought to be of interest and possibly related to the identified variables. It was hypothesized that one or more of the identified group variables could be used as a predictor of a student's ability to complete the course. Because the interest was in potential predictability of student's completion of the course using the identified

[135] Tabachnick, B. and Fidell, L. (2001). *Using multivariate statistics*. Allyn & Bacon.

variables, a chi-square test statistic was used (Table 18). A chi-square test is used to compare an observed result with an expected result, or, how likely are the students to complete the course with a given set of variables.[136] Typically, a chi-square test would be done with one variable and students completion of the course. However, since this research contains ten separate variables, ten chi-square tests must be run, one with each variable. Due to ten separate chi-square analyses being conducted on the same set of data, a Bonferroni adjustment was completed. A Bonferroni adjustment is a correction for running the same test with completion, ten separate times, one with each variable, which reduces the Type I error (false positives).[135] The correction is accomplished by dividing the accepted p-value (0.05) by the number of chi-square test to be completed. The Bonferroni adjustment resulted in a significance level of 0.005.

Table 18. *Chi-square analysis of identified variables versus completion of course.*

Variables	**Significance**
Academic sources	0.073
Non-academic sources	0.385
Organic is Hard info	0.214
Organic is passable info	0.526
Content based info	0.412
Negative Feelings	0.588
Positive Feelings	0.412
Prior exp. caused feeling	0.093
Difficulty caused feeling	0.615
Person caused feeling	0.318

[136] Glass, G. and Hopkins, K. (1996). Statistical methods in education and psychology. *Needham Heights, Massachusetts*, 444–480.

Upon chi-square analysis, it was determined that none of the variables were significant at the 0.005 level (Table 18) and therefore, cannot be used to predict student completion of organic chemistry.

Major Affects

In addition to the outlined statistical analysis, further correlations were investigated using demographic information obtained from student surveys. First, it was noted the majority of majors represented were either chemistry or biology majors. It was thought there may be an affect on four-week grade depending on whether or not students were chemistry or biology majors. A cross tabulation was used to depict the percentages of the types of grade each major received (Table 19).

Table 19. *Cross tabulation of chemistry and biology majors and their respective four-week grades.*

Crosstabulation of Majors and Grade				
		Chemistry	Biology	Total
4 Week Grade	A	23%	23%	23%
	B	15%	29%	27%
	C	31%	25%	26%
	D	30%	20%	21%
	F	<1%	3%	3%
Total		13	65	78

The crosstabulation demonstrates that both the chemistry and biology students were relatively evenly dispersed throughout the grade range (A-D), with the fewest students failing the course (F). Further analysis of the crosstabulation displays that for both chemistry and biology majors, approximately one quarter of the students in those majors

received an "A". However, the majority of biology students, 52%, received a "B" or higher, while chemistry students receiving the same was only 38%. This indicates there may be an unknown factor or variable that is correlated with the grades students from different majors receive in organic chemistry.

To further investigate the effect of student's major on their organic chemistry grades, a chi-square analysis was done to determine if being either major (chemistry or biology) could be used as a predictor of student's four-week grade. The results of the chi-square analysis can be seen in Table 20. The significance value is reported, however, since the value is not less than 0.05, it is said to be statistically insignificant. Therefore, student's major (chemistry or biology) is not an accurate predictor of student's four-week grade and is not correlated with their success in organic chemistry.

Table 20. *Chi-square analysis of chemistry/biology majors and four-week grade.*

Chi-Square Tests		
	Value	Sig.
Pearson Chi-Square	1.908	0.753

Type of Student Affects

It was further thought that there could exist a relationship between the type of student and their four-week grades (Table 21). It was observed there were two different types of students. Those who were freshman during the initial surveys and would therefore be considered "traditional" students, and those who were sophomore or higher during the initial surveys and would therefore be considered "non-traditional" students.

Table 21. *Cross tabulation of type of student (traditional/non-traditional students) and their respective four-week grades.*

Crosstabulation of Type of Students and Grade				
		Non-traditional	Traditional	Total
4 Week Grade	A	26%	17%	22%
	B	28%	26%	29%
	C	26%	23%	25%
	D	13%	20%	20%
	F	6%	<1%	4%
Total		53	47	100

Similar to *major affects*, the cross tabulation was first done followed by a chi-square analysis (Table 22). The crosstabulation showed a fairly even dispersion of student four-week grades within each student type.

Table 22. *Chi-square analysis of type of student (traditional/non-traditional students) and four-week grade.*

Chi-Square Tests		
	Value	Sig.
Pearson Chi-Square	4.487	0.344

The results of the chi-square analysis ,seen in Table 22, display that there is no significance between the class year of the students (traditional or non-traditional) and were therefore, not an accurate predictor of student's four-week grade.

General Chemistry Grade Correlations

Lastly, on the surveys, students were asked two questions concerning their current general chemistry grades. First, students were asked to disclose how they performed previously (final grade) in General Chemistry I, and second, were asked to predict how they anticipated doing in General Chemistry II (with less than 4 weeks to the end of the semester). These grades were merely student reported grades and were not verified with the instructors. It was thought however, there may be a correlation with these student reported/predicted general chemistry grades and their actual four-week grades in organic chemistry.

The correlation between the students' first semester general chemistry grade (FSGC), second semester general chemistry grade (SSGC), four-week organic chemistry grades, and final organic chemistry grade can be seen in Table 23.

Table 23. *Correlations between student general and organic chemistry grades.*

	4 Week Grade	**Final Grade**	**FSGC Grade**	**SSGC Predict**
4 Week Grade	1	0.718**	-0.561**	-0.520**
Final Grade	0.718**	1	-0.537**	-0.492**
FSGC Grade	-0.561**	-0.537**	1	0.449**
SSGC Predict	-0.520**	-0.492**	0.449**	1

As previously described, those values denoted by two stars (**) are significant at a 0.01 level. Students' first semester general chemistry grade and their predicted second semester general chemistry grade were moderately (0.4 - 0.6) correlated with both their respective four-week and final organic chemistry grades. These relationships were

inverse, if students reported higher performance (higher grade) in General Chemistry I and/or General Chemistry II they demonstrated a worse performance in organic chemistry (lower grade).

CHAPTER V

DISCUSSION AND CONCLUSIONS

Summary of Purpose

The overall purpose of this study was to investigate general chemistry students' preconceptions including both the sources of the preconceptions and the feelings associated with the preconceptions. Through these investigations, variables (10) were identified through qualitative analysis. The identified variables were further investigated for possible correlations with students' four-week grades in organic chemistry ($N = 100$). Student survey and interview data were analyzed for identification of preconception variables. Emergent themes relating to the research questions are presented in the following discussion as well as additional findings beyond the scope of the research questions and implications for teaching and research.

Research Question 1

What preconceptions exist for second semester general chemistry students surrounding the organic chemistry lecture?

In this study, participants were asked by survey to identify what, if any, preconceptions they held concerning the organic chemistry lecture course. Further, interviewees were asked to expand upon their answers and describe in depth the

information they had previously identified. In the analysis of student interviews, the researcher observed six different preconceptions or types of information students had commented on concerning the organic chemistry lecture course. After identification of these six preconceptions, using only the interview participants, each participant interview and survey was studied and found to contain some combination of these six variables. As mentioned, due to the extremely low frequency of some of these responses, variables were systematically and statistically combined to form larger group variables. These preconception variables were outlined and presented in Table 6 in the previous chapter.

It was noted that the majority of students (71%) commented on the difficulty of the course. It was thought by the researcher, that to comment on the difficulty of a course, students must have prior experiences with the course itself, otherwise, they could only mention the anticipated or perceived difficulty. Considering that none of the students interviewed had any prior experience with organic chemistry, it was surprising to the researcher that they discussed the difficulty of the course as if they were experts and spoke less about anticipating the course to be difficult. The common theme identified by participants was that the organic chemistry course offered at each of their respective institutions was extremely difficult to complete successfully. Some examples of student comments during the interview, when asked to discuss what they had heard or what preconceptions they had about organic chemistry, are as follows:

> 109182: "…it's just hard and you have to study so much and if you fall behind you're just, you're screwed and that was about the [gist] of it, just everything that made it sound really bad"

> 109010: "…the hardest or one of the hardest classes at the school…time intensive is a common theme that I hear and a lot of memorization is another one…if you're good in general chemistry you might struggle in organic or if you're not so good in general you might do well in organic"

These quotes confirm the researcher's suspicions that general chemistry students have heard information pertaining to the difficulty of organic chemistry. In addition, the second quote identifies the variable that learning organic chemistry involves much memorization and is dependent on how well the student performed in their general chemistry course.

Students identifying that they had heard organic chemistry was difficult was not a surprising result. It was believed by the researcher that this perceived difficulty could be one possible variable affecting a student's success in the course. The confirmation of the presence of this difficulty variable is an important initial step towards investigating this belief.

Very few students (5%) commented that organic chemistry was "doable" or within their capabilities. These students were hopeful and showed optimism towards the organic chemistry course they were planning to take the following semester. Unfortunately, none of the students interviewed identified organic chemistry being within their capabilities as one of their preconceptions. This variable was one of the few that was not identified in the interviews; however, it was retained as a variable because it was identified in the student surveys. Since the interviews were voluntary, a true representative subset of the target population was not achieved. Despite this variable having a very low response, it was a variable showing a different preconception (although not identified by the students as a preconception) and was not dropped from the data set. Since a few students commented that organic chemistry was within their capabilities, it was notable and would make the study appear biased if dropped.

Lastly, some students (27%) commented that the preconceptions they held originated from what they had heard about the content material of the course. These students did not identify any specific topics or aspects of the course, but talked about the course overall. The information students had heard that was considered content-based included the conceptual and mathematical nature, the memorization load, and the workload of the course, as well as its dependency upon content from general chemistry.

In response to the first research question, it was concluded that the most common preconceptions students held related to what they had heard concerning organic chemistry. Students believed that the course was difficult and required an above average amount of work when compared to other courses with the same credit value. Rarely was it reported that organic chemistry was within a student's capabilities.

Research Question 2

Where do students' preconceptions originate?

In addition to identification of preconceptions, students were also asked to disclose the sources of these identified preconceptions. Upon initial analysis of the interviews, there were five identified sources of preconceptions: general peers and family, professor, teaching assistant (TA), advisor, and another class. Survey analysis revealed that many students had heard the information about organic chemistry from a friend. However, many of the students did not specify whether or not their "friend" had taken organic chemistry. Because "friend" was ambiguous, it was decided by the researcher not to differentiate between types of friends (academic or non-academic). Therefore, students indicating they heard the information from a friend were all coded

under the individual variable, general peers and family, and the group variable, non-academic sources. All student surveys were coded using these five identified sources, with many students responding they had heard information from at least one, if not more than one, source. During further analysis of the students' surveys, it was difficult to differentiate between students commenting they had heard information from a professor, versus a teaching assistant or advisor. Since, the organic chemistry background of all the identified sources was largely unknown, the five identified sources were combined into broader categories that could be better defined. The logical and statistical grouping of variables resulted in the formation of two types of sources: academic and non-academic. An emergent theme from all comments was that a student's information always originated from a person and not from any other external source such as a book, magazine, or website.

Academic sources consisted of any source that was an instructor or some person directly related to academia. This included a student's chemistry and biology professors, advisors (advisors from all identified majors would have had some background if not knowledge of organic chemistry), teaching assistants, and other classes (classes where organic chemistry topics may be introduced or discussed). Roughly, one-third of students (35%) commented that they had heard information from an academic source. An example of a student's comment during the interview when asked where the sources of their preconceptions concerning organic chemistry had originated is as follows:

> 109141: "Mostly it was from my chemistry teacher in high school, and he said that it was extremely difficult…"

This student identifies their high school chemistry teacher as being the source of their preconceptions. This was not an uncommon source since a large portion of students interviewed were freshman (47%).

A majority of students had heard information from non-academic sources (72%). Many of these students commented that their information came from either a friend or family member. Since students were not asked at the time of this research about the background of the friends or family members, this group was defined as having an unknown background in organic chemistry. Due to friends and family members having unknown academic backgrounds, they were considered non-academic. An example of a quote from an interview of a student identifying a non-academic source is as follows:

> 109301: “Honestly, it wasn’t anything good about it, I mean I just had mixed reactions because some people, I feel like people that don’t do well in the course give it a bad name, and if you do well in the course, well I mean they say you do have to study a lot for it.”

This student identifies “people” as being the source of their preconceptions. The researcher determined, based on the student’s response, that the “people” were peers of this student. The student differentiates between students who had done well in organic chemistry and those who had not. This interview was important because it was thought by the researcher that many students just listen to the information they are told without consideration of the source. This student highlighted that they had considered the source of the information.

When considering traditional general chemistry students are freshman, and probably live in dormitories, it was expected by the researcher that the main source of

preconceptions would be other students; however, the majority of students in this study received their information from non-academic sources. This may be a result of a majority (53%) of participants in this study being non-traditional students from participating institutions that were commuter schools. Overall, no relationship could be identified between the type of student and the source of their information.

It was concluded in response to the second research question that the most common source of student's preconceptions was non-academic sources. Although not being a majority of students, the number of students hearing information from academic sources was still notable.

Research Question 3

Are students able to define, in basic terms, organic chemistry?

Students mentioning they had heard negative comments regarding the organic chemistry course were often unaware of the content of an organic chemistry course. As a result, students were asked during their interviews if they knew what organic chemistry was or could define what is organic chemistry. Organic chemistry, as defined by this researcher, is the study of carbon containing compounds and the reactions and mechanisms involved. It was anticipated that students knowing what organic chemistry entails and what the course covers would identify some aspects similar to the researcher's definition. All students who were interviewed, however, had little understanding of what the organic chemistry course actually entailed. The most frequent definition of organic chemistry identified by the student interviews was that organic chemistry is, "…just the study of carbon compounds…"

Many of the student's definitions of organic chemistry were not incorrect; however, they displayed the lack of students' ability to explain what an organic chemistry course involves. Based on these results, it appears that a student's lack of explanation could reinforce the idea that students may have preconceptions and feelings associated with an unfamiliar course. In this research, the phenomenon was referred to as "fear of the unknown," and was thought to compound the student's feelings. The "fear of the unknown" and the information they heard from their peers may intensify the students' overall fear of organic chemistry. Additional feelings concerning the preconceptions formed were also identified by the students from what they had heard about organic chemistry.

Research Question 4

Are the preconceptions identified by the students during interviews correlated significantly to their success in the course (as assessed by student grades)?

After identification of student preconception variables, a quantitative analysis was performed to determine if any of the variables were significantly correlated with each student's success in organic chemistry. Due to the categorical nature of the identified variables, and the ordinal nature of student grades, an ordinal regression was chosen to answer this question. Upon statistical analysis, none of the variables showed significant correlation with students' four-week grades. It was initially thought by the researcher, that the information students hear concerning a course could greatly affect their performance. Students who were told the course was difficult were anticipated to have a more negative approach to the course. Student's negative course approach was

hypothesized to impact aspects of the students study habits and their attitudes towards the course. It was thought that students with this negative approach would achieve lower grades in the course. However, upon statistical analysis, it was determined that the information students heard concerning organic chemistry was not correlated with their grades in organic chemistry.

The variable identified as “organic chemistry is hard” had a correlation coefficient of -0.065 at a 0.198 significance level when compared with the four-week grade. This was a very weak correlation and was not statistically significant. It is important to note, however, that although the correlation was neither strong nor significant, the sign associated with this coefficient was negative. This may support the theory of the researcher that negative information heard about organic chemistry adversely affects students’ grades in the course. Further research should be done to investigate if the negative correlation truly affects student success.

The variable identified as “organic chemistry is passable” had a correlation coefficient of 0.005 at a 0.808 significance level when compared with the four-week grade. This variable is therefore insignificant and overall not correlated with students’ grades. This result was surprising because it was thought that students hearing more positive information concerning organic chemistry would perform better in the course. From the results, however, it appeared positive information concerning organic chemistry had no effect on student’s success in the course. It is important to note, however, that there were only five students responding that they had heard information that organic chemistry was within their capabilities. Due to only five percent of the population being

represented in this variable, it is possible there is not enough data to accurately determine and show the significance.

The variable identified as "content-based information was heard about organic chemistry" had a correlation coefficient of 0.037 at a 0.770 significance level when compared with the four-week grade. It was surmised that students would hear information concerning some of the more difficult aspects of organic chemistry such as mechanisms and reactions, instead of just hearing about the overall difficulty. Students hearing this negative information about specific topics could be adversely affected by this information and therefore approach the course more negatively resulting in a lower grade. However, students did not mention any specifics and only mentioned content-based information about the course overall. Student comments included in the content-based information category were those pertaining to the conceptual nature, memorization requirements, mathematical basis, and workload of the course.

Research Question 5

How do the students with identified preconceptions perform, as assessed by students' final grades, in the course when compared to those with minimal preconceptions?

Within the realms of this research, this question was unable to be adequately answered. It was initially thought that student participants would identify on the written survey both the presence and absence of preconceptions. The initial goal was to identify students with minimal preconceptions and compare their success in organic chemistry with those students identifying many preconceptions. This goal was difficult to attain since distinguishing students with minimal preconceptions and those with many

preconceptions is not possible at this point. Students may have only one large preconception but it may be equal to five smaller preconceptions. The inability to quantify preconceptions resulted in preconceptions being viewed as either existing or not existing, or students with and without preconceptions. Analysis of student surveys and interviews showed that all students identified preconceptions (either positive or negative), and no student identified themselves as having no preconceptions. A question on the written survey asked students to circle yes/no regarding whether they had any preconceptions concerning organic chemistry. It is important to note, that there were a few students who circled "no"; however, the researcher thought that these students were unsure about the definition of preconceptions and chose the answer "no" without truly understanding what is a preconception. Despite the novice face validity, interviews were voluntary and, unfortunately, none of the students who circled "no" but outlined preconceptions later in the survey volunteered to be interviewed. Students responding "they had heard no preconceptions" and then proceeded in the next question to identify specific preconceptions they held were included with those students specifically stating "yes they had preconceptions". Since every participant held preconceptions, a comparison as initially proposed in research question five could not be accomplished.

Additional Findings

During the course of this research project, there were many additional questions that arose. Initially, it was thought that the five previously identified research questions were thorough enough to address the various aspects of this project. However, once data collection began, further questions surfaced and were deemed appropriate for inclusion in

this research project. Following are additional questions addressing various aspects integral to the validity of this project.

> AQ1: What feelings do students associate with the preconceptions they have heard from other people?
>
> AQ2: What is the primary cause of the students' identified feelings concerning organic chemistry?
>
> AQ3: Is there a correlation between students General Chemistry I and II grades and their respective Organic Chemistry I grades?
>
> AQ4: Is there any correlation between a student's major and/or the student's class year with their success in organic chemistry?
>
> AQ5: Do any of the identified variables concerning a student's preconceptions, feelings, sources, or cause of feelings help predict whether or not a student is able to complete the organic chemistry course?

The results of these additional questions are presented in Chapter 4. A discussion of these results follows.

Additional Question 1

What feelings do students associate with the preconceptions they have heard from other people?

Analysis of the results of the student interviews revealed two types of feelings associated with organic chemistry, either negative or positive. Negative feelings were typically feelings such as fear, apprehension, concern, nervousness, or fear of the unknown. It was thought by the researcher that a student's feelings would impact their approach to and, therefore, success in organic chemistry. The more negative the feelings the students associated with organic chemistry, the more adversely it was thought to affect their grade. The majority of students (74%) had negative feelings when asked how

they felt about organic chemistry. An example of a student's response in which they identified negative feelings is as follows:

> 109122: "Um, I don't really know exactly what organic chemistry is about as of yet I… I'm kind of nervous about that and I don't know what to expect."

Upon analysis of the statistical results, negative feelings had a correlation coefficient of 0.016 at a 0.616 significance level when correlated to the four-week grade. This variable is therefore insignificant and overall not correlated with students' four-week grades. This result was surprising in two regards. First, the correlation coefficient was insignificant and second, negative feelings were positively correlated with student's four-week grades. It was thought that the more negative the feelings the student had, the lower their four-week grade would be. This may be because if students heard more negative things about a course, they may have been more likely to take it seriously and will have created more rigorous study habits in attempts to perform at a higher level in the course. Therefore, although negative feelings did not appear to be significantly correlated to student's four-week grade here, this is most likely due to the small data set. The finding is an interesting result that warrants further investigation.

Conversely, students with positive feelings towards the course were seen to have a negative relationship with their respective four-week success. The statistical results showed the correlation coefficient of -0.111 at a 0.370 significance level when correlated to the four-week grade. The positive feeling variable is therefore insignificant and minimally correlated with students' four-week grades. The correlation is a negative correlation in this instance, meaning, the more positive the students' feelings were towards organic chemistry, the lower their resulting four-week grade. The negative

correlation may be due to a similar phenomenon as seen with negative feelings. Students with positive feelings have a "false sense of ease" concerning the course. These students may enter the course with the mindset that they will succeed which may be viewed as false confidence. The false sense of confidence may cause these students to perform worse, therefore, receiving a lower four-week grade.

Additional Question 2

What is the primary cause of the student's identified feelings concerning organic chemistry?

One of the questions on the Student Questionnaire asked participants to identify the primary cause of their feelings. Survey analysis showed there were three variables identified by students as being a primary cause of their feelings concerning organic chemistry. The primary cause of a student's feelings was either a prior experience, the difficulty of the course, or what they had heard from a person. It was thought by the researcher that there could be a correlation between the student's identified primary cause of their feelings and their respective four-week grades.

The statistical analysis of student's prior experiences, when related to their four-week grade produced a correlation coefficient of -0.192 at a 0.018 significance level. This was the only variable showing significant correlation with a student's four-week grade; however, it was a very weak correlation. Students mentioning their prior experiences as being a cause of their feelings always spoke about these experiences in a positive manner. For example, students would comment that their prior experiences increased their confidence in chemistry or, because of their prior experiences, they were

not looking at organic chemistry in a negative light. An example of a student comment concerning their prior experiences is:

> 109064: "Um, well I've, I've, I've heard um, talk from different people saying it's a tough class. I don't really pay attention to it because its part of that ochem and biochem combination that I really liked… so um, I was actually really looking forward to it…"

This particular student mentioned prior experience in a positive manner and related this prior experience to their positive outlook towards organic chemistry. Also, due to the student's experiences, additional information the student had heard about the course was ignored.

It was hypothesized that a student's prior experiences and their confidence in chemistry would influence their grades in a positive manner. Students feeling confident with their chemistry knowledge were thought to have the ability to translate that confidence and knowledge from general chemistry to organic chemistry. Analysis of the statistical results determined that the students prior experiences were negatively correlated with their four-week grades. Due to this unexpected result, students' prior experiences were compared with their final grades in organic chemistry to determine if the same trend holds true. After statistical analysis of student's prior experiences with their final grades, the results showed a correlation coefficient of -0.265 at a 0.01 significance level. Again, the correlation was statistically significant; however, it was a very weak correlation. To explain the observed negative correlation, the content of both general chemistry and organic chemistry was considered. Traditionally, general chemistry covers a broad range of chemical topics spanning multiple sub-disciplines of chemistry. General chemistry is also traditionally steeped in mathematics. Organic

chemistry is a course, which delves into one sub-discipline of chemistry and is narrower but more specific in scope. Organic chemistry traditionally involves minimal to no mathematical equations or calculations. The researcher thought that students could be confident about their prior chemistry experiences because of their mathematical abilities. A student's confidence could be due to a successful mathematical background; however, when students begin organic chemistry and realize the mathematical aspect is minimal, they may struggle. Therefore, a student's prior experiences may not necessarily aid them in organic chemistry, adversely affecting their four-week and final grades.

A determination of the correlation between perceptions of the difficulty of the course as related to a student's four-week grade was performed to determine if any of the variables concerning a student's primary cause of their feelings were correlated with their success in the course. The statistical analysis yielded a correlation coefficient of 0.129 at a significance level of 0.575. The results showed an insignificant weak correlation.

The statistical analysis of a person being the primary cause of a student's identified feelings, when related to their four-week grade, provided a correlation coefficient of -0.100 at a significance level of 0.073. The coefficient displayed minimal correlation, also shown to be insignificant. Despite the lack of significance, since results did demonstrate that a person being the primary cause of student's feelings had a negative influence on their four-week grade, further investigation on a larger population should be investigated.

Additional Question 3

Is there a correlation between students General Chemistry I and II grades and their respective Organic Chemistry I grades?

After investigating the existence of correlations between a student's preconceptions, the sources of these preconceptions, student's feelings about organic chemistry, and the primary cause of their feelings, any trends in the demographic information provided by the students were further investigated. On the Student Questionnaire, participants were asked to provide their General Chemistry I grade. These grades were strictly a student reported grade on a scale of A to F. Grades were not validated; however, it was observed that students reported a broad range of grades, and not all students reported grades on the higher end of the scale. In addition to reporting their General Chemistry I grades, students were also asked to predict their General Chemistry II final grade. Since the surveys were administered within one month of the end of the semester, it was theorized that students would have an accurate idea of how they were currently performing in the course and could accurately predict their final grade in the course. Similar to the General Chemistry I grades, students reported a broad range of grades, and grades were not all located on the higher end of the scale.

The correlation between these student reported general chemistry grades and both each student's four-week and final grades in organic chemistry were investigated. The correlation coefficient between a student's General Chemistry I grade and their four-week grade was -0.561; between their General Chemistry I grade and their final grade was -0.537; between their predicted General Chemistry II grade and their four-week grade was -0.520; and between their predicted General Chemistry II grade and their final

grade was -0.492. All correlations were reported at a 0.01 significance level. All were moderate correlations and all were negatively correlated. These results were interesting because the higher the grades students reported in both General Chemistry I and II, the lower the grade they received in organic chemistry both at the four-week mark and as their final grade. Student's success in general chemistry is therefore inversely related to their success in organic chemistry in this study.

During the interviews, some students made statements concerning the inverse relationship between success in general chemistry and success in organic chemistry. Initially, these statements made by the students were thought to be inaccurate. An example of a student's statement can be seen below.

> 109010: "…If you're good in general chemistry you might struggle in organic or if you're not so good in general you might do well in organic"

This inverse relationship identified by the students and supported in the statistical data was an interesting finding of this research that warrants further investigation.

Additional Question 4

Is there any correlation between a student's major and/or the student's class year with their success in organic chemistry?

Another question of interest was the correlation between a student's major and their success in organic chemistry. The question was posed to determine if students with certain majors perform better in organic chemistry than others due to their intrinsic and extrinsic motivation factors. From the survey results, it was determined that the majority of students (65%) were biology majors, some students were chemistry or biochemistry

majors (17%), a few were sports and exercise science majors (6%), and the remaining students were grouped into an ‘other’ category (12%). Since the majority of students were biology or chemistry majors, the researcher decided to investigate the differences in organic chemistry success between these two groups.

Frequencies tables were obtained with the biology and chemistry majors and their four-week grades in organic chemistry. It was observed that all grades A to D were represented in both majors, and a grade of F was the only grade minimally represented. It was apparent that no one grade (A to D) was more represented than the others. A chi-squared analysis was performed to determine if being either a biology or chemistry major could predict a student’s success in organic chemistry. Upon analysis of the chi-square data, it was determined that there was no significant difference in either major as a predictor for organic chemistry success. The Pearson chi-squared significance value was 0.753, which is far from being significant at a 0.05 level. Analysis was not done with other majors because of the extremely small population size, which may result in invalid skewed results. From the data it was determined there was no effect between a student’s major being biology or chemistry and their four-week organic chemistry grade.

In addition to major, the type of student, or class year of the students, was also studied to determine if it affected their success in organic chemistry. As observed in the surveys there were two types of students: traditional (enrolled in organic chemistry as a sophomore) and non-traditional (enrolled in organic chemistry as a junior or senior). Both traditional students (47%) and non-traditional students (53%) had well represented and evenly dispersed grade frequencies (A to D). Upon chi-square analysis, the Pearson chi-square significance value was reported to be 0.344, which is insignificant at a 0.05

level. Therefore, the type of student, traditional or non-traditional, is not an accurate predictor of student success in organic chemistry.

Additional Question 5

Do any of the identified variables concerning a student's preconceptions, feelings, sources, or cause of feelings help predict whether or not a student is able to complete the organic chemistry course?

The last question addressed in this research was the effect of the identified variables on the student's ability to complete organic chemistry. Throughout the duration of this research, participants withdrew from the study, decreasing the overall population. Some of these participants withdrew from the course prior to completion and did not have a final organic chemistry grade. The researcher felt that the students who did not complete the course may have had problems because they had heard the course was too difficult, and their feelings were so negative possibly preventing them from succeeding in the course.

A chi-square analysis was conducted to determine if any identified variable was an accurate predictor of student completion of organic chemistry. Upon analysis of the Fisher exact test ratio, none of the variables were determined to be significant and were not accurate predictors of student completion of organic chemistry. These results were not surprising to the researcher. There are many obvious factors that may contribute to a student's completion of a course independent of their preconceptions including health and financial reasons. Although initial thoughts were that a student's preconceptions could affect their completion of the course, upon analysis of the results and further

thought, no significant correlation was found between the preconception variables and completion of organic chemistry.

Lastly, correlations between a student's four-week or final grades in organic chemistry and their completion of the course were not investigated due to the extremely small population size (N = 11) of those students withdrawing. Upon anecdotal observations, however, students withdrawing from the course were performing poorly (D or F) at their four-week grade. Investigation of any existing trends between a student's organic grades and their completion of the course will be considered in future projects.

Implications for Teaching

The results of this study showed that student preconceptions were not correlated with success in organic chemistry as measured by four-week grade. Due to the small population size used, the merits of these results cannot be generalized beyond the population of this project. Based on the qualitative information obtained during student interviews, it was thought there may be aspects of organic chemistry that could be addressed in an attempt to improve student success in this course.

One finding that stands out is the level of a student's confidence and its effect on student success. Anecdotal results from student interviews show students with a reasonable foundation and confidence in chemistry were more optimistic towards their success and approach to organic chemistry as seen in the quote below.

> 109064: "I have had to help a lot of people with the basic chemistry, which I never thought I would have to do because I never thought I liked chemistry. But the interesting thing is I think once you have some repetition with the material and once you figure out little ways to memorize initially but then uhm, you end up learning it because it makes sense… what you memorize makes sense… Um, so I uh, also hope

> that some of the solution stuff in the Ochem will come a little bit more naturally after I've taken it right after Gen Chem. II."

Student confidence is an important aspect of learning and, as stated by 33% of students in this dissertation study during the surveys, is an important aspect governing their preconceptions and feelings towards a course. Therefore, it is important for instructors to foster student confidence through encouraging students' understanding of course material. In one study with engineering student's confidence in various areas including chemistry, it was seen that students displaying more confidence (as determined by a Likert Scale confident assessment) had significantly greater ability to succeed in engineering.[137] Other studies have looked at the use of visual aides, supporting data, and practice as increasing student confidence[138] as well as investigating various teaching methods and assessments resulting in an increase in students' knowledge and understanding of chemistry.[139] Ultimately it is the students' responsibility to take ownership of the material; however, there are various methods instructors can use to aid the students in this process. Increasing the problem-based learning[140] and structuring certain aspects of the course as inquiry-based[141], are some techniques thought to facilitate students ownership of the material. By structuring courses using problem-based learning, research has shown that students develop the potential to develop a flexible

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[137] Besterfield-sacre, M., et al. (1998). *Understanding student confidence as it related to first year achievement.* Paper presented at the Frontiers in Education Conference.
[138] Blanc, R. and Martin, D. (1994). Supplemental instruction: Increasing student performance and persistence in difficult academic courses. *Academic Medicine*, *69*(6), 452.
[139] Treagust, D. and Chittleborough, G. (2001). Chemistry: A matter of understanding representations. *Advances in Research on Teaching*, *8*, 239-268.
[140] Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235-266.
[141] Green, W., et al. (2004). " Prompted" Inquiry-based learning in the introductory chemistry laboratory. *Journal of Chemical Education*, *81*(2), 239-241.

understanding of material, meaning students take ownership of the material. Additionally, inquiry-based learning is more student-centered and provides students with the opportunity to improve their understanding through practice.[142] Students develop, on their own, an understanding of scientific knowledge and scientific tools. Students then have the inquiry abilities, investigational skills, and an understanding of scientific concepts. Other studies have used inquiry-based learning as a method to encourage students to investigate projects and experiments of personal interest to them. Students were seen to be more excited and had added anticipation towards the learning process. Through these methods (problem-based learning and inquiry-based learning), students were encouraged to take more responsibility for their learning instead of the traditional lecture (not student centered). If learning becomes student-centered, it is hoped that students would become more intrinsically motivated and focus less on the extrinsic motivation. Studies have shown that students who have active learning goals and have greater intrinsic motivation, have higher achievement and performance in a course even in the face of adversity.[143] During this research, student's learning goals were seen to have a positive affect on their performance and motivation, however, learning goals were also seen to predict weakened performance and motivation. The research study displays that both student's learning goals and motivation factors affect their success in a course. Additionally research further supports that students who are specifically intrinsically

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[142] Edelson, D., et al. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences*, *8*(3), 391-450.
[143] Grant, H. and Dweck, C. (2003). Clarifying achievement goals and their impact. *Journal of personality and social psychology*, *85*, 541-553.

motivated showed improved performance and persistence.[144] The research was done with both high school and college students in which they completed a questionnaire about their motivation and engagement with the material after performing a given exercise. The results of this research are important, as they display students can become more dedicated and engaged in the material they are learning through the use of specifically tailored exercises.

Additionally, this research showed that the early introduction of a course induced excitement and caused students to be more positive towards the upcoming course. This finding was the result of an organic chemist teaching a general chemistry class at one of the participating institutions. The instructor used organic reactions in a general chemistry context. The students became familiar with some aspects of organic chemistry and were, therefore, more positive and excited about organic chemistry as demonstrated by the quote below.

> 109064: "And I've had the combination of organic and biochemistry but I don't think that that counts… Now the ochem, where I can draw pictures and its math, is really interesting to me… and before I even knew I had to take organic, I, strangely enough, I was considering taking ochem if I had to have more chemistry hours just because that was the part of the biochem that I loved."

The belief of this researcher is that the early introduction may alleviate the 'fear of the unknown' that was addressed earlier. Further research needs to be done concerning this finding as there may be other factors such as the institution or the instructor's personality that may explain this result. Until that point, early integration of

[144] Vansteenkiste, M., et al. (2004). Motivating learning, performance, and persistence: The synergistic effects of intrinsic goal contents and autonomy-supportive contexts. *Journal of personality and social psychology*, *87*, 246-260.

organic chemistry in general chemistry may help limit students' negative preconceptions and improve their success.

Lastly, it was observed that there were stories and preconceptions surrounding organic chemistry. Many of the preconceptions concerning organic chemistry were about the perceived difficulty reported from non-academic sources, and the negative feelings associated with these preconceptions. These preconceptions could be detrimental to a student's approach to the course as well as their overall success; the preconceptions may hinder student's positive attitudes towards the course.[145] In one such research project, factors affecting student's positive attitudes were investigated, and it was found that students with more negative views about a course had more negative attitudes towards that course. Therefore, instructors may consider creating a positive and comfortable learning environment the first day of class by conveying to the students that the material may be hard; however, by studying, practicing, and asking questions they can improve success in the course. Students consistently hearing about the impossibility of a task, in this case, successful completion of organic chemistry, may allow this information to affect their motivation[9] and self-efficacy[146]. Students may encounter additional "difficult" courses and other obstacles during their academic careers; however, courses and obstacles can be conquered. Instructors may also consider encouraging understanding of the material and problem-solving skills. This understanding can be

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[145]Berg, C.A.R. (2005). Factors related to observed attitude change toward learning chemistry among university students. *Chemistry Education Research and Practice*, *6*(1), 1-18.

[146] Crippen, K.J. and Earl, B.L. (2007). The impact of web-based worked examples and self-explanation on performance, problem solving, and self-efficacy. *Computers & Education*, *49*(3), 809-821.

reinforced using a variety of techniques such as visualizations[147], animations[148], demonstrations[149], and the more traditional explanations and practice. All of these techniques have been shown in previous research to aid in students learning and foster understanding of material, as well as cause students to become more excited about the material.

Although the research presented here was centered on organic chemistry, it is believed that the implications of this research have the potential to affect various aspects when teaching any sub-discipline of chemistry. Based on the results of this research, preconceptions do exist, and the majority of them are negative. Student's negative attitudes are enhanced by their lack of understanding of what the new material entails. These negative thoughts may affect student performance in a course, and therefore, warrant further investigation.

Implications for Research

The focus of this study was to investigate students' preconceptions concerning organic chemistry as well as to correlate the identified information with each student's four-week grade in organic chemistry. In lieu of these results, other potential factors need to be investigated. In addition to identifying other potential research projects, methods to improve *this* research project were also identified.

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[147] Jones, L.L., et al. (2005). Molecular visualization in chemistry education: The role of multidisciplinary collaboration. *Chem. Educ. Res. Pract*, *6*, 136-149.
[148] Williamson, V. and Abraham, M. (2006). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, *32*(5), 521-534.
[149] Meyer, L., et al. (2003). Using demonstrations to promote student comprehension in chemistry. *Journal of Chemical Education*, *80*(4), 431.

After conducting this research, there were some aspects thought to be important for modification. First, instead of collecting grades on an A-F scale, grade collection on a percent scale was determined to be more useful. A percent scale would also allow for further calculations such as average and standard deviation allowing the research to access additional statistics. With more deviations in grade, more significant correlations might exist. Also, students' general chemistry grades would be verified instead of just student reported. Instructors would be asked to provide participants' grades on a percent scale. In this project there appeared to be a significant correlation with the student reported grades in general chemistry and their grades in organic chemistry and subsequent verification would add legitimacy to this result. Additional interviews should be conducted to further novice face validate and elaborate on a student's written comments. Valuable information was obtained during student interviews. As seen in this project, with the limited number of interviews conducted, there were some questions that may have been misinterpreted, however, and were not identified by the interviewees. By conducting more interviews in the future, novice face validity would be enhanced, and students may identify additional preconceptions, which may warrant further investigation. Lastly, to improve statistical results, a larger initial population should be sought (via additional institutions or multiple semesters), with the hope that participant attrition will have less impact on the final number of participants. During the interviews, students identified thoughts and ideas as well as theories that may otherwise have been missed if only a survey had been administered. By interviewing more students from a larger participant pool, other variables may be identified.

Besides amending some aspects of this research, there are also many ideas for future research areas thought to be of interest and worth further investigation. In the opinion of the researcher, and despite the outcomes presented here, it is still hypothesized that student's preconceptions may affect some aspects of their academic careers. Explorations into the identity of possible aspects are of interest. One exploration into identifying suggestions as to the identity of the unknown aspects is the investigation of an intermediate variable that may bridge the identified variables and students' four-week grades. Future research is important to identify this unknown variable and determine if it is correlated with both the identified preconception variables and students' four-week grades. In addition, student grades will be collected more frequently than just at four-weeks and at the end of the semester, and data will be collected over multiple years. The minimal correlations found in this study could be a result of a short time frame. The study was conducted over the course of two consecutive semesters; whereas in the future, the study would be designed to be more longitudinal over a few years so as to increase the population size. Further variables thought to potentially be of interest for further investigations and correlation to the identified variables are a student's study habits and motivation factors. An exploratory qualitative study could be done to categorize student study habits and a student's causes of motivation, whether intrinsic or extrinsic. Lastly, there are other factors that are thought to affect student success in organic chemistry. Course-related factors such as professor or textbook, or external factors such as health, economic status, or other courses could affect a student's success in organic chemistry. These factors warrant further investigation and categorization to determine their affect, if any.

Another interesting finding that became evident during this research was the effect of the early introduction of organic chemistry. In one of the participating institutions, the general chemistry instructor also taught organic chemistry. This professor used organic reactions when explaining general chemistry topics. The instructor commented they never really advertised organic chemistry but subtly worked in organic materials or reactions in their explanations and told the students this was an introduction to organic chemistry. This introduction to organic chemistry topics gave students an early experience with some of the material to be covered the following semester in organic chemistry. The population at this institution commented, on the written surveys, about this early introduction.

> 109109: "My proff [sic] is an organic teacher, so it actually seems more interesting than gen chem… I am excited to say I am in ochem"

> 109061: "I've been told we will study Molecular Structure and the behavior of the chemicals and that there is less math…I am looking forward to organic chemistry… I think it may be more interesting."

Students reported that this introduction to organic chemistry caused them to be less negative towards organic chemistry and more optimistic and confident. This finding is worth further investigation but was not part of the realm of this research. Future research could investigate this phenomenon of the early introduction of organic chemistry in general chemistry and its effects on students' preconceptions and feelings about organic chemistry. The anecdotal information obtained from the surveys about early introduction was due to an instructor affect. In this case, the same instructor taught general chemistry

and organic chemistry. Further research would investigate the effect of early introduction when the instructors for general and organic chemistry are the same and are different.

The last proposed extension of this project is the broadening to encompass all sub-disciplines of chemistry. This project focuses solely on the effects of preconceptions concerning organic chemistry. However, preconceptions may be prevalent in college student populations and therefore may affect more courses than just organic chemistry. Explorations into the entire discipline of chemistry within the scope of this research project are of future interest.

Conclusions

Student preconceptions concerning organic chemistry were investigated for their existence, sources, and feelings associated with them. The most common preconception was that organic chemistry is a difficult course. This negative preconception originated mainly from information obtained from other people (i.e., a student's friends or family members) and not web sources or magazines. Students largely displayed negative feelings when talking about the upcoming organic chemistry course they would be taking the following semester. Students were also unable to explain what is meant by organic chemistry and only knew the course is based on carbon. A student's lack of understanding about organic chemistry promoted their negative feelings.

Once the student's preconceptions, sources, and feelings were identified and defined, they were correlated with students' four-week grades. The only variable significantly correlated with four-week grade was a student's prior experiences identified as being a cause of their feelings. The correlation between a student's prior experiences

was very weak but was significantly correlated with the student's final grade in organic chemistry. This correlation was also negatively related to four-week grade.

The fact that no variables were significantly correlated with four-week grade in organic chemistry resulted in more questions being asked in attempts to determine other factors that could affect student success in organic chemistry.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPLICATION

Application for Expedited IRB Review

I. Statement of Problem/ Research Question

The purpose of this phenomenological study is to determine the variables, and their sources, affecting student attitudes towards organic chemistry prior to taking the course. Once the variables are identified, the second purpose of this study is to determine the relationship or correlation between those variables and the success of the students in the course.

Preconceptions will be generally defined as any attitude or belief held by a student about organic chemistry lecture that is founded by a) something they heard from someone else (way of mouth) or b) something they have read (way of word). These beliefs are based on little to no prior knowledge of the field and have helped to form some preconceptions (either positive or negative) about the course itself and its material.

This study will determine what preconceptions second semester general chemistry students have about organic chemistry. Many of them hear from other students who have already taken the course or are currently enrolled in the course how difficult it is to do well in the course. In addition to the general feeling that many students (including people outside of a science field) have about organic chemistry. The study will determine what if any preconceptions exist on specific topics. For example, if the researcher were to ask a general chemistry student what they though about mechanisms, what would they say? Would this word cause them to have negative or positive feelings? Do students even know what the word "organic" means? The study will probe whether or not students ever have feelings about the word, if they know what it means. It is hypothesized that people, in general, do not necessarily have to know what something means to have feelings

associated with it. Furthermore, this research is designed to discover the sources of these preconceptions as the current literature fails to mention this aspect of preconceptions. It is hypothesized that word of mouth is the most prevalent way that students form these beliefs, but they also may have read or seen something influencing their ideas and opinions about organic chemistry. After it has been determined what preconceptions students have and the sources of the preconceptions, the study will build off of this newly acquired information to determine how these preconceptions affect student success, measuring by obtaining students grades four weeks into the semester. Quantitative methods including an ANOVA analysis will be done to determine the significance of the correlation between specific students preconceptions and success in organic chemistry. Once the students have matriculated from general chemistry into organic chemistry, and data is collected, the information will be used for Jodie Wasacz's dissertation. Based on the findings of this particular study, future research can then be done to develop a teaching method that can be used by organic chemistry professors to de-construct these identified preconceptions to help students to learn the material and not be intimidated or afraid of it and hopefully improve their grades.

Here are the research questions outlined specifically for this particular project.

- What preconceptions exist for second semester general chemistry students surrounding the organic chemistry lecture?
- From where do students acquire these preconceptions?
- Are there any key terms or words from organic chemistry that students are particularly apprehensive about?

- If there are key terms or words, does the student know what it means; are their apprehensions grounded in actual knowledge?
- If there are key terms or words, what attitudes are associated with them? (negative or positive) Are students scared of that topic, do they have preconceived fears about it?
- Are the preconceptions, identified by the students during interviews, correlated significantly to their success in the course (student grades)?
- How do the students with identified preconceptions perform in the course when compared with those without any preconceptions?
- How do the preconceptions affect how the student approaches the course?

II. Methods:

Participants:

To gain access to the participants, the researcher will initially be talking to the professors teaching second semester general chemistry in the spring, as well as teaching assistants for the general chemistry labs. This study will solely focus on second semester general chemistry students, and students will be targeting during lecture and laboratory periods (depending on school). For the initial qualitative part of the research dealing with second semester general chemistry students, participants will also be used from Hartwick College (New York), and Albion College (Michigan), University of Colorado Denver, Metro State College, (signed consent forms attached) in addition to students here at the University of Northern Colorado. All the students in the participating courses will be given the survey and by filling it out and returning it along with the signed consent form

will become the participants for the first part of my study. At the University of Colorado Denver (UCD), Metro State College (Metro), Hartwick, and Albion surveys will be administered to student during lecture to obtain the largest population of students at one time. At the University of Northern Colorado student surveys will be given out during the laboratory sections. Being a teaching assistant myself, it will be easier to gain access to the labs by asking the other graduate student teaching assistants for their assistance. To prevent any sort of bias I will not include my laboratory section I happen to be teaching in the participation phase of this research project.

Once access is gained to the laboratory sections and lecture (UCD, Metro, Hartwick, Albion), short student questionnaires will be distributed for students to fill out. Barring no scheduling conflicts the researcher (Jodie Wasacz) will be distributing the survey to the students at UCD and Metro. If the researcher cannot be there to distribute the survey in person, the professor the lecture will give the survey out for students and read to them an explanation of the research as written by the researcher (Hartwick and Albion). The questionnaire will ask information like what is your major, are you planning on taking organic chemistry, Has anyone told you any information about the organic chemistry course? (Yes / No) Please explain) The last part of the questionnaire will ask the students if they are willing to talk about their feelings about organic chemistry in an interview. This questionnaire will be used to select participants based on the student's yes/no voluntary response. The number of students surveyed will be based on each school and the number of voluntary participants. At all participating school, all the students taking second semester general chemistry will be given the survey (they can choose not to participate). At all schools some discretion will be used during selecting

because participants are only useful if they have to take organic chemistry. Students who do not have to take organic chemistry are not of interest at this time. This will help to narrow down my population and select some volunteers for the interviews without the actual laboratory-teaching assistant knowing who or how the individual students responded.

The students who will be interviewed will be purposely selected from the pool of students responding “yes” to the willingness to participate in a survey question. Purposeful selection of students will be done to ensure that a representative selection of majors, GPA’s, and genders are interviewed. The students who meet my participant criteria and agreed to participate based on the questionnaire will be further contacted and an interview time will be arranged based on the availability and convenience of the student participant. Interviews will be conducted on a maximum of 40 students (this is all subject to the number of volunteers from each institution). The maximum number of students will be interviewed based on their willingness to participate and their answers to the survey questions so as to get the most diverse population to interview. Interviews will be conducted in person (UNC, UCD, and Metro) by the primary researcher (Jodie Wasacz.), and will take place at a convenient location of the interviewee’s choice (ex. Local coffee shop, university center, library, etc). Due to the location of the other two participating school (New York and Michigan) interviews will have to be conducted over the phone. During interviews the researcher will be in an office in Ross 3566 with the door closed so as to maintain student confidentiality. It will be highly suggested to students upon initial contact before interviews, that during the phone interview they should be in a private area such as an office or classroom. However, the researcher will

not be there to ensure this, so it is at the student's own risk that they chose a place in which to participate in the phone interview. The maximum length of time required from participants from beginning to end of this research project will be approximately 1 hour (depending on the duration of interviews).

Following student interviews, since there is no deception involved in the research and all aspects of the research will be outlined to the student prior to their consent to participate, there will be no need for debriefing.

Confidentiality is a concern of any research project containing interviews and questionnaires. In this research project, confidentiality will be maintained at all times. Student questionnaires will be stored in locked file cabinets in the Chemical Education Research Room (Ross 3690) for those students who are selected and agree to participate in this study.

Students participating will be assigned a numerical code, which will be used throughout the duration of this research project. All other student questionnaires will not be useful and will be shredded in a locked paper shredder. Interviews will be coded with the numerical code corresponding to students survey, recorded and transcribed and will be stored in separate locked filing cabinets in the researchers office (Ross 3566) as the questionnaire. Only the researcher will know the numerical codes corresponding to student's names. Throughout the interviews and transcriptions students names will not be referred to or stated. Transcription of the interviews will be done by the primary researcher (Jodie Wasacz). After transcription, interviews will be deleted.

Once student grades are obtained, student names are no longer needed. Grades will be corresponded to the student interview and initial survey. Once this is in place

student names will no longer be of use and will be disposed of. The student name section of the survey will be detached and shredded in locked paper shredder. From this point forward, only numerical codes will identify students and will not be associated with a name. By coding the interview with numbers and not the consent form once student names are discarded, the consent form bearing participants names will be unable to be tied back to corresponding numerical code.

Procedure:

The forms of data that will be most useful for this study are surveys and interviews. To address the first two research questions in this study, open-ended surveys will be given to the participants of the study. The use of open-ended surveys allows students to identify any preconceptions they have freely with no constraints. Since the question is to find out what preconceptions exist, using open-ended questions allows students to identify anything they wish to make known. This was determined to be the best method to determine what preconceptions exist because the ones that students identify may or may not be something expected by the researcher and would otherwise be overlooked. The surveys will be administered during the first 10 minutes of laboratory or lecture (depending on each institution). This initial survey consists of demographic type questions as well as questions aimed at identifying what preconceptions students have and the source of these preconceptions.

To address the third, fourth, and fifth research questions, student interviews will be conducted. As previously stated, participants for the surveys will be chosen to be the most representative sample of students. To be considered a representative sample,

interviewees will be chosen who come from a variety of majors, genders, current course grades, and types of students (traditional verses non-traditional). During these interviews students will be asked more specific questions and asked to expand more on their thoughts. These specifics include any details of the course including, exams, concepts, homeworks, etc that they may have heard something about influencing their preconceptions of the course overall as a whole. Since the written surveys will already be analyzed, the survey questions will be made specifically for each interviewee based on how they answered questions on their surveys. The surveys therefore have a twofold purpose. One is to verify what participants said in the written survey and ensure the researcher understands their perspective; two is to expand on their responses and gain more information than a quick five-minute survey can provide. Through these interviews students will be able to highlight any specific concepts or aspects of the course that they may hold some preconceptions about (positive or negative). This will allow the researcher to address the third-fifth research questions.

Proposed Analysis:

From this point in the research there is a shift from qualitative research to quantitative research. To address the sixth and seventh research questions, analysis of variance (ANOVA) will be used. This will be done to determine if there is a correlation between the preconceptions students have and their success in organic chemistry. To do this first all of the student responses identified in the written surveys will be coded. Since all of the variables identified will be categorical they will be grouped and then coded using numbers. For example, some of the groups expected to be observed are as follows:

students who have heard that organic chemistry is hard in general, students who have heard that the exams are hard, and students who think organic chemistry will be hard based on their current performance in second semester general chemistry. To code the variables, the students who have heard that exams are hard will be designated with a "1" while the students who haven't heard anything about exams will be designated with a "0". Using this coding system for each variable identified, or not identified by participants will result in each student having a certain code (list of zeros and ones for each variable). These will make up the predictor variables. The criterion variable will be student success in the course. Student success in the course will be measure by taking the students average four weeks into the organic chemistry course. This average will consist of four quiz grades only. The reason behind measuring student success after only four weeks in organic chemistry is to minimize the impact of other outside variables. By measuring their grades after only four weeks the following variables will not affect the results: laboratory grades and stereochemistry. Students often comment that their laboratory experiences help them understand the lecture material better. This could cause inflation in their overall lecture grade. Conversely, students often comment they have difficulties "seeing" stereochemistry, due to the problems visualizing objects in 3-D when they are written and presented in the book in 2-D. This tends to cause students grades to deteriorate. These two factors could cause changes in their overall grade resulting in other aspects other than the preconceptions causing changes in the success of students in organic chemistry. By taking student grades only four weeks into the semester, these outside factors will not be influencing student grades, and student grades will, therefore, be affected only by their individual approaches to the course. These individual

approaches are assumed to be shaped by student's preconceptions about the course. The results of the ANOVA analysis will then allow the researcher to determine if there is any significant correlation between student preconceptions and other identified variables and their overall success in organic chemistry.

The last aspect of this research will answer the final research question. To determine if student's preconceptions affect how they approach the course, the last thing that will be done is a post analysis interview. After student's grades are obtained and the ANOVA analysis is done, short follow-up interviews will then be conducted with the participants. These interviews will be designed to ask students if they think any of their identified preconceptions affected their approach to the course.

By starting with qualitative analysis and determining what preconceptions exist, then correlating preconceptions quantitatively to students' success in the course, and lastly, re-interviewing students to see if they think these preconceptions influenced their approach to the course, all the research questions of this particular study can be answered and addressed thoroughly.

III. Risks/Benefits and Costs/Compensation to Participants:

There is minimal risk to the participants. As previously described once all data has been collected prior to analysis student names will be detached from the numerical identifier and shredded. Upon this point there will be no way to connect numerical codes with any student name. All answers will be completely confidential and will in no way ever be traced back to any specific student.

For the interviews conducted in person, the researchers will provide a light snack as well as a gift card in the amount of $10 to a designated place such as Starbucks, Barnes and Nobles, Taco Bell, or Subway.

Interviews being conducted over the phone (Hartwick and Albion) will have minimal risks as well. Students will have complete choice over the location of the interview. Compensation in the form of gift cards or extra credit to the students participating will be used at the discretion of the professor.

IV. Grant Information:

Not applicable

V. Disposition of Data:

Numbers will identify the students participating in the student survey. The same number will be used to identify that student during the interview. The interview recordings will not have the student's name or any information that can directly link them to the interview. Interviews will be stored separately from the student surveys, which will have the numeric identifier on it. Once grades are received student names will no longer be needed and will be discarded. Students will only be identified by a numerical code that will not be able to be traced back to their names. Consent forms will be the only form with student names on it, however, numerical codes will not be on the consent forms. These forms will be stored in locked file cabinets. Interviews will be erased no more than six months after the date of the interview.

VI. Justification for Expedited IRB:

This study qualifies for an expedited IRB because the participants are adults, data will be collected in a normal educational setting, the data are not sensitive in nature and accidental disclosure would not place the participants at risk, and no identifiers will link individuals to their responses.

VII. Documentation:

Informed Consent Form

Student Questionnaire (written survey)

General Student Survey Questions

UNIVERSITY of NORTHERN COLORADO

Informed Consent: Secondary Chemistry Students
University of Northern Colorado
Project Title: Determination of Student Preconceptions about Organic Chemistry, Stage 1

Researcher: Jodie Wasacz, doctoral student in chemistry education.
Phone number: (970) 351 - 1291
Research Advisor: Kimberly Pacheco, Ph D., Department of Chemistry and Biochemistry
Phone Number: (970) 351 - 2148

Purpose: The purpose of this study is to investigate what preconceptions might exist concerning organic chemistry lecture. The specific goal of this step of the research is to understand what preconceptions exist and what the source of these preconceptions is.

Procedure: During this written survey, you will be asked a series of questions pertaining to what you know, have heard, or feel about organic chemistry. Questions will be very general for example: Has anyone told you any information about the organic chemistry course? (Yes / No) Please explain. Students will not be asked to evaluate other students or the teacher just merely to identify any preconceptions they have about the course and their source. The entire survey will take about 5-10 minutes. In addition to survey questions there are a few survey questions pertaining to demographic information (major, class year, projected grade).

Risks and Benefits to Participants: There are no anticipated risks to participants. Your answers will be kept confidential and your name will not be recorded or associated with your interview. Your answers will not be used in the determination of your grade. It is possible that you may benefit from new insights regarding what your preconceptions are about organic chemistry.

Compensation: Due to the shortness of the written survey there will be no compensation, at this point, for participants.

Page 1 of 2 _____
(Participant's initial here)

Confidentiality: We intend to maintain confidentiality by storing signed consent forms separate from the data so that names can not be linked to the information collected. Additionally, we will use numbers rather than participants' names in all reports of our findings. Students names will be cut off the bottom of the survey and shredded to ensure anonymity. The following fall, upon student consent, the grades will be obtained from the first semester organic chemistry professor.

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may ask now. You may also contact me or my advisor at the phone numbers indicated at the top of this form.

Thank you for considering participation in our research.

Sincerely, ________________________

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. Your decision will be respected with no coercion or prejudice. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Sponsored Programs and Academic Research Center, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1907.

Print name____________________________

____ __________________
Participant's Signature Date

____ __________________
Researcher's Signature Date

In addition I give the research, Jodie Wasacz, to acquire my first months worth of grades and my final grade from first semester Organic Chemistry next fall.

____ __________________
Participant's Signature Date

Informed Consent: Secondary Chemistry Students
University of Northern Colorado
Project Title: Determination of Student Preconceptions about Organic Chemistry, Stage 2

Researcher: Jodie Wasacz, graduate student in chemistry education.
Phone number: (970) 351 - 1291
Research Advisor: Kimberly Pacheco, Ph D., Department of Chemistry and Biochemistry
Phone Number: (970) 351 - 2148

Purpose: The purpose of this study is to investigate what preconceptions might exist concerning organic chemistry lecture. The specific goal of this step of the research is to understand what preconceptions exist and what the source of these preconceptions is. In addition student preconceptions will be correlated with student grades.

Procedure: During this interview, I will ask you a series of questions pertaining to what you know, have heard, or feel about organic chemistry. Questions will be very broad for example: Explain/describe in your own words what you think about organic chemistry right now. Students will not be asked to evaluate other students or the teacher just merely to identify any preconceptions they have about the course and their source. The entire interview will take about 30 minutes. Interviews will be audio recorded. Any identifiers specific to the student (i.e student name) will not be said during the audio recording to preserve confidentiality. The following fall, upon student consent, the first month of grades will be obtained from the first semester organic chemistry professor.

Risks and Benefits to Participants: There is a minimal risk to participants. Your answers will be kept confidential and your name will not be recorded or associated with your interview. Your answers will not be used in the determination of your grade. It is possible that you may benefit from new insights regarding what your preconceptions are about organic chemistry. Grades will not correlated to student names once obtained.

Compensation: The researchers will provide a light snack during the interview process as well as a gift card in the amount of $10 to a designated place such as Starbucks, Barnes and Nobles, Taco Bell, or Subway.

Confidentiality: We intend to maintain confidentiality by storing signed consent forms separate from the data so that names cannot be linked to the information collected. Additionally, we will use numbers rather than participants' names in all reports of our findings. These numbers will not be correlated to student names in any way and upon completion of data collection there will be no way to trace student names to any particular number and then deleted. Audio recordings of interviews will be transcribed with numbers replacing participants' names. Names will be kept on the surveys until the grades are obtained. Once obtained names will be cut off the survey and shredded. Upon this point all information is entirely confidential and can not be traced back to any students specific name.

Questions: If you have any questions about the design or results of this study, or about the nature of your participation, you may ask now. You may also contact me or my advisor at the phone numbers indicated at the top of this form.

Thank you for considering participation in our research.

Sincerely, ________________________

Participation is voluntary. You may decide NOT to participate in this study and if you do begin participation you may still decide to stop and withdraw at any time. Your decision will be respected with no coercion or prejudice. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Sponsored Programs and Academic Research Center, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-1907.

Print name____________________________

____ ____________________
Participant's Signature Date

____ ____________________
Researcher's Signature Date

APPENDIX B

STUDENT QUESTIONNAIRE

What is your class year?

Freshman Sophomore Junior Senior Senior+

What is your major?

Chemistry Biochemistry Biology Sports and Exercise Science Other

What grade did you receive in first semester general chemistry lecture?

A B C D F

What is your projected grade in second semester general chemistry lecture?

A B C D F

How many semesters of organic chemistry do you plan to take? (circle one)

0 1 2

If you will be taking organic chemistry, what is the primary reason

major requirement minor requirement might need in the future fun other

Has anyone conveyed to you any information about the organic chemistry course? (Yes / No) Please explain

From whom did you hear this information? (ex. Friend, chemistry major, teacher, website, etc…)

Do you have any concerns about taking the organic chemistry course?

(Yes / No) Please explain.

Thinking about what you know about organic chemistry right now, is there any other source, than previously mentioned, that contributes to your feelings about the course?

What feelings do you have right now about organic chemistry?

What are the primary factors contributing to these feelings?

On a scale of 1-10, 1 being, "I am totally prepared to take organic chemistry and have no apprehensions" and 10 being, "I am considering changing my major so I do not have to take this course," how apprehensive are you of organic chemistry?

1 2 3 4 5 6 7 8 9 10

Would you be willing to participate in a short interview (15-20 minutes) answering questions concerning your current feelings about organic chemistry?

☐ YES ☐ NO

If "Yes" what is the best way for me to contact you (please fill in the appropriate information):

Email:________________________________

Phone:________________________________

APPENDIX C

GENERAL STUDENT INTERVIEW QUESTIONS

General Student Interview Questions:

1. Tell me a little about yourself, like your name, major, etc?
2. How many years of chemistry do you need to take?
    a. Have you taken both semesters of general chemistry?
    b. How are you doing in general chemistry if you are currently in it?
3. Do you need to take organic chemistry?
    c. Do you need to take both semesters or just the first?
    d. Do you need to take it because it is a requirement?
    e. Are you taking it because you might need it in the future?
    f. Are you taking it for fun?
4. Have you heard **anything** about organic chemistry specifically the lecture?
    g. What feelings do you have about the class based on what you have heard?
    h. Do you have reservations about taking the class because of what you have heard?
    i. How has ???? affected your view?
5. Are there any specific topics you have heard about? (what are they?)
    j. Where did you hear about these topics (from where)?
6. Do you know what these topics consist of?
7. Where did you get this information? (a person, read it, a review, online?)
    k. Has your informant taken organic chemistry?
    l. Have you received information from multiple sources?
    m. Which source most affected your view?
8. What **do you** think about organic chemistry right now?
9. What are your apprehensions about the class?

n. Are these based on what you have heard?

o. Are these independent from what you have heard?

p. If independent why do you have these apprehensions?

APPENDIX D

PERMISSION TO ACCESS STUDENTS AT OTHER SCHOOLS

E-mail Communication with Andrew French

FROM: Andrew French

SENT: Friday, May 1, 2009 9:31 AM

Here is our Approval. there is no paper trail, only electronic

Andrew

FORWARDED FROM: Lynne Chytilo

Dear Andy,

I am pleased to inform you that the Albion IRB will accept UNC's Institutional Review Board approval of your study titled "Organic Chemistry Preconceptions: What they are and where are they coming from?". You may now begin collecting your data, a process that should be completed by June 15, 2010. If you need to collect data after that date, please contact me and I will help you extend this approval. Please let me know if you have any questions.

Good luck with your research project!

Sincerely yours,
Lynne Chytilo
Albion College IRB Chair

Apr 30 09 10:52a p.2

University of Northern Colorado

April 8, 2009

To whom it may concern:

I have carefully considered the research project to be conducted by Jodie Wasacz and agree to allow her to conduct her research with the chemistry students at Hartwick College. I understand that the purpose of the study is to correlate students' preconceptions concerning organic chemistry with their initial success in the course. I understand that this information will be used in hopes of identifying possible causes for poor student success in organic chemistry. In addition, I realize that Jodie will be conducting quantitative research to gain students' initial grades to correlate with their preconceptions. She will be supervised in her research by Dr. Kimberly Pacheco.

Jodie has communicated that the participation of the students is voluntary, and the students may decide not to participate in the study. Also, if a student does begin participation he/she may still decide to stop and withdraw at any time. It is understood that the student's decision will be respected and will not result in loss of benefits to which the student was otherwise entitled.

In addition, I understand that at any time Dr. Andrew Piefer or I may withdraw the class from the study.

Sincerely,

Dr. Andrew Piefer
Hartwick College

4/30/09
Date

Department Chair
Hartwick College

4/30/09
Date

FROM :MSCD CHEMISTRY FAX NO. :3035565399 Feb. 25 2009 11:14AM P 2

UNIVERSITY of NORTHERN COLORADO

February 20, 2009

To whom it may concern:

I have carefully considered the research project to be conducted by Jodie Wasacz and agree to allow her to conduct her research with the chemistry students at Metro State College of Denver. I understand that the purpose of the study is to investigate what preconceptions exist in second semester general chemistry students concerning organic chemistry as well as the sources for these preconceptions. I understand that this information will be to correlate with student success in organic chemistry in hopes of identifying possible causes for poor student success in organic chemistry. In addition, I realize that Jodie will be conducting qualitative research to gain descriptive information of the students' preconceptions. She will be supervised in her research by Dr. Kimberly Pacheco.

Jodie has communicated that the participation of the students is voluntary, and the students may decide not to participate in the study. Also, if a student does begin participation he/she may still decide to stop and withdraw at any time. It is understood that the student's decision will be respected and will not result in loss of benefits to which the student was otherwise entitled.

In addition, I understand that at any time Dr. Schelble or I may withdraw the class from the study.

Sincerely,

Susan M. Schelble 2/25/09

Dr. Susan M. Schelble Date
Metro State College of Denver

Charles G Tindall 2/25/09

Department Chair Date
Metro State College of Denver

Attn: Jodie Wasacz
c/o Kim Pacheco
970 - 351 - 2533

UNIVERSITY of
NORTHERN COLORADO

February 20, 2009

To whom it may concern:

I have considered the research project to be conducted by Jodie Wasacz (a graduate student in Chemical Education Research at the University of Northern Colorado) and agreed to allow her to administer a survey at the end of Spring 2009 with students in Dr. Knauss' two sections of General Chemistry II at the University of Colorado Denver. The survey instrument is attached to this letter (pages 8 – 10 in the attached preliminary IRB proposal document that will be submitted to the internal review board for consideration for approval at the University of Northern Colorado and the University of Colorado Denver). I understand that the purpose of Jodie's research study is to investigate potential student preconceptions concerning organic chemistry as well as the sources for these preconceptions. As additional components of Jodie's research project she would like to conduct follow-up interviews with students from the two section of general chemistry II during the summer months as well as obtain these same students' quiz grades from Organic Chemistry Laboratory courses in the Fall 2009. Jodie will be obtaining appropriate additional permissions (from persons other than Dr. Karen Knaus at the University of Colorado Denver) to collect data for these other components of her research study. I understand that Jodie's research advisor is Dr. Kimberly Pacheco at the University of Northern Colorado.

Jodie has communicated to Dr. Karen Knaus that student participation in the research study is completely voluntary, and that students may decide not to participate or withdraw from participation in the study at any time. It is also understood that the student's decision not to participate in the research will be respected and will not result in loss of benefits or potential risks.

In addition, it is understood that at any time Dr. Knaus or Jodie Wasacz may withdraw the class from participation in the research study.

Sincerely,

Karen Knaus   02/19/2009

Karen Knaus, Ph.D.   Date
Assistant Professor of Chemical Education Research
University of Colorado Denver

Mark R Anderson   2/20/2009

Mark Anderson, Ph.D.   Date
Department of Chemistry Chairperson
University of Colorado Denver