Analysis of the Effect of Sequencing Lecture and Laboratory Instruction on Student Learning and Motivation towards Learning Chemistry in an Organic Chemistry lecture course

By

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Abstract

Exposure to organic chemistry concepts in the laboratory can positively affect student performance, learning new chemistry concepts and building motivation towards learning chemistry in the lecture. In this study, quantitative methods were employed to assess differences in student performance, learning, and motivation in an organic chemistry lecture course between groups of students who take the laboratory and lecture simultaneously or separately. Grades in organic chemistry lecture (CHEM 624 and 626) courses were collected from 2008-2010 (fall and spring semesters) to measure difference in student performance. To measure student learning and motivation, data was collected from students enrolled in organic chemistry I (CHEM 624) lecture course (N = ~ 500) in fall 2011. Grades on questions that included specific organic chemistry concepts (example acid-base chemistry, racemic mixture, dehydration, and hydroboration) were collected along with overall exam grades to measure student learning chemistry concepts. These concepts were sometimes introduced in laboratory prior to the lecture and during some other times were introduced in the lecture prior to the laboratory. Chemistry Motivational Questionnaire (CMQ) was conducted on students after midterm and before finals to measure student motivation. From various quantitative analysis (correlations, ANOVA, linear regressions) performed it was apparent that student performance, learning, and motivation were significantly better among students who take laboratory and lecture course simultaneously rather than separately. It was also observed that overall student motivation for the concurrent lab group increased with time over the semester. Results presented includes comparison in student performance (grades), learning, and motivation based on sequence they took the laboratory and lecture, and how demographic and academic measures (ACT score, high school GPA, gender,

ethnicity, and different majors) affect student performance, learning, and motivation in the organic chemistry lecture course.

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At the University of Kansas, I'd like to thank Dr. David Benson, professor with the Chemistry Department for collaborating with my advisor and me on this research study, and providing me with all the required data from Organic Chemistry I course in fall 2011. I'd also like to thank Marcia Powers, research analyst at the College of Liberal Arts and Science, to provide me with all the data from Organic Chemistry I and II courses from 2008 – 2010. I'd like to thank Celeste Smith, Assistant Director of the Testing Services, to provide me with test results of Organic Chemistry I students from fall 2011.

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Chapter 1- Introduction

Learning and motivation to learn has been an active area of study since early 1900s by researchers in the field of psychology like Piaget, Eccles and Wigfield. Constructivist theory posits that, cognitive developments influences how people learn and how they are motivated towards learning something new (Bransford, Brown, Cocking, Donovan, & Pellegrino; Mallory & New, 1994; Sivan, 1986). This research project is based on the underlying concepts of the constructivist theory.

In order to understand the functioning of human brain it is important to understand the process of memory development (Bruer, 1993). Seeing a concept on multiple occasions rather than once gives students repeated exposures to concepts and algorithms which affects how students learn those concepts (Bransford et al.; Bruer, 1993; Driver, Asoko, Leach, Scott, & Mortimer, 1994). Multiple exposures to concepts are one area where the sequencing of laboratory and lecture course could play a part. In college chemistry courses laboratory and lecture can be offered simultaneously in a semester or separately. This study will examine whether the sequencing of laboratory and lecture experiences affects student learning and motivation in learning chemistry, where concept learning is important part of the grade.

There are not many published theoretical and empirical studies on effects of sequencing on student learning and motivation. However, empirical research relating motivational studies to sequencing is less available compared to learning and sequencing or integration of laboratory and lecture studies. Studies show that conceptual learning is important for understanding concepts and conceptual learning is highly influenced by the sequence of laboratory and lecture (Beall, 1997; A. W. Johnson, 1990; M. Johnson & Lawson, 1998). Other factors can influence conceptual learning like teaching strategies, and student reasoning but sequencing plays one of the most important roles. Motivation can also be highly influenced by sequence of laboratory and lecture (Elliot, 2005; Stipek & Hoffman, 1980). Other factors including peers and environment can influence intrinsic and overall motivation but prior knowledge plays an important role in developing intrinsic and overall motivation.

Literature Review of Sequencing and Integration of Lecture and Laboratory

Understanding science is a process of combining practical knowledge from laboratory and theoretical knowledge from classroom lectures. Studies in many colleges and universities around The United States of America, have found that topics covered in classroom lectures are not integrated with laboratory. Instead, some of the chemical concepts are introduced in the laboratory prior to being introduced in the lecture and vice-versa (A. W. Johnson, 1990; M. Johnson & Lawson, 1998). These studies indicate that when there is a time lag between when a topic is introduced in laboratory and lecture, conceptual understanding of chemical techniques or methods from the laboratory can provide better foundation to perform in the lecture (Beall, 1997). Concepts introduced in the laboratory help students to understand the material studied in lecture, and also help with motivating the students when the laboratory and the lecture are asynchronous (Beall, 1997; A. W. Johnson, 1990; M. Johnson & Lawson, 1998).

Integrated learning environments, where students learn concepts in the laboratory and lecture simultaneously on the same day or week, are very different than asynchronous learning environments, where students learn concepts in laboratory prior to lecture or vice-versa and there is a time lag in introducing a concept (Bailey, Kingsbury, Kulinowski, Paradis, & Schoonover, 2000). Non- simultaneous learning environment is followed at the University of Kansas (KU) where the study has been conducted. Students at KU enrolled in the introductory organic chemistry course are the subjects of this study. KU students are not required to enroll for laboratory and lecture simultaneously in a semester. Students who are enrolled in both laboratory and lecture during the same semester are introduced to chemical concepts in organic chemistry in both the laboratory and the lecture with a short time lag, which leads to learning in a non-simultaneous enrollment environment. This gives students an option to learn chemical concepts twice (practical and theoretical learning in laboratory and lecture respectively) or just once (theoretical learning in the lecture) during the semester. Theories about memory development prove that understanding and learning improve when learners encounter concepts more than once in a small time lag rather than when there is a significant time difference in the process of learning (Chi, 1978; Cowan & Alloway, 1997; Kail, 1990).

The traditional discovery laboratory environment involves students working in a group towards discovering scientific relationships and concepts (BODNER, HUNTER, & LAMBA, 1998). Discovery laboratory are also part of the KU organic chemistry curriculum, requiring students to predict, observe and explain the techniques and concepts. In most cases these concepts are not well integrated with the concepts learnt from the lecture curriculum. In recent studies researchers and teachers tend to integrate concepts learned in both laboratory and lecture by using the time factor and introducing the concepts in both laboratory and lecture at the same time. The other way a concept can be integrated for better student learning and understanding is when a concept is introduced in both lecture and laboratory within a short time frame, which is equivalent to integrating concepts at the same time.

In a 1965 study Bradley (1965), compared the differences in learning methods between lecture classroom and laboratory. The concepts introduced in both the classroom environments were similar. The sample groups were similar in demographics, gender distribution, and instructions given. The only difference was the way data was gathered and analyzed for the two groups. The study concluded that there is no difference among both the methods of teaching, both laboratory and lecture teaching methods are equally effective for student understand of concepts. Therefore, it would be interesting if this study could determine whether there is any difference in learning when students enroll for both laboratory and lecture compared to enrolling for just the lecture.

Researchers have observed that active and cooperative learning in classroom environments affects student's conceptual understanding and learning process (Gabel, 1999; Hoellwarth, Moelter, & Knight, 2005; Paulson, 1999; Shibley Jr & Zimmaro, 2002). Peer-led group learning and active learning can be experienced from practical laboratory experiences and therefore, that can enhance concept learning in the lecture classrooms where active learning is not very well supported like in the organic chemistry course taught at KU. This change in teaching style might influence student motivation towards learning new concepts along with science learning experience. The organic chemistry mechanisms and reactions learned from the practical experiences in the laboratory can provide background knowledge about the lecture material where similar mechanisms and reactions are being taught. Exposure to content information in both the laboratory and lecture should help students understand chemistry and get motivated to learn chemistry.

In a variety of studies over the past 20 years, researchers have tried to integrate laboratory and lecture in sciences and engineering in an effort to combine practical and theoretical knowledge for better conceptual understanding (Bailey et al., 2000; DiBiase & Wagner, 2002; Lunsford, 2004; May & Etkina, 2002; Nakhleh, Polles, & Malina, 2003). Little research has been done to analyze the programs across the country where learning involving non-simultaneous enrollment is prevalent. This study examines how enrolling for laboratory and lecture simultaneously vs. separately impacts student learning and motivation

Literature Review of Motivation towards Learning

For the studies of human learning, motivation can be defined as "the internal state that arouses, directs, and sustains students' behavior toward achieving certain goals" (Glynn, Taasoobshirazi, & Brickman, 2007). In this study we will focus on intrinsic motivation along with overall student motivation to learn something new. Intrinsic motivation is motivation that is self-generated, as opposed to motivation from any external or outside source, which is referred to as extrinsic motivation (Garrison, 1934; Ornstein, 1994; Ryans, 1942; Scott Rigby, Deci, Patrick, & Ryan, 1992). Research suggests that an intrinsically motivated person can process learning faster and have increased conceptual understanding including better personal growth and adaptability (Deci, Vallerand, Pelletier, & Ryan, 1991). Intrinsic motivation in the classroom can be influenced by teacher's differential treatment, self-efficacy, goal orientation, and self-determination, but seems to be most dependent on prior student knowledge (Elliot, 2005; Stipek & Hoffman, 1980). The process of learning new content can lead to increase or decrease in motivation (Garrison, 1934; Ornstein, 1994; Ryans, 1942).

A short time difference in learning process between theoretical and practical learning can provide background knowledge for the students enrolled in the lecture, and they are better than the novices who learn new content for the first time in the lecture classroom (Maheswaran & Sternthal, 1990). Novices will show different motivational qualities compared to individuals with prior background knowledge. In a study by Maheswaran & Sternthal (1990), graduate students were given different perception questions on various topics; half the participants were novices whereas the other half had prior knowledge about the facts in the questionnaire. The arithmetic means for the prior knowledge group were higher than the novice group (Maheswaran & Sternthal, 1990). The one-way ANOVA analysis suggested that there was significant variance (alpha = 0.05) between the novice and prior knowledge group (Maheswaran & Sternthal, 1990). The study suggests that the group with background knowledge has more motivation to answer those perception questions than the novice group (Maheswaran & Sternthal, 1990).

Non-simultaneous enrollment that leads to time differences between content presentations provides background knowledge to students enrolled in both laboratory and lecture, and this group of students should be more motivated compared to the novices who are enrolled for either the laboratory or lecture. The question remains whether background knowledge from the past keeps students more motivated compared to students who experience practical learning along with theoretical learning during the same time frame. The study by Guthrie and Wigfield (1999) suggested that when a person wants to construct meaning while reading, intrinsic motivation is highly required for better understanding and explanation of the reading. The motivation of an individual to read and learn from reading depends on the person's goals and beliefs. These goals and beliefs are formed by background knowledge about reading along with number of times the reading is performed (Guthrie & Wigfield, 1999). Activating previous knowledge and integrating previous knowledge and text is a cognitive process, which induces motivation and thereby helps with text comprehension. Increase in knowledge about a text can be due to increase in recall about the text, which builds previous knowledge along with increasing brain capacity due to increasing memorization. Then the construct causal inferences will induce high motivation for reading (Guthrie & Wigfield, 1999; Harlen & Crick, 2003; Lowman, 1990).

Pintrich et.al. (1993) claimed that student motivation is related to the process of conceptual change or the conceptual learning process. There are four motivational constructs, and those are goals, values, self-efficacy, and control beliefs. These are mediators in the process of conceptual change. These four motivational constructs are influenced by students' ability to learn through exposure to the concepts more than once along with previous conceptual knowledge. Exposure to knowledge more than once is a cognitive model based on increasing memory capacity that results in an increased motivational level. Also, previous knowledge from past experience is a cognitive model that influences motivational level and helps with the useful and relevant conceptual student learning process (P. Pintrich, Marx, & Boyle, 1993).

Tobias (1994) in his study discusses how student interest and motivation relies on prior knowledge and number of exposures to the same conceptual content. The author draws a conclusion that there is a linear relationship between interest and motivation with the number of exposures to the conceptual content (Tobias, 1994). Interest or intrinsic motivation is also largely affected by past or previous knowledge. Researchers have claimed that "prior knowledge explains between 30 to 60 percent of variance" in the interest or intrinsic motivation (Tobias, 1994). Another researcher noted that "prior knowledge overrules all other variables in the study" (F. Dochy, 1994). Tobias (1992) studied the effects of interest and use of metacognition checking techniques (previous knowledge included) in mathematics. The self-report Likert scale of interest (high alpha reliability of 0.87) and the previous domain knowledge (high alpha reliability of 0.93) showed a significant medium correlation of 0.53, demonstrating there was a relationship between previous knowledge and intrinsic motivation (Tobias, 1992).

Literature Review of Conceptual Learning

The learning process from meaningful understanding of scientific concepts differs greatly from the algorithmic learning process (Hoellwarth et al., 2005; May & Etkina, 2002; Pushkin, 1998). Students believe that understanding the math behind an equation is conceptual learning, which is not true when it comes to learning chemistry concepts. Conceptual learners bring in the skills of integrating knowledge, critical thinking, and reasoning, which is developed in people who are at the higher end of the spectrum of cognitive development.

Different learning theories, acknowledge that people learn more by doing activities themselves (practical learning) rather than by watching and listening (theoretical learning) (Felder & Peretti, 1998). Initially trying to do something by themselves give students better conceptual understanding and motivation towards chemistry while they are watching and listening to the classroom lectures (Felder & Peretti, 1998). Students get this opportunity when they enroll for laboratory and lecture simultaneously in a semester rather than separately where there is a huge time lag between practical learning and theoretical learning.

In lectures environments people often fail to understand the relations between concepts stated in the text. Also, it can be difficult for people to relate the material learned in a lecture environment with the content they have seen in the past. One of the consequences of such learning is that students have incomplete understanding of the material they are learning. It is preferable to analyze new experience based on the experience they have gained before in a practical setting like in the laboratory (Pressley et al., 1992).

According to constructivist learning theory, "students incorporate new knowledge into their existing knowledge framework" (Schwarm & VanDeGrift, 2003). Learning is an active process of the brain and it can be hypothesized that the sequence of laboratory and lecture can influence how students understand or learn new concepts. Learning is a mixture of "conceptual understanding and flexible use of knowledge" (Deci et al., 1991). To increase student learning and build a connection between new content learned in lecture with similar content learned in the laboratory, students should answer questions related to new concepts based on their previous content knowledge from laboratory (Pressley, et al., 1992).

One of the primary factors that can help with student learning in college science courses is the practical knowledge learned from the laboratory sequence that is associated with the lecture. For example, in biology or chemistry courses without practical knowledge new conceptual knowledge in the lecture cannot be formed (M. Johnson & Lawson, 1998). Previous laboratory experiences account for much of student's prior practical knowledge. Significant improvement in the final course grade was observed for students with more practical knowledge prior to taking the lecture (M. Johnson & Lawson, 1998).

Chemistry is thought to be a very complex subject and the nature of the content knowledge affects the ways chemistry should be taught to students. Pervious research shows that problem with chemistry teaching lies in conceptual understanding, problem solving methods, and misconceptions (Gabel, 1999; Hoellwarth et al., 2005). Students possess various misconceptions and tend to use algorithms rather than critical thinking to solve any problems or conceptual questions. Some of the chemistry concepts are considered to be abstract and are difficult to explain to students without models or background references. Due to lack of proper explanation for some concepts misconceptions arise. Misconceptions can thus make learning difficult and uninteresting, which induces lack of motivation to learn chemistry.

Researchers found that students sometimes have difficulty in understanding chemistry in laboratory (Bradley, 1965; Cunningham, 1946). The reason for this difficulty is that students "make observations at the macroscopic level, but instructors expect them to interpret their findings at the microscopic level" (Gabel, 1999). On the other hand, laboratory experiences enhance students understanding of concepts, problem solving ability, interest and motivation (Bradley, 1965; Cabrera, Colbeck, & Terenzini, 2001; Cunningham, 1946; Nakhleh et al., 2003). Integration of practical knowledge from laboratory with theoretical knowledge from lectures does help solve the difficulty and clear misconceptions. Opposing the above study some researchers have determined that enrolling for either lecture or laboratory by itself enhances misconceptions and induces difficulty in learning (DiBiase & Wagner, 2002; Lunsford, 2004).

Purpose of this study

A meaningful understanding of science includes understanding scientific ideas and their purposes. This includes the prediction and description of real world occurrences (E. Smith, Blakeslee, & Anderson, 2006). Understanding science is a process of combining practical knowledge from laboratory and theoretical knowledge from classroom lectures. In most of the colleges and universities around The United States of America, topics covered in classroom lectures are not integrated with laboratory; instead, some of the chemical concepts are introduced in the laboratory prior to being introduced in the lecture. Alternately, these concepts can also be introduced in the lecture prior to the laboratory (A. Johnson, 1990). The primary objective of the study is to determine "will non-simultaneous sequencing of lecture and laboratory affect student learning in lectures and student motivation towards learning chemistry." Prior research on "conceptual learning", "sequencing" and "motivation" has indicated that when there is a "short time lag" between when a topic is introduced in laboratory and lecture, conceptual understandings of chemical techniques or methods learned from the laboratory can provide meaningful understanding of similar concepts learned in the lecture (Beall, 1997; Keane et al., 1997; Kintsch, 1994). The "short time lag" is important because it helps to establish the understanding of new knowledge and increase student motivation for learning. Concepts introduced in the laboratory can provide prior knowledge to students, helping them understand the material studied in lecture, and also help with motivating the students when the laboratory and the lecture are asynchronous (Beall, 1997; A. Johnson, 1990).

It would be desirable to know how common practices in scheduling the lecture and laboratory affects student learning and motivation. In this study, it is determined whether the sequence of the lecture and laboratory affects student learning in the lecture and student motivation towards learning chemistry.

Theoretical Framework for the experiment

Literature describing how the sequence and integration of laboratory and lecture affects student learning and motivation focuses on social-cognitive behavior and constructivist learning theory as a theoretical framework. According to the social-cognitive behavior framework students use their working memory to encode and store the concepts and knowledge with more accuracy when they learn something twice within a small time lag rather than just once (Chi, 1978; Cowan & Alloway, 1997; Flavell, 1979; Keane et al., 1997; Kintsch, 1994; Potter, 1976). Also, every student has a self-regulatory system that affects beliefs and thus develops motivation that cognitively enables learning behavior (Glynn et.al, 2007). Added to the social-cognitive behavior framework, constructivist framework also explains the theoretical framework of this experiment. Constructivist learning theory describes how students learn and understand new concepts based on their prior knowledge and experiences (Bransford et al.; Bruer, 1993; Driver et al., 1994). Prior knowledge can mean knowledge from either the recent or distant past (Beier & Ackerman, 2005; F. Dochy, 1994). This theory explains how students make connections between new concepts learned in lecture (theoretical knowledge) with similar concepts learned in the laboratory (practical knowledge).

Constructivist theorist like Jean Piaget and Lev Vygotsky believed in learning as cognitive and social psychology development (Mallory & New, 1994; Moore, 1975; Piaget, 1964; Terwel, 1999). Constructivist theory created by Lev Vygotsky has been developed in the context of socio-cultural behavior and theory by Jean Piaget was developed in the context of personal development of individual cognitive levels. Piaget and Vygotsky developed theories of understanding and knowledge based on personal and social constructivism (Driver et al., 1994). Many educational researchers and teaching professionals have used these theories in classroom to develop better understanding among students and support them during personal and social process of understanding new material (Richardson, 2003). Constructivist researchers concluded by saying that improving student learning includes improving the conceptual understanding of the novices and bringing them at-par with the experts. Also, learning depends on social background according to Vygotsky, which affects the student's motivation to learn something new (Moore, 1975; Richardson, 2003; Sivan, 1986). It is both the socio-cultural behavior and personal constructivism that plays a role in setting the theoretical framework for this research project.

Constructivist-based methods are used by researchers to increase student success with the help of conceptual learning (Driver et al., 1994; Dubinsky & Mcdonald, 2002; Mallory & New, 1994). Constructivist-based theories of learning have led to constructivist pedagogies in science classrooms, and the theme for curriculum development and research based on constructivism and constructivist-based pedagogies play a role in explaining student difficulty with conceptual learning (Gabel, 1999). These pedagogical theories help determine the choice of analytical methods used in this study to measure any significant difference between students enrolling for laboratory and lecture simultaneously or separately in their conceptual learning and motivation.

Conceptual short-term memory, a cognitive process, and is very different from the short-term memory function, as measured by memory span. Conceptual short-term memory is the basis for long-term memory, concepts that are well understood and structured are stored at least for a brief time in the long-term memory. Prior learned conceptual information stored in the long term memory helps in connecting prior knowledge with the new information learned during a course with the help of recalling. Thus, it can be said that when a student learn concepts in chemistry laboratory, seeing the same concept more than once over a short time gap in the lecture can help them create connection and build well understood and structured information in their long-term memory. In contrast when a student takes laboratory and lecture separately there is a long time gap, which creates incomplete understanding of the chemistry concepts from just one course leading to improper connections from long term memory. This results in lack of proper conceptual understanding.

An individual's motivation is analyzed based on social-cognitive framework of motivation (Bandura, 1989, 1991). Motivation is dependent on an individual's behavior and characteristics, gender, and interaction with environment, like the environment in a chemistry lecture classroom or chemistry laboratory. In the social-cognitive framework, students are "viewed as self-regulating system that affects beliefs and aids in the development of motivation that enables behavior cognitively and affectively" (Glynn et al., 2007). There are five constructs within the self-regulatory system which affects student's overall motivation to learn and they are *intrinsic and extrinsic motivation*, *goal orientation, self-efficacy, and assessment anxiety*. The *Chemistry Motivational Questionnaire* (CMQ) accounts for all the five constructs of motivation and for this study help us determine student motivation in learning chemistry.

Hypotheses

Preliminary research was conducted on the data obtained from the Office of Institutional Research and Planning (OIRP) at KU from 2008 till 2010 to examine effect of sequencing on student performance in Organic Chemistry I and II courses. Student performance was measured by final grades they received in both the courses. To measure the effect of prior knowledge on student performance from the past (long time lag), ACT score and high school GPA were collected from OIRP. Additional data relating to student demographics, gender, ethnicity, and major information were collected from OIRP to study the influence of these variables on student performance. Both the prior knowledge and demographics are used as covariates or intervening variables to study the real effect of sequencing on student performance. The research study addressed the following hypothesis:

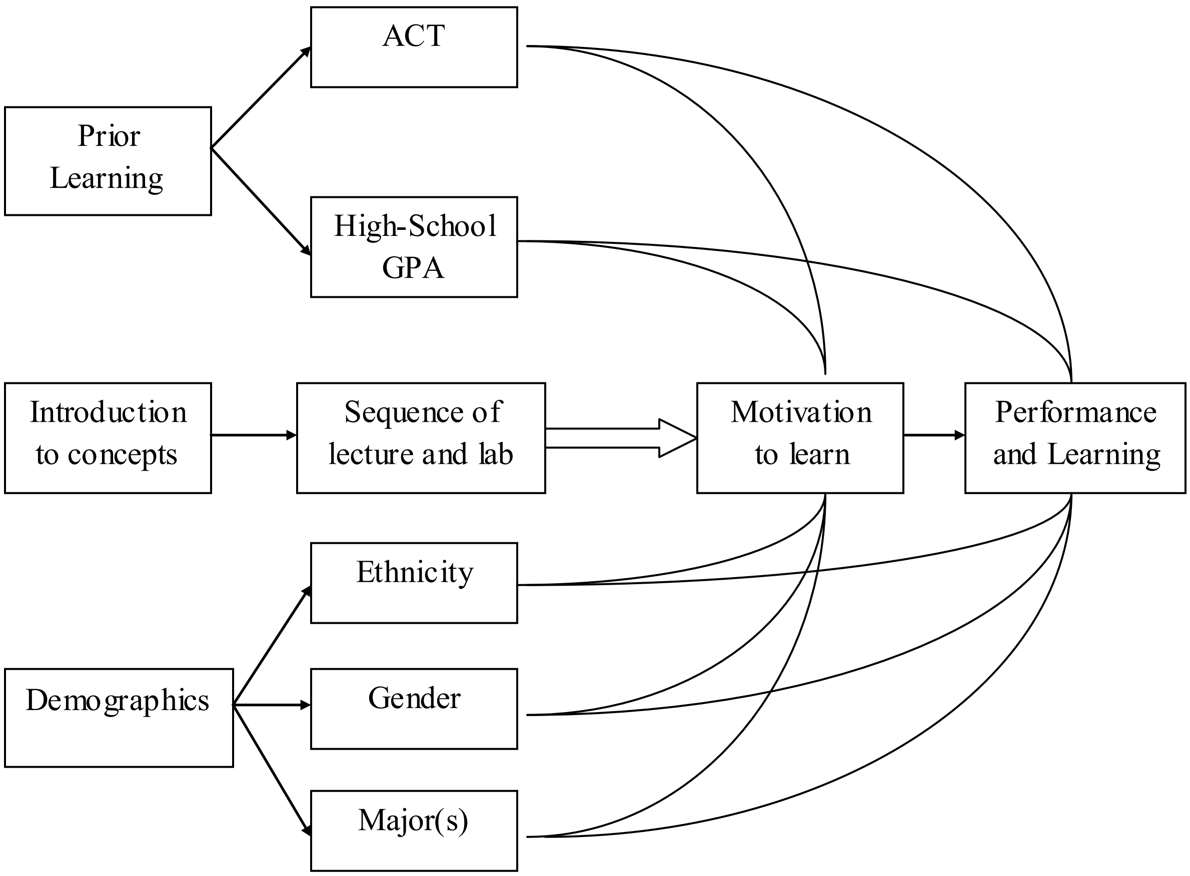
1. Students enrolled for laboratory and lecture simultaneously in a semester would significantly differ from students enrolled for laboratory and lecture separately in their lecture course performance.

The design of the course structure in fall 2011 was similar to that of previous years (2008-2010). There were total of four exams and a final in the lecture component of both the Organic Chemistry I and II courses. Each exam was 100 points and the final was 200 points. The laboratory had scheduled a midterm and a final exam. Both the midterm and final exam were 100 points each. Lecture and laboratory grades are separate and students can self- select to simultaneously enroll in the lecture and laboratory course. As a result, some students that choose to enroll for both laboratory and lecture during the same semester and others choose to enroll in just the lecture course.

In fall 2011 the effect of sequencing on student learning and motivation were analyzed using the data obtained from Organic Chemistry I lecture course at KU. Student learning was measured using the grades of conceptual multiple choice questions given in each exam during the semester. The questions tested were related to the concepts learned the laboratory. As a result, students taking both the laboratory and lecture are exposed to similar concepts twice compared to students taking just the lecture who get exposed to the concept only once. Student motivation was measured by conducting a questionnaire named chemistry motivational questionnaire (CMQ) during the middle and the end of the semester. This was to ensure to measure any motivational change over the course of the semester. Data collected from OIRP included, academic background information (ACT, high school GPA) and demographics (gender, ethnicity, and major) information. The research study for fall 2011 addressed the following hypothesis:

1. Students enrolled for laboratory and lecture simultaneously in a semester significantly differ in their learning of the lecture material from students enrolled for laboratory and lecture separately.
2. Students enrolled for laboratory and lecture simultaneously in a semester significantly differ in their motivation to learn chemistry in the lecture course from students enrolled for laboratory and lecture separately.

Structure of Dissertation



Scheme 1: Schematic Diagram of the experimental setup

Scheme 1 describes the overall experimental setup for this study. Chapter 2 gives an overview of the literature review of the memory function in the light of social-cognitive behavior and constructivist theory along with the constructivist pedagogies for analyzing student learning. Chapter two also includes literature review of the potential confounding variables for this experiment, prior knowledge and demographic influence. Chapter 3 gives an overview of the preliminary research done on Organic Chemistry II students at KU to measure performance based on sequencing of laboratory and lecture course. It includes detailed information about how the student groups were selected and what information was gathered from OIRP to measure the effect of the confounding variables on learning and motivation. Chapter 3 also includes the course structure from 2008 till 2010, methods of analysis including ANOVA (analysis of variance), correlation, and regression, results found after the analysis, and discussion of those results. Chapter 4, like the previous chapter, gives an overview of the preliminary research done on Organic Chemistry I students at KU to measure performance based on sequencing of laboratory and lecture course. It includes detailed information about how the student groups were selected and what information was gathered from OIRP to measure the effect of the confounding variables on learning and motivation along with the course structure from 2008 till 2010, methods of analysis similar to chapter three, results found after the analysis and discussion of those results.

Chapter 5 summarizes the methods used to measure the effect of sequencing laboratory and lecture instruction on student learning. This section outlines the purpose of the experiment and discusses the hypothesis 1 from fall 2011 study in details. It also includes the course structure of Organic Chemistry I course in fall 2011, selection of student groups, data collected from various sources like the OIRP and lecture course, methods of analysis which are similar to previous chapters, results found and discussion of those results. In chapter 6, analysis of the effect of sequence of laboratory and lecture instruction on student motivation is measured. It gives a background about the questionnaire CMQ (chemistry motivational questionnaire) including its validity and reliability. It also includes detailed information about the voluntary participation of students for the questionnaire and their responses, survey results, data analysis, results and discussion of those results.

The last chapter, chapter 7 outlines the conclusions drawn from this research study and also gives an overview of some prospective future research. The original version of the CMQ is attached in the appendix section after chapter seven along with the approval letter for conducting this study by the human subjects committee at Lawrence. Some sample multiple choice questions from the exams in CHEM 624 (fall 2011) study has also being included in the appendix.

Chapter 2- Literature Review of Theoretical Framework and Confounding Variables

The initial section of this chapter provides an overview of the constructivist theory including social and personal constructivism. Then it continues to consider chemical education research, where constructivism plays a role in analyzing learning process quantitatively.

The second section provides an overview of the theory of development of the working memory in the light of social cognition. This section further summarizes the role of repetition of content on working memory and thus improved understanding and learning. Added to this discussion is another explanation of how practical learning and theoretical learning simultaneously experienced within a short time gap can be more beneficial for student learning and motivation compared with similar learning experiences separated by longer time gap.

The third section expands on the role of social cognition in building motivation among college students. It also discusses the Eccles and Wigfield's theory on motivation, which is the basis for the chemistry motivational questionnaire (CMQ). CMQ is used in this study to measure the motivation of the students enrolled in organic chemistry I course at KU. Information about CMQ and the analysis will be provided in a later chapter.

The fourth section provides an overview of the constructivist pedagogies based on which the quantitative analysis of learning is performed in this experiment.

The last two sections provide an overview of the confounding variables and their effect on learning and motivation. Confounding variables includes academic background knowledge measured by ACT score and high- school GPA, and demographics information includes gender, ethnicity, and choice of college major.

Constructivism

Constructivism explains how an individual's prior experience and knowledge help build and interpret new knowledge in both formal and informal classroom learning environments. Constructivism is considered a reaction to the behaviorist-based theories of learning introduced by Edward Thorndike from the 1910s to the 1930s, popularized by B. F. Skinner in the mid-1950s. Behaviorist theory formed the basis of the programmed-instruction classrooms of the 1960s and 1970s (Piaget, 1964; Richardson, 2003; Terwel, 1999). Constructivism has played a major role in educational research and its theories have become a part of the science classrooms over the last thirty to forty years (Piaget, 1964; Richardson, 2003; Terwel, 1999). Behaviorists believed in learning as stimulus-response theory. Constructivists like Jean Piaget and Lev Vygotsky believed in learning as cognitive and socio psychological development (Mallory & New, 1994; Piaget, 1964; Richardson, 2003; Terwel, 1999). Stimulus-response theory was based on the fact that students should react to the correct stimulus in all educational setting and they should respond by learning the material as explained to them by their teachers. Constructivists changed the way people thought about the learning process by stressing the importance of the individual's experience in learning. Constructivist theory also states that all students have a unique background of experiences and knowledge that influences how new information is perceived, organized, and stored in their minds (Bandura, 1989, 1991; COUNTY, 1987; Moore, 1975).

Constructivist theory has been developed in the context of studies of socio-cultural behavior pioneered by Lev Vygotsky. Socio-cultural behavior includes the learning process of human beings under social impacts. According to Vygotsky, meaningful understanding is developed within cultural contexts. The learning process is based on principles that grow within a human since early childhood, where "classrooms are communities, learning is social mediator, curriculum is contextually relevant and problem based, and assessment is authentic and personally meaningful" (Mallory & New, 1994). During the learning process, individuals internalize their socio-cultural surroundings by building on their prior knowledge (Driver et al, 1994). Vygotsky furthered constructivist theory by arguing that there is a certain level of information an individual can learn by themselves, while certain others need assistance from advanced peers or other knowledgeable people (Golde, McCreary, & Koeske, 2006; Shibley Jr & Zimmaro, 2002).

Constructivist theory has also influenced understanding of personal development of individual cognitive levels. The theory of personal constructivism was developed by Jean Piaget. It attempts to model the process of how people develop their understanding of reality. Researchers have concluded on the fact that people can perceive reality of the knowledge the way they want as the effect of the surrounding environment (Moore, 1975). Knowledge is gathered from experience and human understanding that builds on that experience. According to Piaget's research, experience is gathered from the stages of early cognitive development of children. As children begin to age they undergo a change in their process of reasoning (cognitive) ability, starting from sensorimotor, to preoperational, to concrete operational, and finally ending with formal operational (Bruer, 1993; Piaget, 1964). This explains cognitive functioning of children and their understanding process as they grow up.

Piaget came up with the idea that learning occurs when new knowledge presented to individuals conflicts with their prior knowledge or experiences (Piaget, 1964). To incorporate new knowledge or information an individual should adapt to change their prior understanding of concepts (Piaget, 1964). It is always a struggle to adapt prior knowledge to incorporate new knowledge to promote meaningful learning. According to Piaget, this mental state of accommodation of new knowledge is called *equilibration* (Piaget, 1964). During the time of equilibration, experience and knowledge based on prior or old contexts are developed and altered.

Theories of understanding and knowledge were developed by Piaget and Vygotsky based on personal and social constructivism (Driver et al, 1994). Many educational researchers and teaching professionals have used these theories in the classroom to develop better understanding among students and support them during personal and social process of understanding new material (Cabrera et al., 2001; Gabel, 1999; Richardson, 2003). Constructivist learning is a tool used to guide curriculum development and was most commonly executed in lecture classrooms (Cabrera et al., 2001; Gabel, 1999; Hoellwarth et al., 2005; May & Etkina, 2002). Constructivist teaching methods help in creating complex cognitive maps and in forming connections with learner's previous knowledge to create a better understanding of the subject (Cabrera et al., 2001; Domin, 2007; Gabel, 1999; Hoellwarth et al., 2005; May & Etkina, 2002). As framed by researchers, constructivist theory is the theory of learning and not teaching, and there have been many misinterpretations of constructivist-based pedagogies. One of the major misinterpretations in this field is that "teachers should never tell students anything directly but, instead should always allow them to construct knowledge for themselves" (Bransford et al, 2000).

An individual's prior knowledge always has a unique characteristic; hence current educational researchers are emphasizing the importance of determining prior knowledge of students based on constructivist theories (F. Dochy, 1994; Hewson & Thorley, 1989). Researchers believed that teacher's knowledge about the prior understandings of students help them introduce new information and concepts in a way that enhances learning (Hewson & Thorley, 1989). Lack of prior experiences can lead to improper assimilation of new knowledge and thus contribute to the construction of incorrect information (Bradsford et.al, 2000). This concept is consistent with the idea that students should get opportunity in lecture or laboratory to explore concepts on their own before building new knowledge (Bradsford et.al, 2000). Laboratory environment can provide practical learning and help students explore concepts visually. This can be a good prior experience for students before they experience theoretical or abstract knowledge in lecture classrooms (Bodner et al., 1998; Nakhleh et al., 2003). This view of constructivism plays a role in conventional KU lecture classrooms and laboratory and hence provides a pedagogical framework for the determination of the role of sequencing in learning and motivation.

George Bodner's article written in 1986 on theories of constructivism and its role in learning and doing sciences caused a revolution among the chemical educators who also wanted to apply this theory among science and math classrooms. Constructivist researchers addressed the lack of conceptual understanding by studying conceptual understanding among experts and comparing that with those of the novices (Alexander, 1992). Experts are defined by those who have well established domain knowledge, whereas novices are those who have limited-domain knowledge. In the above study, conceptual understanding was measured by giving experts and novices questions that were related to problem solving and critical thinking, and the time the two groups took to respond while processing any connection from their prior knowledge (Alexander, 1992). The results indicated that there is a significant difference among the two groups and the procedure by which they solve any problem. The study concluded that improving student learning requires improving the conceptual understanding of the novices and bringing them at-par with the experts. Also, learning depends on social background according to Vygotsky, and hence that affects the student's motivation to learn something new (Mallory & New, 1994;

Moore, 1975). Both socio-cultural behavior and personal constructivism play a role in setting the theoretical framework for this research project.

Memory in social-cognition

Social cognitive theory is an expansion of Vygotsky's social constructivism and cognitive psychology together, that is more focused on learning methods. According to Bandura (1991), academic self-regulation in a student is "a changeable attribute over which one can exercise some control by developing and using metacognitive skills." Metacognitive skill is defined by researchers as "skills regulating the cognitive, motivational, affective, and social aspects of an individual's intellectual function" (Bandura, 1991).

In one article Potter (1993) mentioned that memory holds conceptual understanding that actually resides in long-term memory. Conceptual knowledge cannot be easily demonstrated by testing short-term memory because it is a part of the cognitive processing and the way long-term memory formation takes place. Conceptual understanding arises earlier in childhood where individuals process information after perceiving something and then retrieves it from their memory. Conceptual understanding develops by combining cognitive processes in the conceptual short-term memory and the long-term memory. Conceptual short-term memory, a cognitive process, is very different from just short-term memory function, as measured by memory span. According to Potter (1993), "unlike short-term memory, conceptual short-term memory is central to the cognitive processing." When an individual reads anything new he or she tries to activate meaningful knowledge stored in their long-term memory and connect it with their current conceptual understanding with the help of the recall process (Potter, 1993). Conceptual short-term memory is the basis for long-term memory. Concepts that are well understood and structured are stored at least for a brief time in the long-term memory. The recall process helps connect new knowledge with prior learned conceptual information. Thus, when a student learn concepts in chemistry laboratory, seeing the same concept again following a short time gap in the lecture help create connection and build well understood and structured information in long-term memory. On the other hand when a student takes laboratory and lecture separately there is a long time gap. The longer time gap creates incomplete understanding of the chemistry concepts because the assimilation of information from only one course leads to improper connections from long-term memory. This leads to lack of proper conceptual understanding.

According to researchers there are two kinds of memory, short-term and long-term memory, and they work separately. Contrary to the above researchers there were different research groups that agreed on the fact that memory processing works by combining both the memory systems and are dual processing system (Cowan & Alloway, 1997; Kail, 1990; Potter, 1976). Previously the two memory systems were thought to be very different and incompatible because one is used for slow learning processes and the other is used for faster learning processes. One type of memory "slowly learns general regularities" and the other type "can quickly form representations of unique and novel events" (E. R. Smith & DeCoster, 2000). Researchers believed that "the second processing mode is more conscious and effortful; it involves the intentional retrieval of explicit, symbolically represented rules from their memory system" (E. R. Smith & DeCoster, 2000). On this dual processing system, the first mode is a slow processing mode and the second mode is faster and works more effortlessly to gather information from the well learned prior knowledge and also involves rule-based inference connections. This procedure employs with both cognition capacity and individual motivation. The conceptual learning process is due to the combination of both the memory processing system. The dual memory processing system works better when there is short time lag in learning concepts compared to longer time lag in learning (E. R. Smith & DeCoster, 2000).

Reproducing certain knowledge is easier when it is related to a certain context. Individuals struggle to reproduce knowledge when they are required to connect two concepts and apply it to a new situation. Recently learned prior knowledge form a basis for connection with a related context an individual is currently learning. Memorizing text is not at all similar to learning and understanding text. Learning can be defined as using the information from one context in other situations and building connections between their prior knowledge with their current context to solve new problems. Some researchers say that the difference between learning and memory is similar to the difference between building connections and solving new problems (Hidi, 2001; Kintsch, 1994; Paris, Cross, & Lipson, 1984). Others deny this, claiming that there is a connection between learning and memory processing (Hidi, 2001; Kintsch, 1994; Paris et al., 1984). Memorization can lead to very little learning and can also lead to some meaningful understanding and that depends on the way a context is *comprehended*. Memory processing leads to learning when frequent engagement with text allows information to be imbibed from the short-term memory to the long-term memory. Long-term memory holds the conceptual learning and thus leads to better understanding of the text and easier connection of the text with other situations (Chi, 1978; Hidi, 2001; Keane et al., 1997; Kintsch, 1994; Paris et al., 1984).

From early childhood children are aware that their metacognition or cognitive skills play a major role in their learning and development. One study concluded that metacognition is improved in classroom lecture courses and this increased awareness improves learning and understanding of the text (Paris et al., 1984). A significant body of research has examined the effects of practical teaching on individual's cognitive development (Cunningham, 1946; Oliver-Hoyo, Allen, Hunt, Hutson, & Pitts, 2004; Paulson, 1999; Shibley Jr & Zimmaro, 2002). The method of instruction, practical or theoretical, has an effect on an individual's perception, memory and processing of the text. Practical knowledge (for example knowledge from the laboratory) provides learning strategies to students and an experience to understand concepts visually. Practical knowledge improves learning when the students are exposed to theoretical knowledge from classroom lectures. Individuals try to build connections between their visual practical learning and theoretical learning, enhancing their understanding of concepts and promoting the storage of concepts in the long-term memory.

Individual interest in a subject, topic or concept can lead to better performance in a classroom (Hidi, 2001). Interest can be aroused by an individual's receptiveness to learn in a particular type of learning environment. For example some learners perform better in a practical environment compared to others who learn in a classroom lecture environment that emphasizes on theoretical learning. Interest in learning aroused by learning in different environments is called situational interest. This is often cited as a trigger for individual interest to learn something new. Learning from either laboratory or lecture can arouse interest in learning and affect cognitive function. During the 1990s researchers started to find differences between situational and individual interest. Researchers have suggested that individual interest leads to intrinsic motivation and situational interest leads to extrinsic motivation. Both of these factors contribute to the ability of a person to understand and learn concepts better (Hidi, 2001).

All of this background research is connected to this study done at KU. Students have the opportunity to enroll in both laboratory and lecture or in either laboratory or lecture during the same semester. Students enrolling for both laboratory and lecture simultaneously are exposed to concepts more than once, which affects memory and social cognition and thus promote better understanding and learning. On the other hand, students who enroll for either laboratory or lecture are exposed to concepts only once. The background study suggests that on-simultaneous enrollment will be less likely to support the transfer of concepts learned from short-term memory to the long-term memory. This should disfavor deeper understanding and learning of chemical concepts. In contrast, practical learning that occurs in coordination with theoretical learning motivates students, should result in a better learning environment.

CMQ: Eccles and Wigfield's Theory and social-cognition

Motivation can be defined as "the internal state that arouses, directs, and sustains students' behavior toward achieving certain goals" (Glynn et al., 2007). Student motivation to learn science can be explained by their feelings and emotions towards science along with their personal goals and how much they want to achieve their goals. An individual's motivation can be analyzed in the context of social-cognitive framework of motivation (Bandura, 2001). Motivation is dependent on an individual's behavior and characteristics, gender, and interaction with the learning environment, like the environment in chemistry lecture classrooms or laboratories.

In the social-cognitive framework, students are "viewed as self-regulating system that affects beliefs and aids in the development of motivation that enables behavior cognitively and affectively" (Glynn et al., 2007). Self-regulatory systems influence behaviors like studying, group participation, and attendance, which in turn affect student learning and academic performance. Bandura (2001) suggested there are five constructs within the self-regulatory system that affects the student's overall motivation to learn. The first construct is *intrinsic* (motivation to learn something for their own self) and *extrinsic* (motivation to learn because of some external benefits) motivation. The next construct is *goal orientation,* which takes two forms -- *learning goals* (influence intrinsic motivation) and *performance goals* (influence extrinsic motivation). The third construct is *self-determination,* which influences how much a student wants to learn. The fourth construct is *self-efficacy,* which Bandura defines as "beliefs in one's capabilities to organize and execute courses of action." The last construct is *assessment anxiety,* which is the level of anxiety a student faces during time of examination; this can hinder student learning, motivation and performance. Based on this social-cognitive framework *Chemistry Motivational Questionnaire* (CMQ) was built by Glynn in 2007 to measure student's overall motivation to learn chemistry and other sciences.

Bandura (1991) suggested that "human behavior is extensively motivated and regulated by the ongoing exercise of self-influence." Self-regulation for motivation includes self-efficacy and an individual's behavior. Self-regulation is a cause-effect system provides a basis for any meaningful action from an individual. Previously, researchers believed that present motivation and behavior cannot predict future performance, but more recent studies have found a cognitive relationship between future performance and present motivation and behavior.

Over past 20 years, researchers have investigated differences between cognitive phenomena or *metacognition* in children compared to mature individuals. College students enrolling for an organic chemistry course, who are the subjects for this study, can generally be classified as mature adult individuals. Children appear to have limited knowledge and metacognition, whereas adult individuals seem to acquire knowledge rather quickly (Flavell, 1979). *Metacognition* affects an individual's oral communication and comprehensive, memory, problem solving skills, self-instruction and social cognition. These learning characteristics are also found to be a key element in social-learning theory, personality development and education (Flavell, 1979). As adult individuals college students are expected to have higher metacognition, learning skills and greater motivation to learn.

Researchers have identified that different individuals have different personalities and motivational characteristics. Given the same situation, the fact that two individuals would be expected to react differently can be explained by goal setting and *self-efficacy* in social-cognitive theory. Motivation to learn is also an element of social-cognitive theory that is based on an individual's goal orientation. Goal orientation can be either performance based (to get a better grade) or learning based (to increase their competence). Researchers have observed that different personality variables lead to dynamic motivational processes and produce patterns that affect cognition and behavior (Dweck & Leggett, 1988). Added to this theory, researchers have observed that self-efficacy beliefs-- including self-observation, self-judgment, and self-reactions-- support the social-cognitive formulation in improving an individual's motivation to learn and succeed in an academic environment (Zimmerman, 1989).

Eccles and Wigfield developed a theory related to an individual's motivation called the *expectancy-value theory* (Wigfield, 1994; Wigfield & Eccles, 2000). Like the social-cognitive framework, expectancy-value theory is based on three different constructs, which include *intrinsic and extrinsic* motivation, *self-efficacy* and *interest*. Eccles and Wigfield believed that there are differences among children's and adolescent's self-efficacy or self-beliefs that affect their choice of activity and their performance (Wigfield, 1994; Wigfield & Eccles, 2000). These theorists along with others, measure achievement motivation of individuals by analyzing their persistence on the task, how fast they carry out the task, and their performance in the task.

Expectancy-value theory was first developed to analyze mathematics performance of students. The above theory is task specific and influences individual performances, persistence and effort that is later used to analyze their science performances (Wigfield, 1994; Wigfield & Eccles, 2000).

Researchers believe that there are differences between ability beliefs and expectations of success. Ability beliefs focus on one's present ability and expectations of success are focused on anticipated future outcomes (Bandura, 2000). Bandura (2000) suggested that self-efficacy or ability beliefs should be measured because these factors relate closely to an individual's behavior. Overall, in expectancy-value theory both ability and expectancy beliefs play an important role.

Constructivist pedagogies for analyzing student learning

Constructivist theory explains that students are actively involved in creation of their knowledge from the information that is presented to them in different learning environments (Richardson, 2003). This could lead to the hypothesis that KU students enrolled in an organic chemistry lecture course and not in the laboratory will show reduced ability to create a connection between their practical knowledge and theoretical knowledge. Conversely, students enrolled in both the laboratory and lecture courses might, on average, create better connections between theoretical and practical knowledge. For this reason, constructivism together with social-cognitive theories of memory were selected as appropriate theoretical frameworks for the study of the effect of the sequence of laboratory and lecture instruction on student learning and motivation to learn chemistry.

Researchers used constructivist-based methods to increase student success with conceptual learning (Driver et al., 1994; Terwel, 1999). Constructivist-based theories of learning have led to the incorporation of constructivist pedagogies in curriculum development for science classrooms. Research based on constructivism and constructivist-based pedagogies have been used to explain student difficulties with conceptual learning (Gabel, 1999).

Researchers such as Dorothy Gabel, Diane Bunce, George Bodner, and Mary Nakhleh suggest that differences between expert and novice learning strategies lead to differences in conceptual understanding. On average, students who are exposed to both laboratory and lecture courses should be more expert than students who enroll only in the lecture course. In contrast, students enrolled to only the lecture course are exposed to chemical concepts once during the semester with no exposure to practical knowledge from laboratory investigations. Gabel and Bunce (1994) outlined three suggestions for the transition of novices in chemistry into experts:

1. "By increasing the underlying conceptual understanding of novices"
2. "Making explicit the actual steps taken by experts to solve problems"
3. "Helping construct explicit relationships among the chemical principles, laboratory investigations, and mathematical applications for a given topic."

So, constructivist research supports the concept that improving student learning should include both increasing conceptual understanding in lectures and increasing practical understanding from laboratory investigations.

Previous research shows that knowledge among novices is more compartmentalized than is knowledge among the experts. Due to this compartmentalization of knowledge, novices cannot build connections between different domains of knowledge. Thus novices are less likely to transfer knowledge from one domain to another, increasing their conceptual understanding (Benander & Lightner, 2005). The findings of previous research suggest that students enrolling for lecture should also enroll for laboratory during the same semester to experience practical knowledge from the laboratory investigations, increasing their conceptual understanding of chemical concepts. Learning the concepts along with their applications helps students increase success in solving problems related to the concepts learned in lecture classrooms (VanderStoep).

Constructivist learning theories explain how conceptual understanding of a question or problem is created. Active cognition helps to integrate prior knowledge with new information. So, when students engage in practical learning in a short time lag with theoretical learning, they can build connections between prior knowledge and practical experience learned in the laboratory course, which students enrolled in just the lecture cannot experience. Students enrolled for the lecture can experience prior knowledge from previous experiences, but due to the compartmentalization of their knowledge, this conceptual knowledge is difficulty to connect with the new knowledge from the current lecture course. This leads to a difference between the groups who are enrolled for both the laboratory and lecture compared to those who are enrolled in only the lecture.

The previous discussion shows that constructivist-based pedagogies and teaching strategies can explain many aspects of student learning success, including:

1. The assimilation of a student's prior knowledge from their past experiences (long time lag),
2. The knowledge incorporated from laboratory investigations and experiments, which provide relevant experiences on which students can anchor their similar conceptual knowledge learned from the lecture, and
3. Engagement of students in active cognitive processes.

This helps determine whether prior knowledge from the past experiences or practical knowledge provides a better anchor for learning concepts in the lecture. Constructivist pedagogies help answer the primary research question of this study, whether enrolling for laboratory and lecture simultaneously vs. separately effect student (conceptual) learning and motivation to learn chemistry.

Effect of prior knowledge on learning and motivation

Prior knowledge can be defined as "the knowledge, skills, or ability that students bring to the learning process" (Filip Dochy, Segers, & Buehl, 1999). Student prior knowledge can be reflected in their ACT or SAT score, high-school GPA, and prior courses taken in the same subject area. There is a 25 to 30 year history of research in the field of prior knowledge and learning, and prior knowledge and motivation. Many theorists have offered definitions of prior knowledge, but in the context of this study, research prior knowledge means previous conceptual knowledge of chemistry that students have learned in their past.

Many lecture environments fail to define the relationship between different chemical concepts stated in the text. One of the consequences of such learning environments is students have incomplete understanding of the material they are studying. Students gain greater benefit from analyzing new information in the context of the information they already know (Pressley et al., 1992). Learning is an active process of the brain and prior knowledge influences how students understand or learn new concepts. Learning is a mix of "conceptual understanding and flexible use of knowledge" (Deci et al., 1991). To increase student learning and build a connection between new content and prior knowledge, students should answer questions related to new concepts based on prior knowledge (Pressley, et al., 1992).

One of the primary factors that can help with student learning in college science courses is domain-specific prior knowledge of that science. For example, in biology or chemistry courses without prior knowledge, it is difficult for students to form new conceptual knowledge (M. Johnson & Lawson, 1998). Significant improvement in the final course grade was observed in students with more prior knowledge (M. Johnson & Lawson, 1998).

Intrinsic motivation along with overall motivation is the major focus of this study. Intrinsic motivation is the motivation that comes from inside an individual rather than from any external or outside source, which is referred to as extrinsic motivation. Intrinsic motivation in the classroom can be influenced by teacher's differential treatment, self-efficacy, goal orientation, and self-determination, but the most important influence is prior student knowledge (Elliot & Dweck, 2005; Stipek & Hoffman, 1980). Maheswaran & Sternthal (1990) said that individuals with prior knowledge have an advantage over novices who have absolutely no background knowledge. In the Maheswaran & Sternthal study, graduate students were given different perception questions on various topics; half the participants were novices whereas the other half had prior knowledge about the facts in the questionnaire. The arithmetic means of the responses to the perception questions for the prior knowledge group were higher than the novice group (Maheswaran & Sternthal, 1990). The study suggested that the prior knowledge group had more motivation towards answering perception questions than the novice group (Maheswaran & Sternthal, 1990).

Four motivational constructs --goals, values, self-efficacy, and control beliefs -- are mediators in the process of conceptual change. These four motivational constructs are also influenced by students' prior conceptual knowledge. Prior knowledge is a cognitive model that influences motivational level and helps with the useful and relevant conceptual student learning process (P. Pintrich et al., 1993; P. Pintrich, Smith, Garcia, & McKeachie; P. R. Pintrich, 2004). Tobias (1994) in his article discusses the relationship between student learning, and interest and motivation with prior knowledge. The author draws a conclusion that there is a linear relationship between interest/motivation and prior knowledge (Tobias, 1994).

Efforts to integrate prior knowledge can lead to either correct understanding or misunderstanding through the formation of incorrect connections. These misconceptions can negatively affect student performance and understanding, and thereby affect their motivation to learn new concepts (Filip Dochy et al., 1999). Misconceptions researchers have tried to characterize student's understandings of new information and check if they were consistent with their prior knowledge. These misconceptions create cognitive conflicts among individuals. This increases stress and induces a lack of motivation, leading to incomplete conceptual understanding of a subject (Filip Dochy et al., 1999). Consequently, misconceptions can lead to lack of proper understanding, but insufficient prior knowledge can also reduce the student ability to build and structure new information or knowledge (Filip Dochy et al., 1999).

The influence of student characteristics on learning and motivation

In this study, student characteristics were analyzed by gender, ethnicity, and major information data obtained from the OIRP. Along with educational environments and peers, gender and ethnicity play a role in influencing student achievement and motivation towards learning (Nora, Cabrera, Serra Hagedorn, & Pascarella, 1996). In a study done by Nora et al (1996), family environment and relationships were shown to affect student learning and motivation. Minority students in this study tended to drop out of college, and this behavior was highly influenced by family environments and working off-campus. The commitment of males towards education was highly influenced by the interactions with their advisors or teachers outside of the classroom. Continuing enrollment in college is one of the important criteria for success in learning. This appears to be lacking among many minority students, though minority males appeared to possess an increased likelihood of continuous enrollment in the college. Interaction with peers and relationship with other peer students affected motivation towards learning for both males and females equally.

In previous studies done on gender and science education, no differences were observed among women and men, especially in the Western countries, with respect to giving education in schools (Severiens & Ten Dam, 1994; Weinburgh, 1995). Even then, fewer women have been involved in science and math education due to their tendency to drop out of school or engage in off-campus work. Previous empirical research was conducted to determine the relationship between gender and success in science learning. Variables examined in this study included teaching methods and the role of education in an individual's life (Severiens & Ten Dam, 1994; Slater, Lujan, & DiCarlo, 2007; Weinburgh, 1995; Wigfield, Battle, Keller, & Eccles, 2002). Studies based on gender differences on learning and performances were explained by learning styles, cognitive styles, and different learning strategies (Severiens & Ten Dam, 1994; Shaw & Marlow, 1999; Slater et al., 2007; Weinburgh, 1995; Wigfield et al., 2002).

In a study done by Severiens et al (1994) reviewed the learning styles associated with gender. Different learning styles influence how different contexts and concepts are learned. The different learning styles can include reading/writing, visual, auditory, and kinesthetic. Various studies note that females have a wide variety of learning styles compared to the males (Severiens & Ten Dam, 1994; Slater et al., 2007; Weinburgh, 1995). Learning style characteristics help in developing teaching strategies that will enhance student's motivation and learning concepts for both the genders. Both males and females prefer multimodal learning styles that include both reading/writing and visual or practical learning styles. From this, it is possible to posit that students enrolling for both laboratory and lecture should be more benefited than students who just enroll for the lecture for conceptual learning.

US government policies recognize that recruiting a diverse population of students and faculty members to science remains a significant problem. With this limited diversity, minority students like African-Americans and Hispanics find it difficult to interact with peers who are of similar ethnicity. This has the potential to negatively affect peer learning environments. In turn, peer learning environments can affect student motivation towards learning along with their learning concepts. It can be sometimes be easier to learn certain concepts from your peers rather than from expert professors. The lack of an affective learning environment can have a negative impact on the overall learning process and motivation. Diversity does influence a student's academic or intellectual outcome. It has been also observed that when students of different diversity interact in classrooms there is an increased level of concept understanding, problem solving skill and group skill among individual students (Gardner, 1988; Nora et al., 1996; Terenzini, Cabrera, Colbeck, Bjorklund, & Parente, 2001).

There is an extensive history of studies focusing on gender differences, why and how are they developed, and how they influence different learning styles, cognitive abilities and achievements (Severiens & Ten Dam, 1994; Slater et al., 2007; Weinburgh, 1995; Wigfield et al., 2002). Learning style and conceptual learning stems from a combination of cognitive and psychological traits that serve as the indicator of how someone perceives, interacts and responds to the learning environment (Terenzini et al., 2001). There is always characteristic way of an individual, male or female, when they approach a learning task. General cognitive and learning characteristics are specific for every individual. The learning style inventory defines four different stages of learning (Terenzini et al., 2001):

1. Concrete experience
2. Reflective observation
3. Abstract conceptualization
4. Active experimentation

Males and females tend to have different learning styles: Males are more visual and peer-motivated compared to the females (Severiens & Ten Dam, 1994). Females are more self-motivated and learn better with reading and writing. Males tend to learn more when they are competitive compared with females, who learn more when they are in a supportive small group environment. All these learning strategies tend to promote males prove themselves better than females in the laboratory, and females outperform males in lecture classrooms. Taking laboratory and lecture together appears to be more beneficial for male students compared to females in their concept learning process (Severiens & Ten Dam, 1994).

Chapter 3- Preliminary Research on Student Performance: Overview, Results, and Discussions for Organic Chemistry II

Purpose and Overview

The preliminary study was conducted to examine the effect of sequencing (enrolling to both laboratory and lecture vs. enrolling only in the lecture) on student performance in a lecture course. Demographic and academic background information (to measure prior knowledge of the student) was also collected for the students enrolled in organic chemistry II course (CHEM 626/627) at the University of Kansas (KU) from spring of 2008 till 2010. Organic chemistry II is offered at KU, only during the spring semesters. The preliminary study also helped better define of the backgrounds of the students in the course. This helped to determine which background variables were associated with student performance. Anecdotal observations of student achievement led to the idea that there was a significant difference among students enrolling for both the laboratory and lecture compared to those enrolling for just the lecture course, but this fact was not well supported by any quantitative data. This preliminary study helped to quantitatively determine the difference between students enrolled in both the laboratory and lecture with students enrolled for just the lecture, and how this sequence of enrolling in courses affects student performance in the lecture. Studies of student performance in organic chemistry can add to our understanding of student learning and motivation to learn organic chemistry. Data was obtained from university records regarding demographic and academic backgrounds of the students, along with their final grades in the lecture course. These factors were correlated with student performance in organic chemistry II lecture course.

The data obtained from the university records were coded with non-specific student identifiers. This was done to maintain the students' privacy. The results from this preliminary study were purely used to better describe the overall student population enrolled for organic chemistry II and their performance. This preliminary study provided information that further helped in analyzing the effect of sequence of enrollment in student learning and motivation. It also helped in understanding the student population who were enrolled in organic chemistry I course because the students enrolled for organic chemistry II are a subset of students from organic chemistry I course.

Course Structure for Lecture and Laboratory

The second semester organic chemistry course, from spring of 2008 till 2010 was selected for this preliminary study. The same professor taught the course in 2009 and 2010, but a different professor taught the course in 2008. From the spring of 2008 till 2010, the professors were using the same textbook, *Organic Chemistry by Janice G. Smith*, and the structure of both the laboratory and lecture course were similar for all three years. The structure included 50-minutes lecture class that met three days per week and five-hour laboratory that met once per week. Along with the five-hour laboratory sessions there was a separate laboratory lecture conducted for an hour and fifteen minutes once per week. One professor was responsible for the lecture course, and a separate professor responsible for the laboratory-lecture course. Different graduate teaching assistants are responsible for teaching the various laboratory sections and these students are usually conducting graduate work in organic chemistry. All the students enrolled for the lecture met in a single large group in an auditorium for their classes, and students who also enrolled for laboratory were divided into groups of 20 or less for their individual lab sections.

The most important factor leading to sequencing issues involving laboratory and lecture is that students are not required to enroll for both laboratory and lecture during the same semester, though many self-select themselves into the group who are simultaneously enrolled in laboratory.

During the springs of 2008 till 2010 approximately 800 students enrolled for the lecture course, and among these 537 students completed the course for a grade, and had demographic and academic background information available with the university. For this study, the students who enrolled for both the laboratory and lecture course, called the concurrent lab group, included 478 students. The students who just enrolled for the lecture and not the laboratory are called the no-lab group and included 59 students.

Student grades for the lecture and laboratory are assigned separately and are independent of each other. For the lecture, students can earn a maximum of 570 points, and for the laboratory, students can earn a maximum of 602 points. The lecture grade was determined by four one-hour exam scores worth 100 points each, out of which only the three best scores are considered for the final grade, along with top seven quiz scores which are worth 10 points each, and the final exam worth 200 points. These assignments sum up to 570 total points for the final lecture grade. The laboratory grade consisted of two exam scores (a midterm and a final) each worth 100 points, along with 9 quiz scores worth 8 points each, laboratory techniques worth a total of 30 points, and finally 12 graded laboratory notebooks sections and reports on laboratory experiments which are worth 25 points each. All these sums up to 602 points for the final laboratory grade in CHEM 627. The final lecture grade was collected from university records to measure student performance. The course final grade is given to the students in form of A, A-, B+, B, B-, C+, C, C-, D+, D, D-, and F, where getting above a 93% is an A and getting below 60% is a F grade.

The resources available to students during the course included the assigned textbook, instructor office hours, laboratory and lecture TA office hours, along with emailing system between the students and the instructors. The only pre-requisite for enrolling in the lecture course is that students should have completed organic chemistry I course successfully (first semester organic chemistry). To enroll for the laboratory the pre-requisites state that a student must have completed organic chemistry I laboratory (first semester organic chemistry laboratory) and should have been concurrently enrolled or completed organic chemistry II lecture course (second semester organic chemistry). This gives a student the choice of whether to enroll for the laboratory and lecture simultaneously or separately.

Lecture and laboratory are treated as separate courses with separate grades. The concepts that were introduced in the laboratory had similarity to some concepts introduced in the lecture course. The common topics introduced in both lecture and laboratories were oxidation of alcohols, Diels-Alder reactions, electrophilic aromatic substitution, Aldol reaction, Grignard's synthesis and reagents, and kinetic and thermodynamic products of organic reactions. Some of these concepts were introduced in the laboratory before they were introduced in the lecture and some other concepts were introduced in the lecture before being introduced in the laboratories; however, all of these particular concepts were introduced in both the lecture and laboratory. Exposure to concepts twice in a row for students enrolled in both the laboratory and lecture courses compared with learning concepts once for the students enrolled in just the lecture course should affect student understanding of these concepts.

Selection of Student Groups for analysis from 2008-2010

Data obtained from the university records consisted of approximately 800 students who were enrolled for the second semester organic chemistry lecture course. Some of these were concurrently enrolled for the laboratory and some of them were not enrolled for the laboratory. Out of these students some of students were enrolled for the lecture course for the second time. To eliminate the possibility that prior exposure to the lecture material might have an effect on student performance, such students were excluded from the sample data. Some other students had already received a grade in the laboratory, but had no recorded lecture grade,. This group of students was also removed from the sample data. The sample analyzed in this study included only students who were enrolled for the lecture and laboratory or just the lecture course for the first time and earned a grade of A through F in the course.

Demographic data were also collected from the university records. This additional information included gender, ethnicity and major information, and prior background knowledge information, which was characterized by ACT score and high-school GPA. Some of the student data did not have all these records and had to be removed from the sample data to maintain equality and homogeneity among student data during the analysis. On this basis, approximately 263 students were removed from the sample. The remaining students were part of the sample data (N = 537) for the spring of 2008 through 2010. The total sample size for the concurrent lab group (students enrolled for both the laboratory and lecture) was N = 478, and the total sample size for the no-lab group (students enrolled for the lecture) was N = 59. All of this data was used for the preliminary research data analysis.

Overview of Data from OIRP

Demographic data

The demographic information obtained from the university records included gender, ethnicity, and academic major. According to the demographic data, as shown in Table 1, there were 287 females and 250 males in the student population. There was little diversity among the ethnicities. Approximately 80.3% of students applying to KU self identify as white. Other ethnicities included African-American, Hispanic, Asian, and others (which includes students from international background/non-Asians, and who identified themselves as multi-ethnicity and non-specific). Minority students include African-American and Hispanic populations with 2.1% and 3.4% respectively, as stated in Table 1.

Student majors included biology, biochemistry, chemistry (BA and BS), students self-identified as pre-med (pre-med), student self-identified as pre-pharmacy (pre-pharm), and engineering. The student population also included some health science majors. Biology majors were approximately 48% of the population. Following them were the biochemistry and the pre-pharmacy majors with 11.5% and 17% of the population, respectively. The population description and percentages are included in Table 1. Most of the students enrolled for this course were in their sophomore or junior year. Although, detailed information about the student's number of years of enrollment at KU was not collected from the university.

Table 1: Demographic Information CHEM 626, 2008-2010

Demographic Information Table			
Variables		N	Percent
Gender	Male	250	46.6
	Female	287	53.4
Ethnicity	White	419	80.3
	Hispanic	18	3.4
	African-American	11	2.1
	Asian	69	13.2
	Others	5	1.0
Major	Biochemistry	62	11.5
	Biology	257	47.9
	Chemistry BA	29	5.4
	Chemistry BS	31	5.8
	Engineering	13	2.4
	Pre-Med	20	3.7
	Pre-Pharmacy	91	16.9
	Others	34	6.3

Academic background

Academic background data collected from university records included ACT score and high-school grade point averages (HSGPA). Of those enrolled for second semester organic chemistry course approximately 85-90% of the students reported their high-school GPA and ACT score. Different school districts apply different methods for reporting high-school grade point averages. Some of the schools report grade point averages on an un-weighted scale, which means grades in all courses are worth equal points, while other schools report grade point averages on a weighted scale, meaning that grades in advanced courses are awarded more points than standard-level courses. The HSGPA of the students enrolled for the second semester organic chemistry course ranged from 4-point un-weighted, 4-point weighted, 5-point un-weighted, 5-point weighted, 100-point un-weighted, and 100-point weighted. On some weighted scales, for students taking advanced coursework it is possible to obtain values above the value used in the scale. For example a student getting A in an advanced course can get 4.2 rather than 4.0 in a weighted scale. During admission to KU, the university converts all the weighted HSGPAs that range above the scale of 4.0. In this process all the weighted HSGPAs ranging above 4.0 are reported as a 4.0 value. As a consequence, the HSGPA's for students enrolled in second semester organic chemistry ranged from 2.0 to 4.0.

From 2008 till 2010, students enrolled in organic chemistry II had an average HSGPA of 3.77 with standard deviation of 0.4. Figure 1 shows a histogram of the HSGPA (converted) with respect to a normal curve. Note that the curve is negatively skewed. This seems to be because numerical grade point averages above a 4.0 were truncated and reduced to a 4.0. This version of the HSGPA is not acceptable because the analysis we have planned includes correlations, ANOVAs and regressions. To run all this analysis it is important that the variables used should have a population distribution that is approximately a normal curve. Thus, un-converted HSGPA values were obtained from the university records.

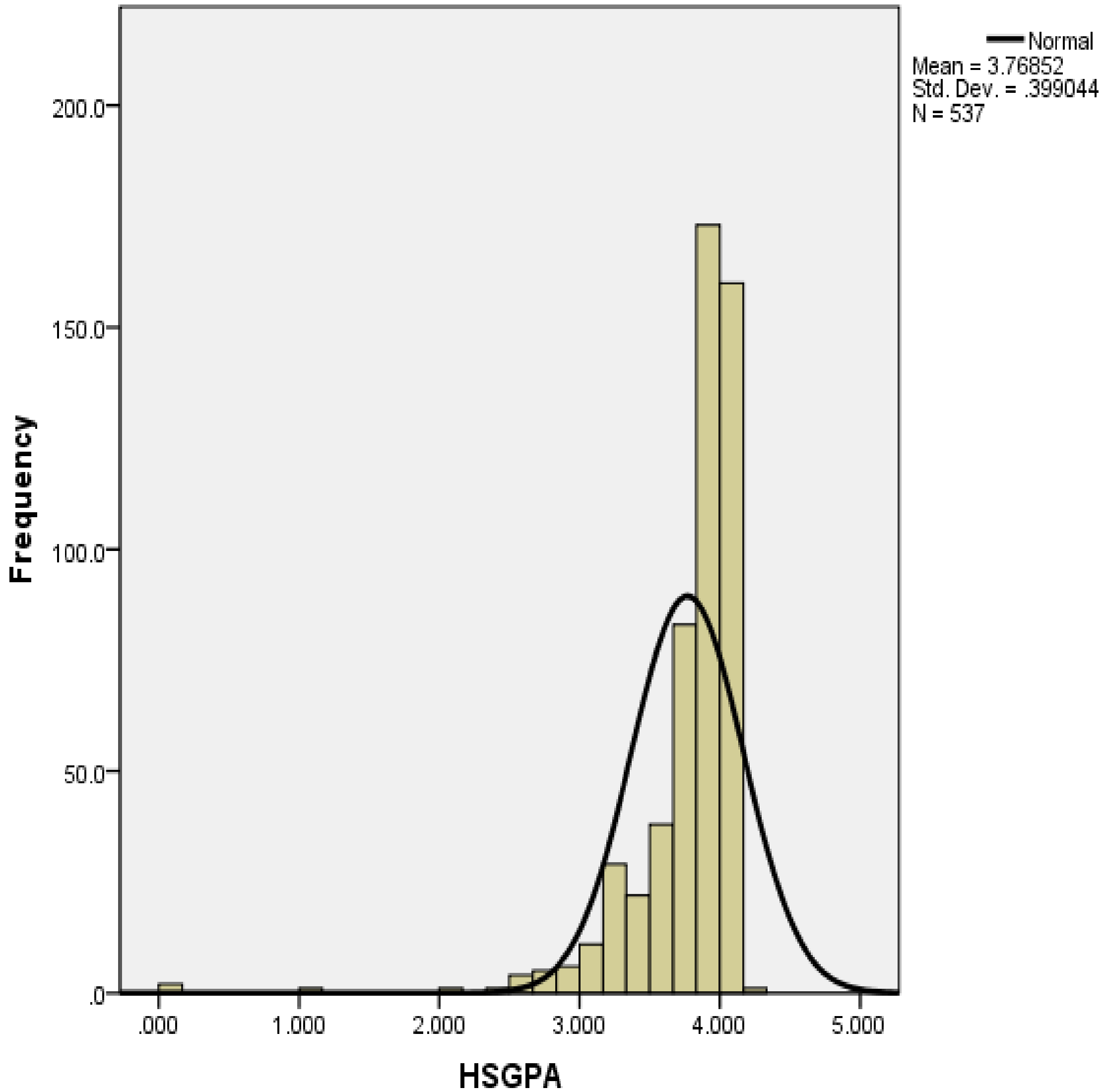


Figure 1: The histogram shows the distribution of high school GPAs (HSGPA) for students in organic chemistry II (CHEM 626) from 2008 till 2010. This distribution does not fit a normal curve due to a strong ceiling effect and is negatively skewed.

These un-converted high-school GPAs, shown below in Figure 2, were used for the analyses in this study. The new grade distribution now more closely resembles a normal curve (Figure 2). The HSGPA has a mean of 3.72 with a standard deviation of 0.52. This mean and standard deviation is a little different compared to the truncated HSGPA but is more useful with standard statistical methods.

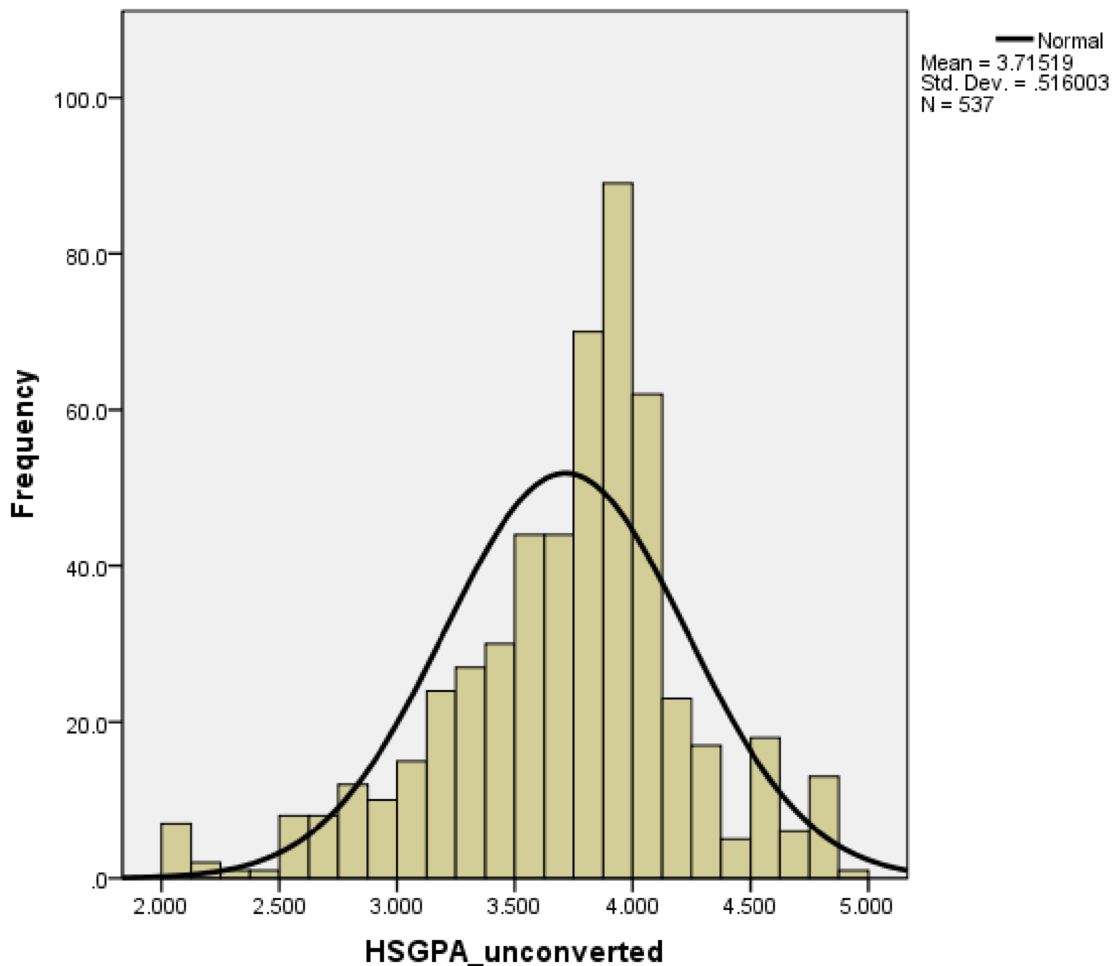


Figure 2: The histogram shows the distribution of unconverted high school GPAs (HSGPA_unconverted) for students in organic chemistry II (CHEM 626) from 2008 till 2010. This distribution fits into a normal curve.

ACT composite scores can be a good predictor of prior background knowledge (Thompson Ross, 2004). The ACT score data was collected from the university records to determine if ACT composite scores correlate with student performance in Organic II. Our of the students who enrolled in the organic chemistry II course, approximately 85-90% reported their ACT score to the university. The average ACT composite score is 27.15 with a standard deviation of 3.44. Figure 3 shows the values, and it can be concluded that this variable is normally distributed within the group of enrolled students.

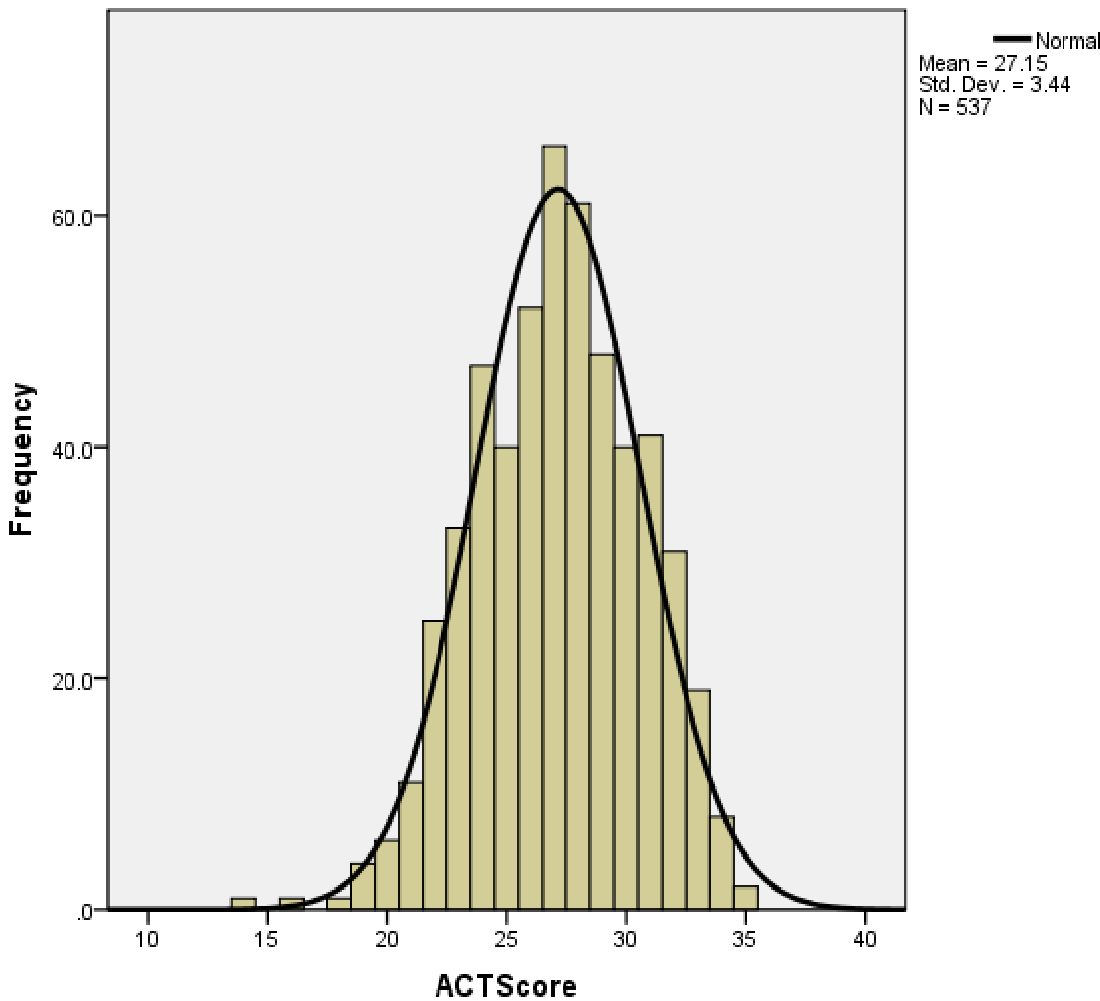


Figure 3: The histogram shows the distribution of ACT scores for students in organic chemistry II (CHEM 626) from 2008 till 2010. This distribution does fit into a normal curve.

Course performance based on final grades

Course performance for the second semester organic chemistry (organic chemistry II) course was analyzed based on the final grades of students obtained from the university records. The mean grade for students enrolled in organic chemistry II (N = 537) was 3.0, with a standard deviation of 0.92. The grades ranged from A (4.0) through F (0.0). The histogram for student grades was negatively skewed. Both the skewness (-0.7) and kurtosis (-0.2) values were less than ±1.0. If both the skewness and kurtosis are between ±1.0 then the curve can be generalized as normal distribution. Other than grades of A through F, grading options also included credit (CR), no-credit (NC), and withdrawal (W). Students with those grades were excluded from the sample data because they did not successfully complete the course. Furthermore, these students did not fit the research question that was being solved in this study. Figure 4 shows the histogram that defines the course performance based on grades. The figure also lists the mean, standard deviation, and plots the idealized normal curve for the data set.

The organic chemistry II course was taught by different professors in 2008 and 2009-2010. The mean grade for students enrolled in organic chemistry II in 2008 (N = 200) was 3.0, with a standard deviation of 0.92, and for students enrolled in 2009-2010 (N = 337) the mean grade was 2.7 with a standard deviation of 1.10. The histograms for student grades were negatively skewed. Both the skewness (-0.7) and kurtosis (-0.2) values were less than ±1.0 for both 2008 and 2009-2010. The skewness and kurtosis values signify that both the curves could be generalized as normal distributions and were comparable. For this study the student population was mixed together from 2008 till 2010, as the grade distributions for all the years were comparable and had normal distributions. Figure 5 shows the histogram that defines the course performance based on grades in 2008 and Figure 6 shows the histogram that defines the course performance based on grades in 2009-2010.

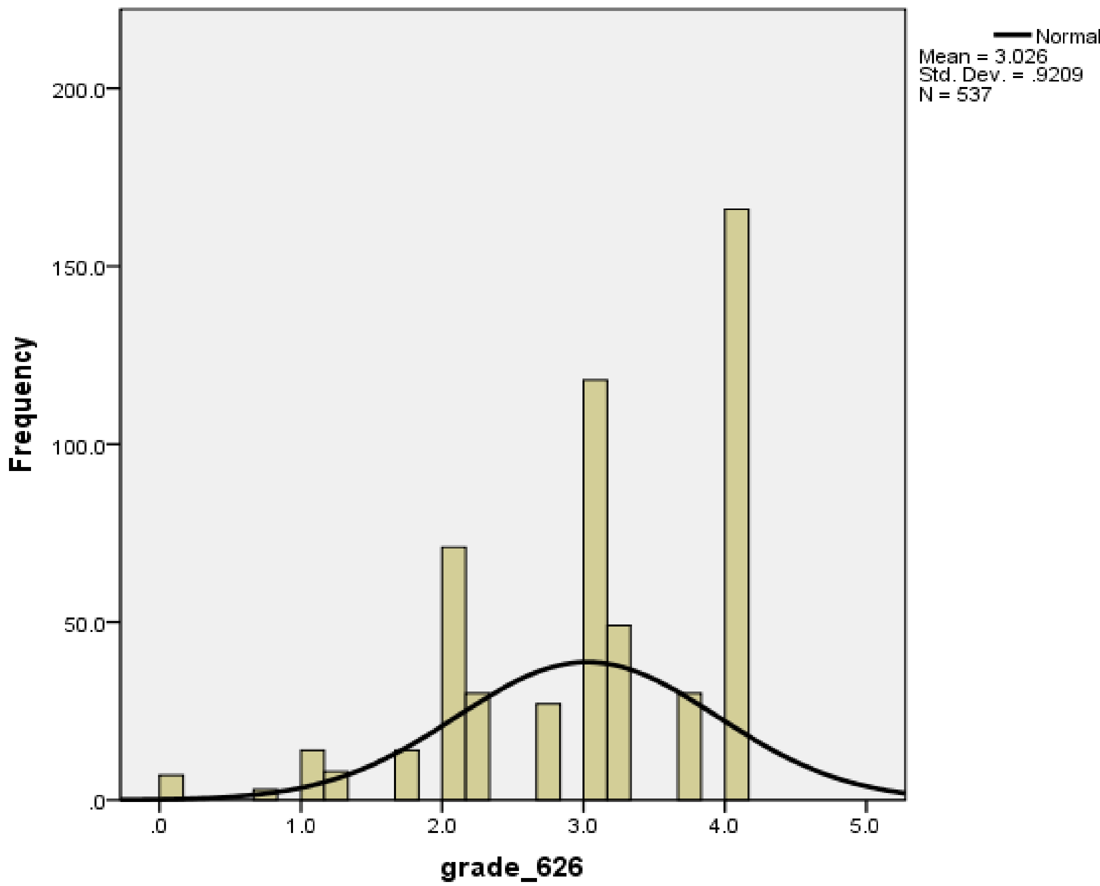


Figure 4: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry II (CHEM 626) from 2008 till 2010. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

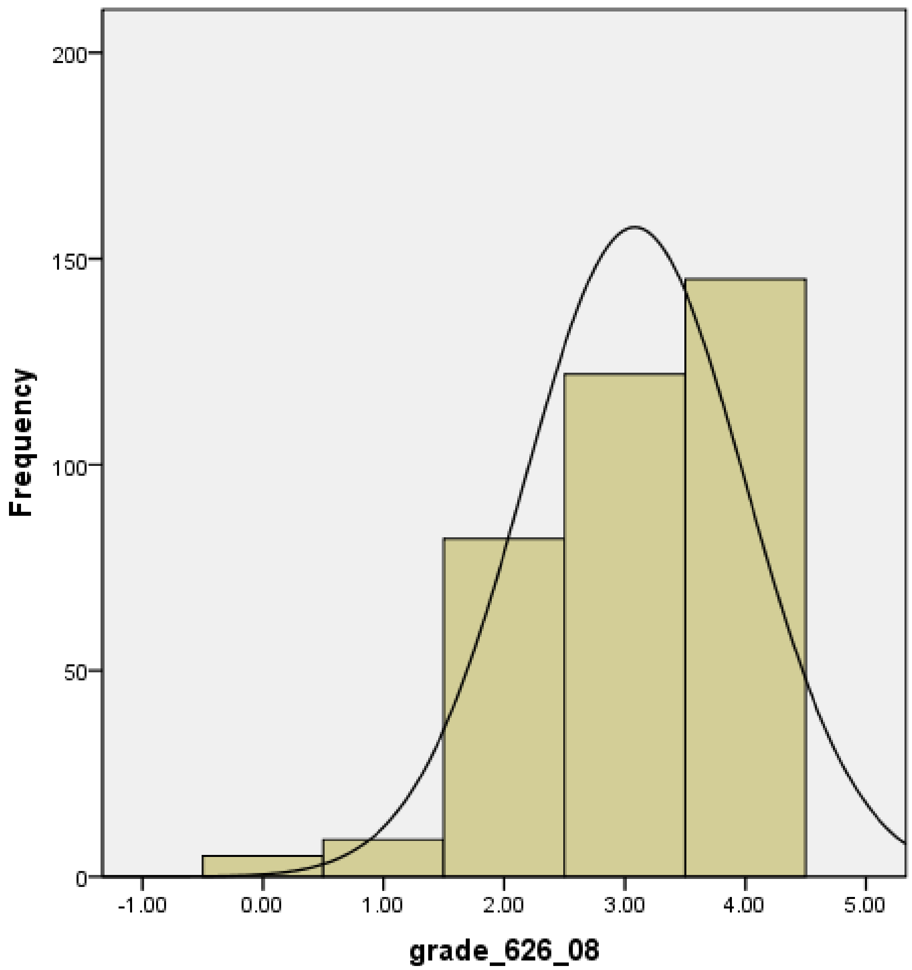


Figure 5: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry II (CHEM 626) in 2008. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

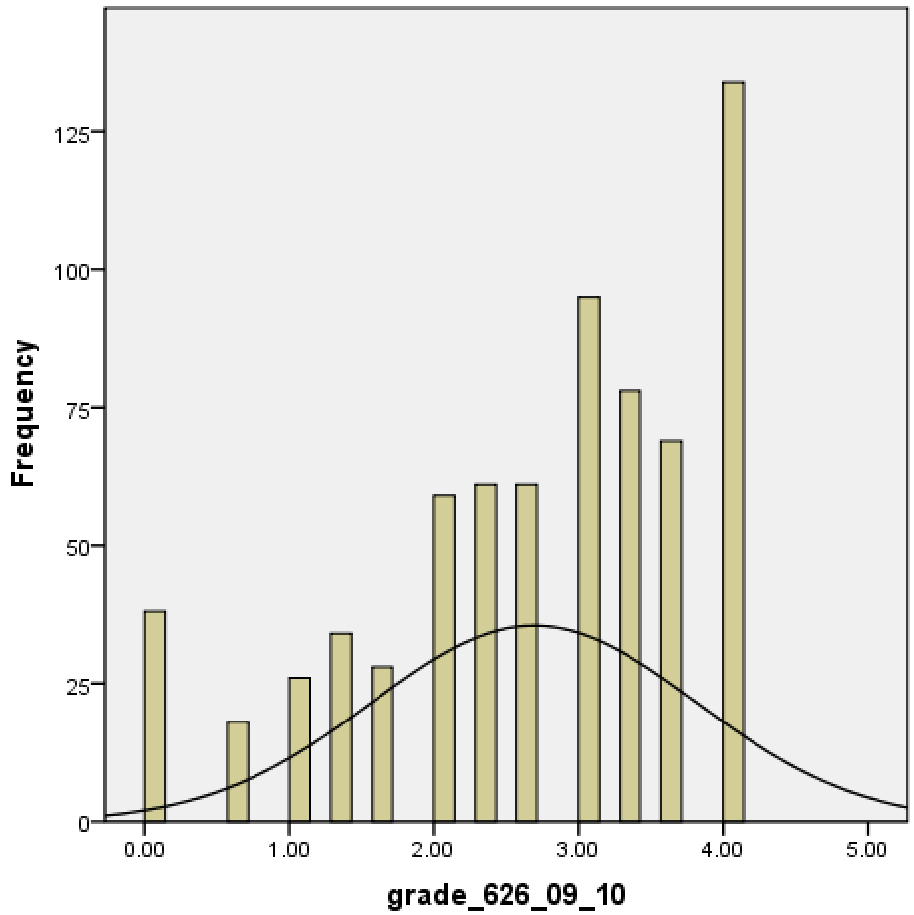


Figure 6: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry II (CHEM 626) in 2009-2010. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

Methods of analysis

The analysis of student performance in Organic Chemistry II (CHEM 626) included statistical analysis of final lecture grades from spring 2008 to fall 2010, using SPSS (Statistical Package for the Social Sciences) software. Statistical analysis included correlations, partial correlation, one-way analysis of variance (ANOVA), T-tests, and multiple linear regressions.

Correlations

Correlation can be defined as a number that describes a relationship or association between two variables. The correlation coefficient can also describe the strength and the direction of the relationship. It is important that both the variables are at interval level or above. Correlations range from -1 to +1, where close to a zero is a weak correlation and close to a +1 or -1 is a strong correlation. The negative number signifies that the relationship between the two variables is negative (one variable increases and the other variable decreases), and the positive number signifies a positive relationship (one variable increases and the other variable also increases) between the two variables. The equation used to calculate Pearson's correlation (r) by hand is:

Equation 1: Pearson's correlation (r) (William, 2006)
N = sample size, and x, y are two variables.

Partial Correlations

Partial correlation is a method for measuring three-way overlap of the three variables. All the variables should be interval level or above. Another way of defining partial correlation is to determine if there is any correlation between two variables when the third variable is held constant. Partialling method can exert statistical control over other variables. For this study partial correlation coefficients are determined to define the relationship between independent variable and dependent variable after controlling for (common variance accounted) other predictor or confounding variables. The equation used to calculate partial correlation r by hand is:

Equation 2: partial correlation equation (Lowry, 1999)

One-way Analysis of Variance (ANOVA)

One-way analysis of variance (ANOVA) compares the mean of one or more groups based on one independent variable. ANOVA operates by dividing the total variability into systematic and non-systematic sources of variability. The amount of variation is observed in the dependent variable. ANOVA helps us to answer the question that how much variability is accounted by each group or how are the mean values of the dependent variable are related to the independent variable. ANOVA draws inferences among group differences. When systematic (treatment) variance is significantly different compared to non-systematic (error) variance, the groups are considered to be statistically different. ANOVA is determined by the F-test and the following equation is used to find the observed F value:

Equation 3: Observed F value calculation by hand. (Chart, 2001)
Where, MS_B = mean square between (sum of squares between÷ degrees of freedom between groups) and MS_W = mean square within (sum of squares between ÷ degrees of freedom within groups)

Alpha level can be defined as "a priori threshold that represents an acceptable level of error" and most commonly 0.05 is used as the alpha level by the researchers. After the research question and null hypothesis is decided by the researcher, a critical F value is found out for the total sample size at the 0.05 level of significance (alpha level). Then the observed F value is calculated using the equation above and if the observed F value is greater than critical F value then we can conclude that the two groups are significantly different from each other.

Independent sample T-test

Independent sample T-test is used by researchers to determine whether two groups are statistically different based on measurement of one independent variable. The independent variable should be at least interval level or above. Level of significance or alpha level has to be defined prior to beginning of the experiment. Alpha level can be defined as "a priori threshold that represents an acceptable level of error" and most commonly 0.05 is used as the alpha level by the researchers. After the research question and null hypothesis is decided by the researcher, a critical t value is found out for the total sample size at the 0.05 level of significance (alpha level). Then the observed t value is calculated using an equation and if the observed t value is greater than critical t value then we can conclude that the two groups are significantly different from each other. One-way ANOVA and independent sample T-tests are similar because both of them compares between two groups (two levels of one independent variable), it depends on the researchers which value they want to use because both values will be identical. The equation used for calculating T- value by hand is:

Equation 4: Observed T-test calculation (Zhang, 2006)
Where, n1 and n2 are sample sizes for group 1 and group 2

Multiple Linear Regressions

A linear equation can estimate the coefficients of the linear equation when one or more independent variables predict the value of the dependent variable. The test quantifies the relationship between the independent variable and the dependent variable in the light of effect of effects from other independent variables. It also helps in predicting the dependent variable from the independent variable with the help of the equation and it considers every individual in the population rather than generalizing samples into groups where information is lost, like in ANCOVA (analysis of covariance). The linear regression equation can estimate how much the dependent variable changes when the independent variable changes by one unit. The linear regression equation accounts for the covariance of all the independent variables including the error factor on the dependent variable. The linear regression equation is:

$$Y = b1X1 + b2X2 + b3X3 + error$$

Equation 5: Multiple linear regression equation.
Where, Y is the dependent variable, X is the independent variable, b is the coefficient.

Results of the statistical analysis for measuring student performance in CHEM 626, 2008-2010

A correlation analysis was performed to understand the relationship between two interval level variables. This study was performed to examine the relationship between the *independent variable* (taking lab and lecture together vs. separate) and the *dependent variable* (grades obtained in CHEM 626), along with the relationship between the *dependent variable* and the *covariates or antacedents* (demographic and academic information). Students who were enrolled in the laboratory and lecture course together, the *concurrent-lab group* (N = 478) had a mean score of 3.07 with standard deviation of 0.89, and students enrolled for just the lecture course, the *no-lab group* (N = 59) had a mean score of 2.65 with standard deviation of 1.07. The correlation between the no-lab group and the grades obtained by the students in CHEM 626, $r (535) = -0.15$, $p < 0.01$ is negative and weak, but is significant at 0.01 level of significance (α). The level of significance established as a benchmark for this research study was 0.05 (α). When correlation analysis was performed among the covariates and the grades obtained in CHEM 626, significant correlation was observed among the academic background information, ACT score $r (535) = 0.21$, $p < 0.01$, and HSGPA $r (535) = 0.16$, $p < 0.01$ respectively. One of the demographic information, male gender, had a significant correlation with grades obtained in CHEM 626, $r (535) = 0.12$, $p < 0.01$. Table 2 shows that all the other demographic information (ethnicity and major) did not have any significant correlation with the grades of CHEM 626.

Table 2: Correlation Table for CHEM 626, 2008-2010

	ACT score	HSGPA	Gender	Ethnicity	Major	Concurrent lab group vs. no-lab group
grade 626 r	.211**	.157**	.119**	-.003	.021	-.145**

**signifies statistical significance at 0.01 level

A Partial correlation analysis was performed to measure the effect of sequencing on student performance after controlling for the significant confounding variables, like the ACT score, HSGPA, and male gender. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for ACT score resulted in, $r (534) = -0.134$, $p < 0.01$. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for HSGPA gave, $r (534) = -0.138$, $p < 0.01$. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for male gender showed, $r (534) = -0.156$, $p < 0.01$.

To determine whether the results included any significant effect of demographic information and academic background on student grades obtained in CHEM 626 separate one-way ANOVAs were performed. The academic background (ACT score, HSGPA, and major) and demographic information (gender and ethnicity) were used as the independent variables, and the student grade in CHEM 626 as the dependent variable. Ethnicity categories constituting 3% or less of the groups of interest were determined to have insufficient power to stand as alone as independent variables. Consequently, these categories were combined together in a category labeled *others*, also the major category constituting of 3% or less of the groups of interest were combined together in a category labeled *others*. All of the background variables that were interval level or dichotomous, like the gender, did not have to be altered prior to the ANOVA analysis, whereas, the nominal or ordinal level variables had to be altered into interval level, like the ACT score, before performing the analysis. In total, 5 confounding variables were analyzed for their effects on student performance.

Table 3 presents the percentages of students in each group along with ANOVA results obtained by comparing these groups of interest for the 5 confounding variables. Levene's test was performed prior to each ANOVA on the interval level variable and the dichotomous variable to test the homogeneity of variance among the groups of interest. When Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and their statistical significance was better described by Welch-F statistic rather than traditional F-statistic. The Welch-F statistic is a robust test of equality of means that can be used in a modification of the traditional version of ANOVA that does not assume homogeneity of variance among the variables. The ANOVA results in Table 3 clearly identifies the variables for which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore requiring the application of a significance test based on Welch-F statistic.

Whether there is a difference in performance between students enrolled in the concurrent lab group and the no-lab group, a one-way ANOVA was also performed with students enrolled in concurrent lab group and no-lab group as the independent variable and the student grades in CHEM 626 being the dependent variable. From the ANOVA test it was determined that there was a significant difference between the students enrolled in the concurrent lab group (N = 478) and the no-lab group (N = 59). The mean grades for the concurrent lab group (M = 3.07, SD = 0.89) and for the no-lab group (M = 2.65, SD = 1.07). There was found to be a significant difference between the two groups, $F (1, 535) = 11.52$, $p = 0.001 < 0.05$, hence significant at 0.05. Prior to conducting ANOVA Levene's test of homogeneity showed that the variables conformed to homogeneity of variance, $p = 0.354 > 0.05$.

Figure 7 illustrates the difference in mean grades between the two groups (concurrent lab group and no-lab group) with regards to gender. Figure 8 shows the distribution of students enrolled in CHEM 626 based on gender. Figure 9 illustrates the difference in mean grades between the two groups (concurrent lab group and no-lab group) with regards to ethnicity. Figure 10 shows the distribution of students enrolled in CHEM 626 based on ethnicity. Figure 11 explains the difference in mean grades between the two groups with regards to the major information obtained from the students. Figure 12 shows the distribution of students enrolled in CHEM 626 based on major information. Ethnicity, major, and gender information is not significantly different for the two groups.

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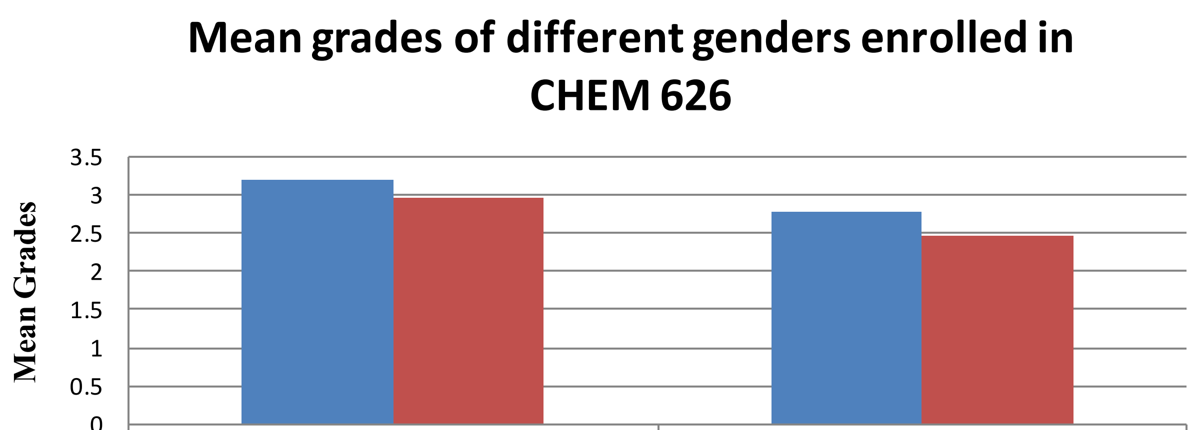
Table 3: Summary Statistics and ANOVA table for CHEM 626, 2008-2010

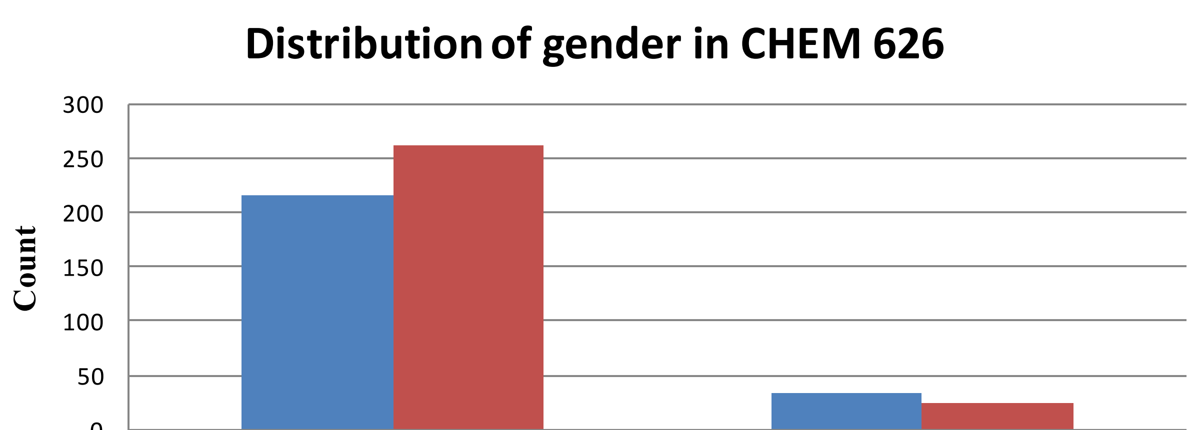
Summary Statistics and ANOVA results of Organic Chemistry II (CHEM 626) from spring of 2008-2010			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 478)	No- lab group (N = 59)
Gender	Female	54.8	42.4
	Male	45.2	57.6
ANOVA	Gender*	F (1, 535) = 1.60, p = 0.221 > 0.05	
Ethnicity	White	89.4	10.6
	Hispanic	85.0	15
	African-American	69.2	30.8
	Asian	92.9	7.1
	Others	71.4	28.6
ANOVA	Ethnicity*	F (1, 535) = 1.39, p = 0.243 > 0.05	
Major	Biochemistry	93.5	6.5
	Chemistry BS	80.6	19.4
	Chemistry BA	89.6	10.4
	Biology	85.9	14.1
	Pre-pharmacy	96.7	3.3
	Pre-Med	90.0	10.0
	Engineering	84.6	15.4
	Others	91.2	8.8
ANOVA	Major	F (1, 535) = 1.238, p = 0.22 > 0.05	
ACT score		83.0	17.0
ANOVA	ACT score*	F (1, 535) = 1.38, p = 0.245 > 0.05	
HSGPA		79.8	20.2
ANOVA	HSGPA*	F (1, 535) = 1.67, p = 0.231 > 0.05	

Bolded ANOVA results are significant; *signifies that variables are homogeneous (Levene's Test)



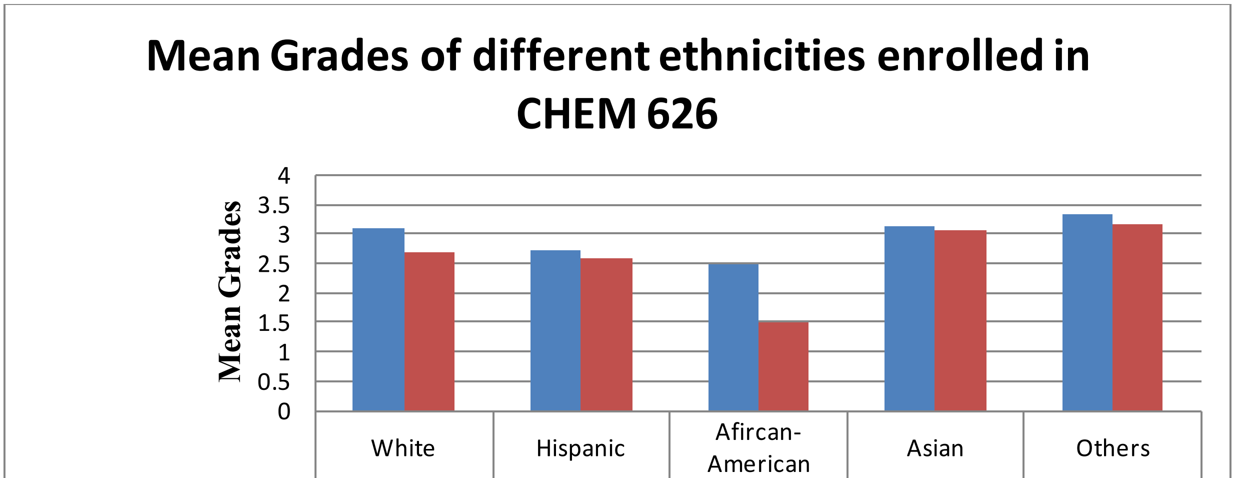
	concurrent lab group	no-lab group
male	3.201	2.776
female	2.967	2.468

Figure 7: Difference in mean grades based on gender difference between the two groups (concurrent lab group and no-lab group)



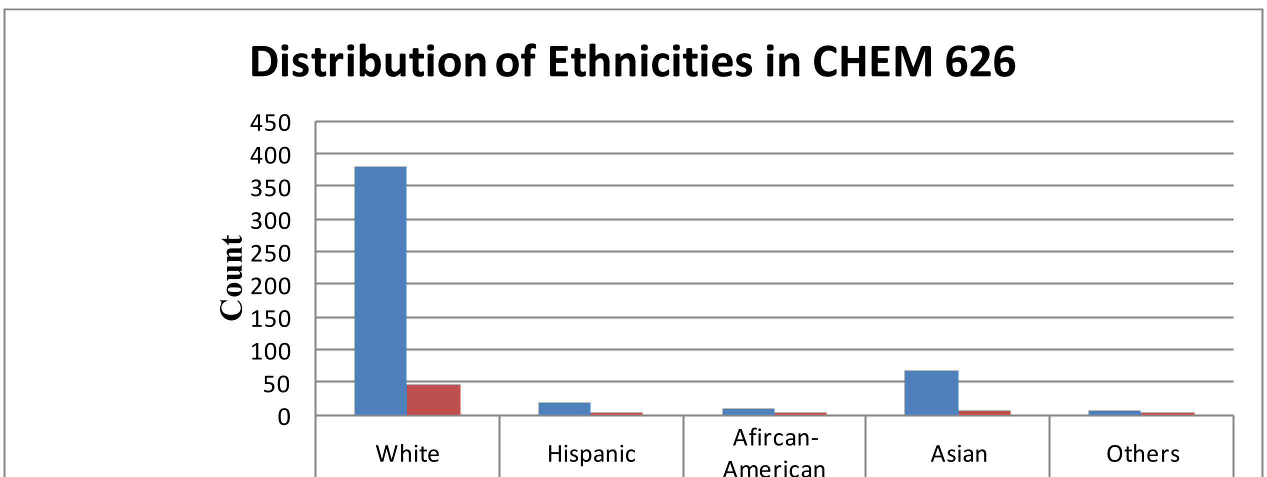
	concurrent lab group	no-lab group
male	216	34
female	262	25

Figure 8: Distribution of gender enrolled in both the groups (concurrent lab group and no-lab group) in CHEM 626



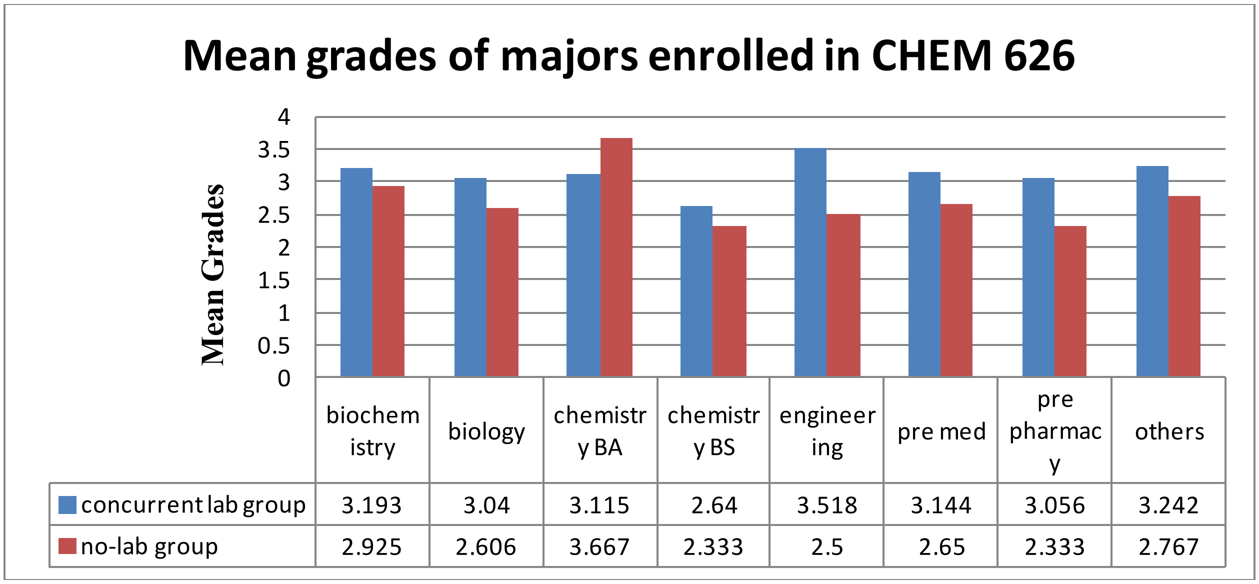
	White	Hispanic	Afircan-American	Asian	Others
concurrent lab group	3.091	2.706	2.478	3.124	3.34
no-lab group	2.684	2.587	1.5	3.06	3.15

Figure 9: Difference in mean grades based on ethnicity difference between two groups (concurrent lab group and no-lab group)



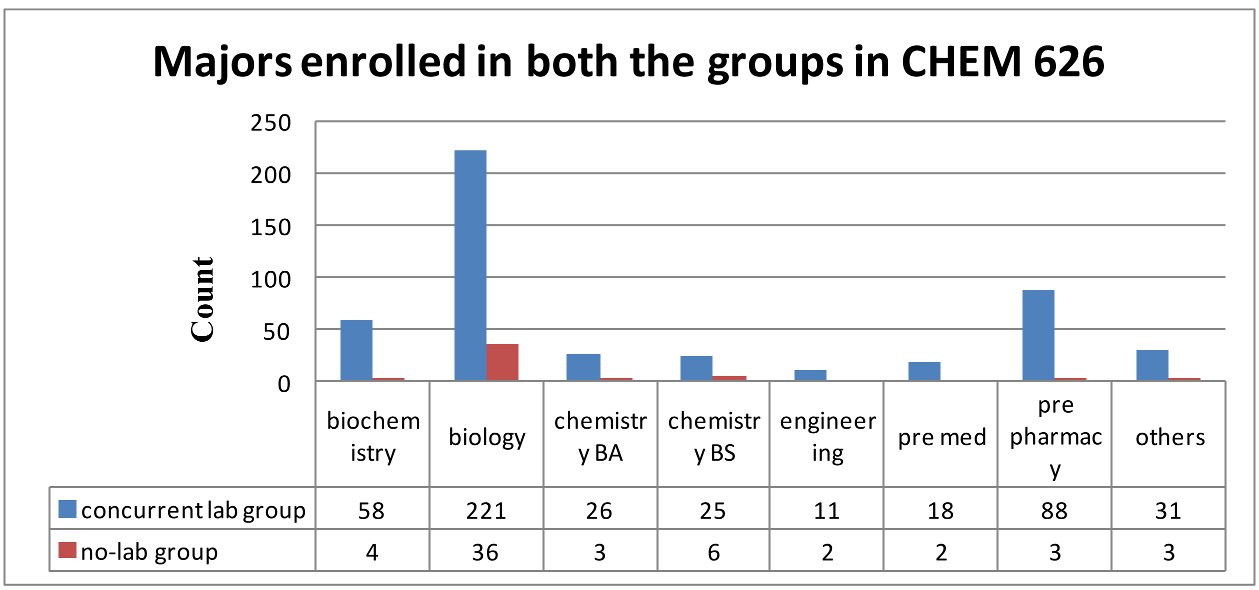
	White	Hispanic	Afircan-American	Asian	Others
concurrent lab group	381	17	9	66	5
no-lab group	45	3	4	5	2

Figure 10: Distribution of ethnicities enrolled in both the groups (concurrent lab group and no-lab group) in CHEM 626



	biochemistry	biology	chemistry BA	chemistry BS	engineering	pre med	pre pharmacy	others
concurrent lab group	3.193	3.04	3.115	2.64	3.518	3.144	3.056	3.242
no-lab group	2.925	2.606	3.667	2.333	2.5	2.65	2.333	2.767

Figure 11: Major information difference among the two groups (concurrent lab group and no-lab group)



	biochemistry	biology	chemistry BA	chemistry BS	engineering	pre med	pre pharmacy	others
concurrent lab group	58	221	26	25	11	18	88	31
no-lab group	4	36	3	6	2	2	3	3

Figure 12: Distribution of majors enrolled in both the groups (concurrent lab group and no-lab group) in CHEM 626

In Figure 13, the difference between the two groups, concurrent lab group and no-lab group is explained based on the mean grades of students obtained in CHEM 626.

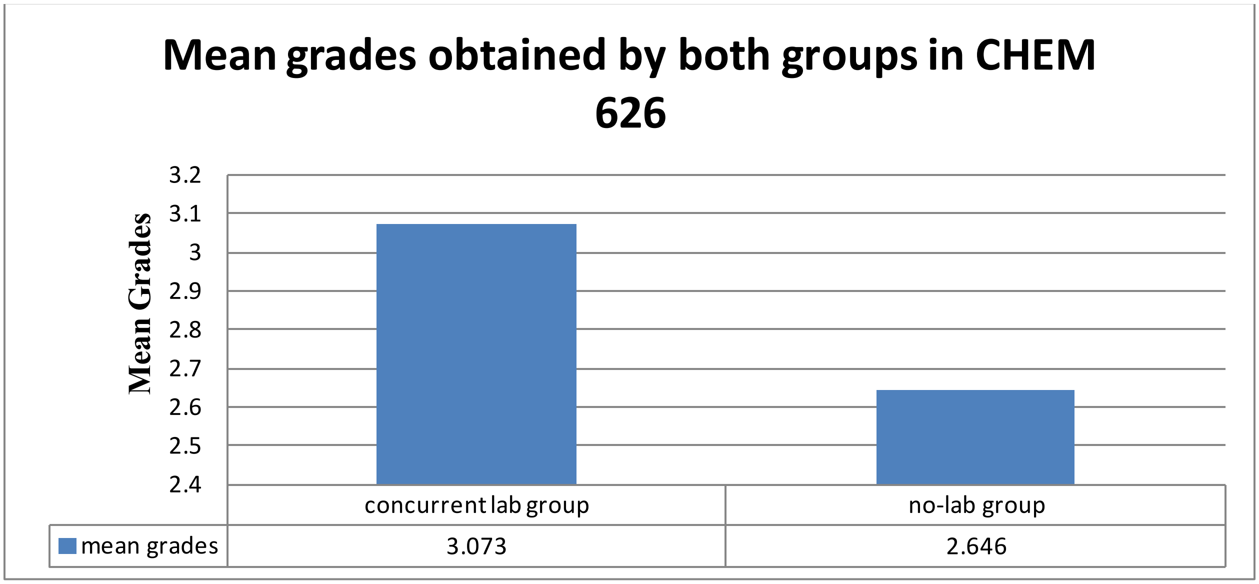


Figure 13: Difference in mean grades obtained by the concurrent lab group and the no-lab group in CHEM 626, 2008-2010.

A multiple linear regression (MLR) analysis was conducted to predict the final exam grades (student performance) from demographic and academic background information along with lecture and laboratory sequencing information. This analysis showed that the predictor variables accounted for a significant amount of the final exam grades points, $R^2 = 0.073$ (adj. $R^2 = 0.064$), $F(5, 531) = 8.35$, $p < 0.05$ (Model 1, Table 4).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted final exam grades over and above the background and academic information variables. A significant amount of the final exam grades were accounted by the sequence in which students enrolled for the laboratory and lecture course, after controlling for the effects of background knowledge and demographic information variables, $R^2 = 0.091$ (adj. $R^2 = 0.081$), $F(1, 530) = 10.83$, $p < 0.05$ (Model 2, Table 4).

Equation 6:

CHEM 626 final grades = 0.625 + 0.044 (ACT score)* + 0.274 (HSGPA)* + 0.271 (Male gender)* + 0.029 (ethnicity) + 0.010 (major) – 0.404 (no-lab group)*

Table 4: Model Summary for CHEM 626 grades - MLR, 2008-2010

	Model Summary for Organic Chemistry II (CHEM 626) grades MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.270[a]	.073	.064	.8909	.073	8.345	5	531	.000
2	.302[b]	.091	.081	.8827	.019	10.827	1	530	.001

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry grade 626

Table 5: Coefficients of CHEM 626 grades – MLR, 2008-2010

Coefficients of Organic Chemistry II (CHEM 626) grades

Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.485	.442		1.097	.273
	ACT score	.047	.012	.174	3.906	.000
	HSGPA	.282	.103	.122	2.732	.007
	Male Gender	.254	.079	.138	3.226	.001
	Ethnicity	.030	.035	.036	.855	.393
	Major	.013	.017	.034	.811	.418
2	(Constant)	.625	.440		1.420	.156
	ACT score	.044	.012	.166	3.754	.000
	HSGPA	.274	.102	.119	2.675	.008
	Male Gender	.271	.078	.147	3.463	.001
	Ethnicity	.029	.035	.036	.851	.395
	Major	.010	.017	.025	.597	.550
	No-lab group	-.404	.123	-.137	-3.290	.001

Dependent Variable: chemistry grade 626

Figure 14 shows that the MLR assumption of normally distributed residuals was met for this analysis. The relatively good fit of the data to the diagonal line in Normal P-P plot shown in Figure 15 explains that variables involved describe all cases relatively well. Figure 16 shows that all levels of the criterion variable and range of the residuals have similar ranges and all this indicates that MLR analysis met the homogeneity of residual error assumption.

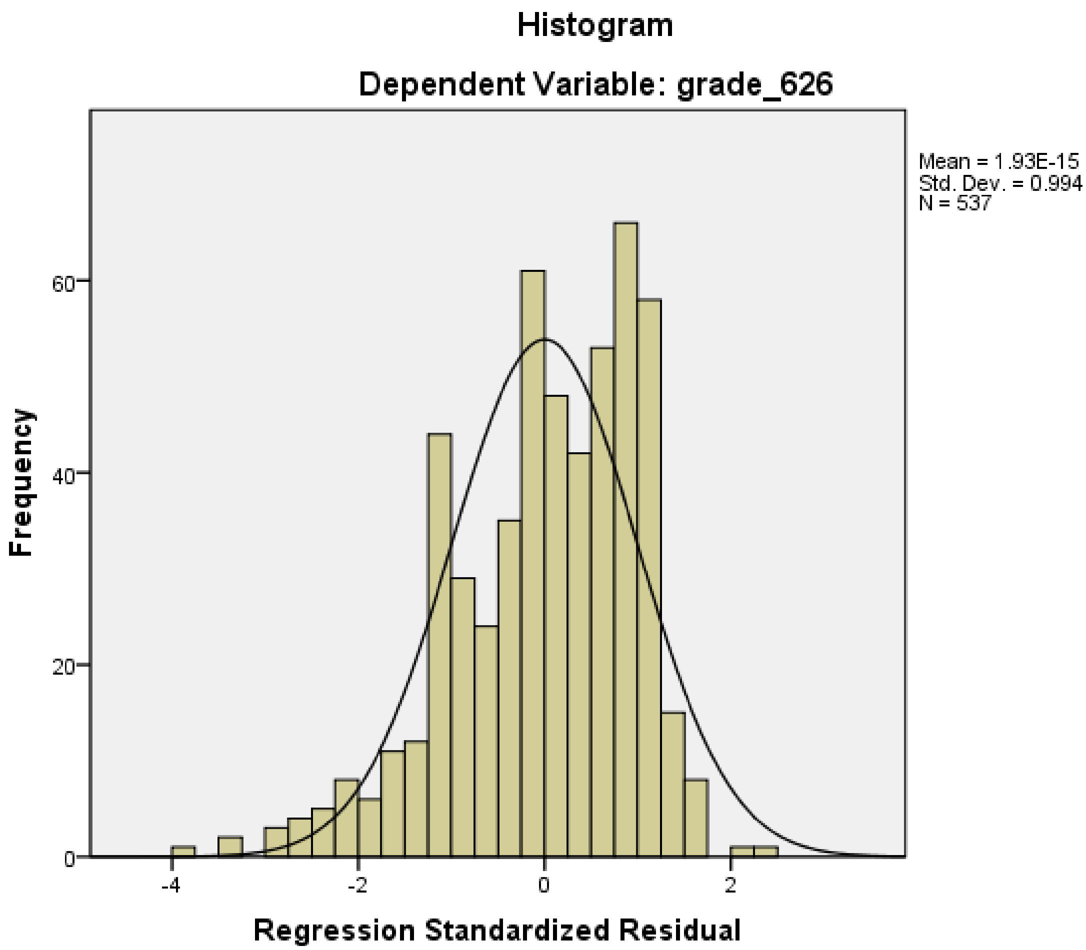


Figure 14: Normally distributed residual plot resulting from the MLR analysis using background variables and sequence of lecture and laboratory course of CHEM 626 (described in Table 4 and Equation 6) to predict final exam grade in CHEM 626 from spring 2008-spring 2010. The residual values were obtained by subtracting observed final exam grades from predicted final exam grades.

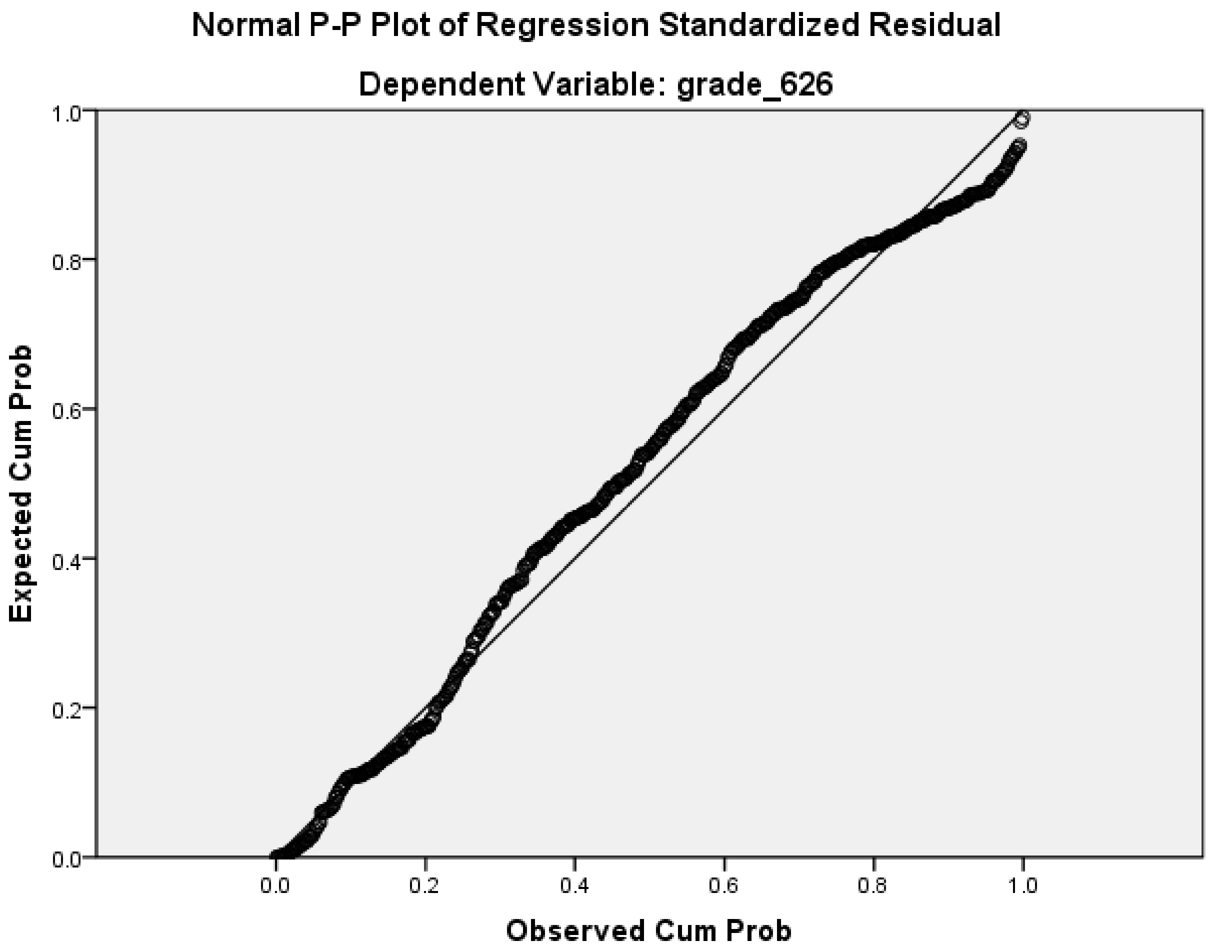


Figure 15: Normal P-P plot of regression standardized residuals confirmed that the residuals for 2008-2010 were well modeled by the normal curve. The diagonal line represents the relationship that would be expected if the predicted distribution was perfectly normal. Small deviations from this diagonal are acceptable. Therefore, predicted distribution produced by Equation 6 models the expected normal distribution for final exam grades in CHEM 626.

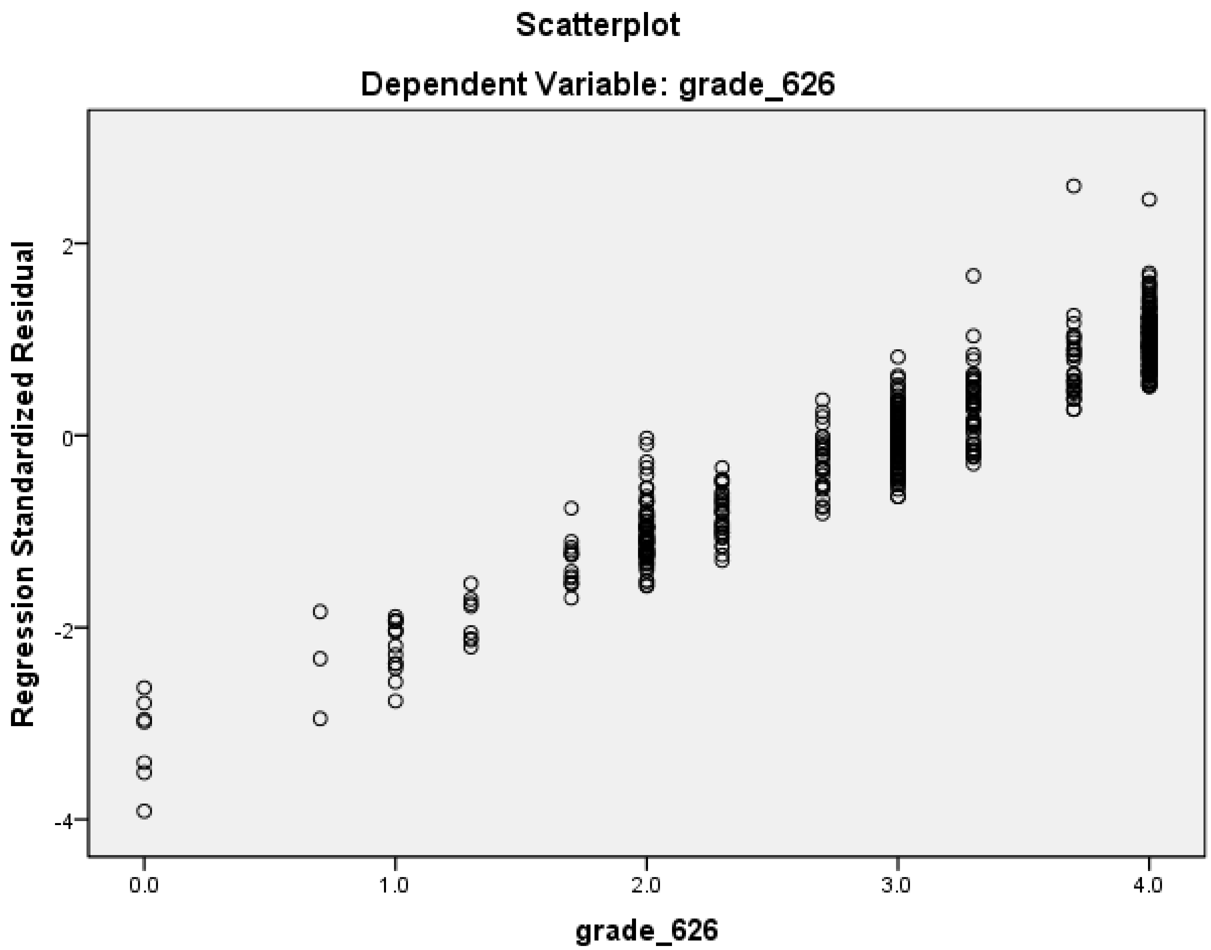


Figure 16: Scatterplot of regression standardized residual versus exam grades in CHEM 626 for 2008-2010. This plot illustrates that the MLR assumption of residual homoscedasticity was met for this model of final exam grade in CHEM 626 based on student background variables and sequencing of lecture and laboratory instruction, as measured by the sequencing of lecture and laboratory instruction. The variances of residuals are equal across the range of the dependent variable.

Discussion of statistical analysis

Prior to starting this experiment, the level of significance was decided to be 0.05 (α). The correlation study, of grades obtained in for students concurrently enrolled in CHEM 626 with the laboratory course and students enrolled in just the lecture showed a negative and weak correlation. This negative number signifies when one variable increases the other variable decreases, they have an inverse relationship. Even though the correlation was weak, but it was observed to be significant at $\alpha = 0.01$ level. For the other confounding variables, academic background variables and one of the demographic variable was significant at $\alpha = 0.01$ level. The correlation among ACT score and grade obtained by students in CHEM 626 was positive and medium in strength, and between HSGPA and grade obtained in CHEM 626 was again positive but weak. Positive correlation signifies when one variable increases the other variable also increases, that means they have a direct relationship. The correlation among male gender and grade obtained in CHEM 626 is positive and weak, but significant at 0.01 level ($\alpha = 0.01$ level means there is only 1% chance for Type I error or rejecting the null hypothesis when it is actually true). For the other demographic information variables like ethnicity, the correlation was negative and very weak, and for the majors the correlation was positive and very weak. Both the correlations of the variables with the grade were not statistically significant.

A partial correlation was performed to measure the effect of sequencing on student performance after controlling for the significant confounding variables, like the ACT score, HSGPA, and male gender. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for ACT score signifies that the correlation dropped from 0.145 to 0.134. Approximately, 1.1% of the correlation was actually due to the significant ACT score and not the no-lab group. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for HSGPA signifies that the correlation dropped from 0.145 to 0.138, and 0.7% of the correlation was actually due to the significant HSGPA and not the no-lab group by itself. The partial correlation between no-lab group and the grades obtained in CHEM 626 after controlling for male gender signifies that the correlation went up from 0.145 to 0.156, and 1.1% of the correlation was due to no-lab group and not due to the male gender. Even after controlling for the covariates it was found that the relationship between the no-lab group and grades obtained in CHEM 626 are statistically significant at a 0.01 (α) level.

To determine any significant effect of demographic information and academic background on student grades obtained in CHEM 626 separate one-way ANOVAs were performed. The academic background (ACT score, HSGPA, and major) and demographic information (gender and ethnicity) were used as the dependent variable, and the student grade in CHEM 626 as the independent variable. To demonstrate that there was a difference in performance between students enrolled in the concurrent lab group and the no-lab group, one-way ANOVA was also performed. In this study, student enrollment in concurrent lab group and no-lab group were used as the independent variable and the student grades obtained in CHEM 626 were assigned as the dependent variable. Due to unequal sample sizes between the concurrent lab group and the no-lab group, Levene's test of homogeneity was conducted prior to conducting the ANOVAs. When the Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and then the statistical significance is based on Welch-F statistic rather than traditional F-statistic.

From ANOVA Table 3, it can be observed that there was no significant difference between the concurrent lab group and no-lab group with regards to gender differences at $\alpha = 0.05$ level (which was the level of significance set for this study or experiment), and also the Levene's test of homogeneity was not statistically significant hence the two groups were homogeneous and the traditional F statistic was used. From the one-way ANOVA it was found that there was no significant difference between the concurrent lab group and no-lab group with regards to different ethnicities at $\alpha = 0.05$ level, but the Levene's test of homogeneity was not statistically significant either and hence traditional F statistic was used. There was no significant difference between the concurrent lab group and no-lab group with regards to different academic majors at $\alpha = 0.05$ level, and the Levene's test of homogeneity was statistically significant hence Welch F statistic was used for this test. There was no significant difference between the concurrent lab group and no-lab group with regards to the ACT scores at $\alpha = 0.05$ level, and the Levene's test of homogeneity was not statistically significant and hence the traditional F statistic was used. For the last covariate, there was no significant difference between the concurrent lab group and no-lab group with regards to HSGPAs at $\alpha = 0.05$ level, and the Levene's test of homogeneity was not statistically significant and hence the traditional F statistics was used. When the two groups were tested for their performance based on grades in CHEM 626, there was found to be a statistically significant difference between the two groups (concurrent lab group and no-lab group) on their performance (final grade of CHEM 626) at $\alpha = 0.05$ level, hence the null hypothesis was rejected.

Figure 7 illustrates that there is no significant difference between the two groups (concurrent lab group and no-lab group) even though males performed better in CHEM 626 compared to females. In Figure 9 it can be observed that there is no significant difference between the two groups, concurrent lab group and the no-lab group, but the no-lab group performed lower than the concurrent lab group. The African-American population had the lowest performance for both the groups, whereas rest of the ethnicity lies close to each other in their performances. The White, Asian, and Others population performed higher compared to African-Americans and Hispanics, but there was no significant difference between the different ethnicities in their performances between the concurrent lab group and no-lab group. Figure 11 shows that there is no significant difference between the two groups based on the different academic major information. Students in each category of major performed lower in the no-lab group than students in the corresponding major in the concurrent lab group. Student in the Chemistry BA program, where the no-lab group performed better than the concurrent lab group, were the only exceptions to this trend. Overall there was no significant difference between the concurrent lab group and no-lab group. Figure 8, 10, and 12 shows the distribution of students enrolled in CHEM 626 based on gender, ethnicity, and major information respectively.

Figure 13 illustrates the difference between the concurrent lab group and no-lab group based on the mean grades of students obtained in CHEM 626. The mean of the concurrent lab group was higher compared to that of the no-lab group.

Figure 14 shows that the MLR assumption of normally distributed residuals was met for this analysis. The relatively good fit of the data to the diagonal line in Normal P-P plot shown in Figure 15 explains that variables involved describe all cases relatively well. Figure 16 shows that all levels of the criterion variable and range of the residuals have similar ranges and all this indicates that MLR analysis met the homogeneity of residual error assumption.

A multiple linear regression (MLR) was conducted to predict the final exam grades (student performance) from demographic and academic background information along with lecture and laboratory sequencing information. The data resulting from this analysis, collected in Table 4, determine that together the predictor variables account for a significant amount of the final exam grades of CHEM 626. After controlling for the covariate effects of background knowledge and demographic information variables, on the second analysis outlined in this table demonstrated that a significant amount of the variance in the final exam grades was accounted by the sequence in which students enrolled for the laboratory and lecture course.

From the data shown in Table 5, an MLR equation was determined for unstandardized coefficients B (Equation 6). According to the equation, one point change in the ACT score on an average result in statistically significant 0.044 points change in the final grade. For every one point change in the HSGPA there will on an average be ~0.3 point change in the final grade for the course and it is also significant. Students of male gender will on an average receive ~0.3 points higher than the females in their final grade of CHEM 626 and it is significant. Both ethnicity and major contribute an average of 0.03 and 0.01 points change in the final exam grade respectively and both are not statistically significant. Finally, students in the no-lab group on an average experience a 0.4 points decrease in the final grade point compared to the students in the concurrent lab group, and it is significant. This preliminary analysis helped confirm the preliminary hypothesis of this study.

Conclusion

The data analyzed in this chapter confirmed that there is a statistically significant difference in student performance among the concurrent lab group and the no-lab group in CHEM 626 (Organic chemistry II). Based on the MLR analysis, students in the no-lab group are likely to achieve a half a letter grade lower course grade than the concurrent lab group. The approximate letter grade performance of 0.3 points lower for the no lab group corresponds with a half a letter grade (from A to A- etc.) difference in final grade performance. This result controls for potential confounding effects of background information. This data supports the conclusion that students, as measured by final grades, benefit from enrollment in the laboratory and lecture course simultaneously rather than enrolling for them separately.

Chapter 4- Preliminary Research on Student Performance: Overview, Results, and Discussions for Organic Chemistry I

Purpose and Overview

Similar to the study mentioned in the previous chapter, this preliminary study was conducted to examine the effect of sequencing (enrolling to both laboratory and lecture vs. enrolling for lecture) on student performance in a lecture course. Demographic and academic background information (to measure prior knowledge of the student) was also collected for the students enrolled in Organic Chemistry I course (CHEM 624/625) at the University of Kansas (KU) from spring of 2008 till fall 2010. Organic Chemistry I is offered at KU, during both the fall and spring semesters. The preliminary study also helped better define of the backgrounds of the students in the course. This helped to determine which background variables were associated with student performance. Anecdotal observations of student achievement led to the idea that there was a significant difference among students enrolling for both the laboratory and lecture compared to those enrolling for just the lecture course, but this fact was not well supported by any quantitative data. This preliminary study helped to quantitatively determine the difference between students enrolled in both the laboratory and lecture with students enrolled for just the lecture, and how this sequence of enrolling in courses affects student performance in the lecture. Studies of student performance in Organic Chemistry can add to our understanding of student learning and motivation to learn organic chemistry. Data was obtained from university records regarding demographic and academic backgrounds of the students, along with their final grades in the lecture course. These factors were correlated with student performance in organic chemistry I lecture course.

The data obtained from the university records were coded with non-specific student identifiers. This was done to maintain the students' privacy. The results from this preliminary study were purely used to better describe the overall student population enrolled for organic chemistry I and their performance. This preliminary study provided information that further helped in analyzing the effect of sequence of enrollment in student learning and motivation. It also helped in understanding the student population who were enrolled in organic chemistry II course because the students enrolled for organic chemistry II were a subset of students from organic chemistry I course.

Course Structure for Lecture and Laboratory

The first semester organic chemistry course, from spring of 2008 till fall of 2010 was selected for this preliminary study. One professor taught the course in the fall semester and a different professor taught the course during the spring semester. The same professors taught the course in 2008 and 2009, but a different professor taught the same course in 2010 for both the semesters. For the fall and spring semesters of 2008 till 2010 the professors were using the same textbook, *Organic Chemistry by Janice G. Smith*, and the structure of both the laboratory and lecture course were similar for all three years. For both the semesters the structure included 50-minutes lecture class that met three days per week and five-hour laboratory that met once per week. Along with the five-hour laboratory sessions, there was separate laboratory lecture conducted for an hour and fifteen minutes once per week. One professor was responsible for the lecture course, while a separate professor was responsible for the laboratory-lecture course. Different graduate teaching assistants majoring in organic chemistry were responsible for teaching various laboratory sections. All the students enrolled for the lecture met in a single large group in an auditorium for their classes, and students who also enrolled for laboratory were divided into groups of 20 or less students who met for their individual lab sections.

The most important factor leading to sequencing issues involving laboratory and lecture was that, the students were not required to enroll for both laboratory and lecture during the same semester, though many self-select themselves into the group who are simultaneously enrolled in the laboratory. During the fall and spring semesters of 2008 through 2010, approximately 1620 students enrolled for the lecture course, and among these 1500 students completed the course for a grade, and had demographic and academic background information available with the university. For this study, the students who enrolled for both the laboratory and lecture course, called the concurrent lab group, included 1212 students. The students who just enrolled for the lecture and not the laboratory were called the no-lab group and it included 288 students.

Student grades for the lecture and laboratory course were assigned separately and they were independent of each other. For the lecture, students could earn a maximum of 560 points, and for the laboratory, students can earn a maximum of 580 points. The lecture grade was determined by four one-hour exam scores worth 100 points each, out of which only the three best scores were considered for the final grade, along with top six quiz scores each worth of 10 points, and the final exam worth of 200 points. These assignments sum up to total of 560 points for the final lecture grade. The laboratory grade consisted of two exam scores (a midterm and a final) each worth 100 points, along with 10 quiz scores worth 8 points each, laboratory techniques worth a total of 25 points, and finally 11 graded laboratory notebook sections and reports on laboratory experiments each worth of 25 points. These sums up to a 580 points total for the final laboratory grade. The final lecture grade was collected from university records to measure student performance. The course final grade was given to the students in form of A, A-, B+, B, B-, C+, C, C-, D+, D, D-, and F, where getting above a 93% is an A and getting below 60% is a F grade.

The resources available to students during the course included the assigned textbook, instructor office hours, laboratory and lecture TA office hours, along with emailing system between the students and the instructors. The only pre-requisite for enrolling in the lecture course was that, the students should have completed two semesters of general chemistry (CHEM 184 and CHEM 188) courses successfully. To enroll for the laboratory the pre-requisites state that a student must have completed two semesters of general chemistry laboratories (CHEM 184 and CHEM 188) and should have been concurrently enrolled or completed organic chemistry I lecture course (first semester organic chemistry). That gives a student the choice of whether to enroll for the laboratory and lecture simultaneously or separately.

Lecture and laboratory are treated as separate courses with separate grades. The concepts that were introduced in the laboratory had similarity to some concepts introduced in the lecture course. The common topics introduced in both lecture and laboratories were acid-base chemistry, boiling point and melting point concepts, racemic mixtures, dehydration, and hydroboration. Some of these concepts were introduced in the laboratory before they were introduced in the lecture and some other concepts were introduced in the lecture before being introduced in the laboratories; however all of these particular concepts were introduced in both the lecture and laboratory. Exposure to concepts twice in a row for students enrolled in both the laboratory and lecture courses compared with learning concepts once for the students enrolled in just the lecture course should affect student understanding of these concepts and their overall performance.

Selection of Student Groups for analysis from 2008-2010

Data obtained from the university records consisted of approximately 1620 students who were enrolled for the first semester organic chemistry lecture course. Some of them were concurrently enrolled for the laboratory and some of them were not enrolled for the laboratory. Out of these students, some students were enrolled for the lecture course for the second time. To eliminate the possibility that prior exposure to the lecture material might have an effect on student performance, such students were excluded from the sample data. Some other students had already received a grade in the laboratory, but had no recorded lecture grade. This group of students was also removed from the sample data. The sample analyzed in this study included only students who were enrolled for the lecture and laboratory or just the lecture course for the first time and earned a grade of A through F in the course.

Demographic data were also collected from the university records. This additional information included gender, ethnicity and major information, and prior background knowledge information, which was characterized by ACT score and high-school GPA. Some of the student data did not have all these records and had to be removed from the sample data to maintain equality and homogeneity among student data during the analysis. On this basis, approximately 120 students were removed from the sample. The remaining students were part of the sample data (N = 1500) for the spring of 2008 through fall of 2010. The total sample size for the concurrent lab group (students enrolled for both the laboratory and lecture) was N = 1212, and the total sample size for the no-lab group (students enrolled for the lecture) was N = 288. All of this data was used for the preliminary research data analysis.

Overview of Data from OIRP

Demographic data

The demographic information obtained from the university records included gender, ethnicity, and academic major. According to the demographic data, as shown in Table 6 for the first semester organic chemistry course the number of females were slightly more than the males by 3.06%. There were 773 females and 727 males in the student population. There was little diversity among the ethnicities. Approximately 79% of students applying for KU self-identified themselves as white. Other ethnicities included African-American, Hispanic, Asian, and others (which includes students from international background/non-Asians, and who identified themselves as multi-ethnicity and non-specific). Minority students include African-American and Hispanics population with 2.8% and 4.1% respectively, as stated in Table 6.

Student majors included biology, biochemistry, chemistry (BA and BS), students self-identified as pre-med (pre-med), students self-identified as pre-pharmacy (pre-pharm), and engineering students. The population also included some health science majors. Biology majors were approximately 48.8% of the population. Following them were the engineering and the pre-pharmacy majors with 10% and 11.4% of the population. The population description and percentages are included in Table 6. Most of the students enrolled for this course were in their sophomore or junior year. Although, detailed information about the student's number of years of enrollment at KU was not collected from the university.

Table 6: Demographic Information of CHEM 624, 2008-2010

Demographic Information Table			
Variables		N	Percent
Gender	Male	727	48.4
	Female	773	51.6
Ethnicity	White	1186	79
	Hispanic	62	4.1
	African-American	42	2.8
	Asian	197	13.1
	Others	14	0.9
Major	Biochemistry	131	8.7
	Biology	732	48.8
	Chemistry BA	52	3.5
	Chemistry BS	82	5.5
	Engineering	150	10.0
	Pre- Med	60	4.0
	Pre- Pharmacy	171	11.4
	Others	122	8.1

Academic background

Academic background data collected from university records included ACT score and high-school grade point averages (HSGPA). Of those enrolled for first semester organic chemistry course approximately 85-90% of the students reported their high-school GPA and ACT score. Different school districts apply different methods for reporting high-school grade point averages. Some of the schools report grade point averages on an un-weighted scale, which means grades in all courses are worth equal points, while other schools report grade point averages on a weighted scale, meaning that grades in advanced courses are awarded more points than standard-level courses. The HSGPA of the students enrolled for the first semester organic chemistry course ranged from 4-point un-weighted, 4-point weighted, 5-point un-weighted, 5-

point weighted, 100-point un-weighted, and 100-point weighted. On some weighted scales, for students taking advanced coursework it is possible to obtain values above the value used in the scale. For example a student getting A in an advanced course can get 4.2 rather than 4.0 in a weighted scale. During admission to KU, the university converts all the weighted HSGPAs that range above the scale of 4.0. In this process all the weighted HSGPAs ranging above 4.0 are reported as a 4.0 value. As a consequence, the HSGPA's for students enrolled in first semester organic chemistry ranged from 2.0 to 4.0.

From 2008 till 2010, students enrolled in organic chemistry I had an average HSGPA of 3.73 with standard deviation of 0.38. Figure 17 shows a histogram of the HSGPA (converted) with respect to a normal curve. Note that the curve is negatively skewed. This seems to be because numerical grade point averages above a 4.0 were truncated and reduced to a 4.0. This version of the HSGPA is not acceptable because the analysis we have planned includes correlations, ANOVAs and regressions. To run all this analysis it is important that the variables used should have a population distribution that is approximately a normal curve. Thus, un-converted HSGPA values were obtained from the university records.

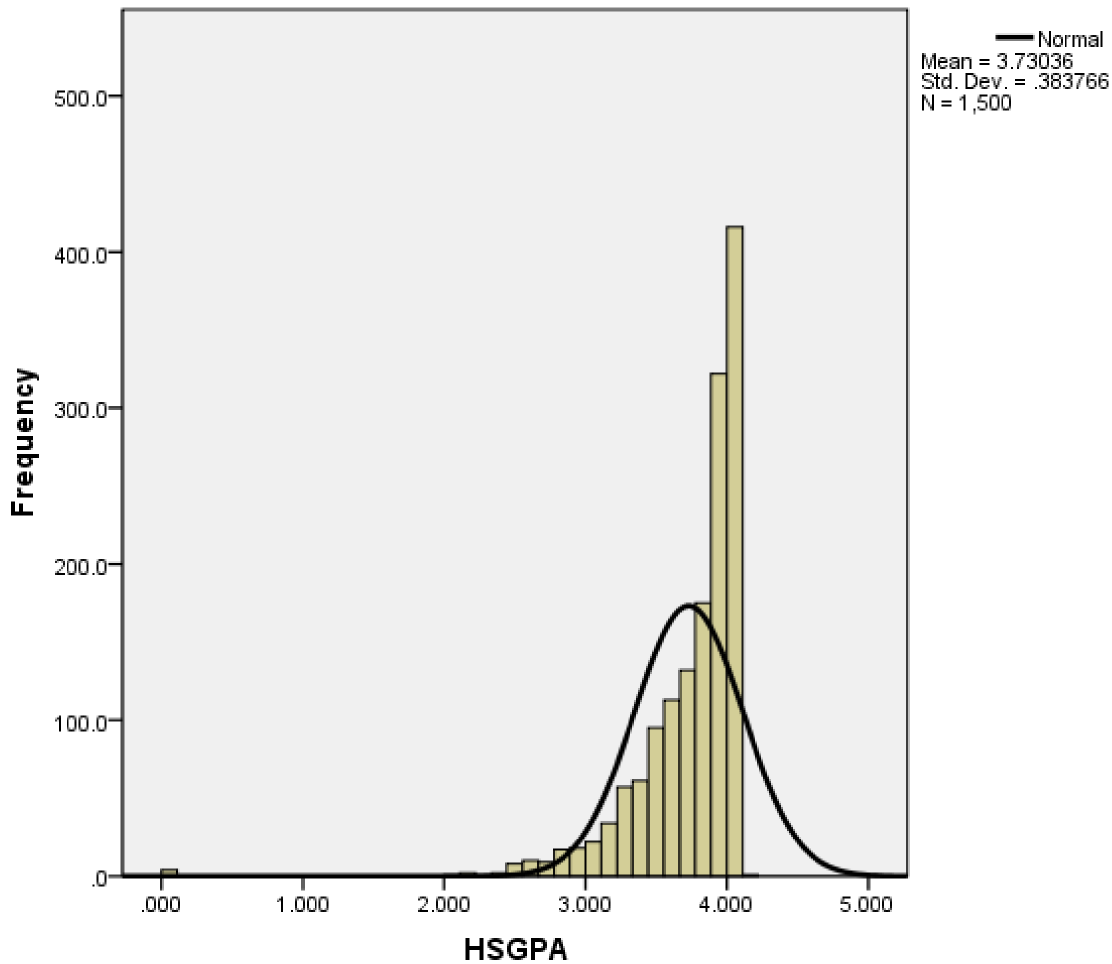


Figure 17: The histogram shows the distribution of high school GPAs (HSGPA) for students in organic chemistry I (CHEM 624) from 2008 till 2010. This distribution does not fit a normal curve due to a strong ceiling effect and is negatively skewed.

These un-converted high school GPAs, shown in Figure 18, were used of the analysis in this study. The HSGPA included the original HSGPA values from un-weighted 4.0 to weighted 4.0 scales. The new grade distribution now more closely resembles a normal curve (Figure 18). The HSGPA has a mean of 3.73 with a standard deviation of 0.49. This mean and standard deviation are very close for both the converted and unconverted HSGPAs, but the unconverted HSGPA was more useful with standard statistical methods due to its normal distriution.

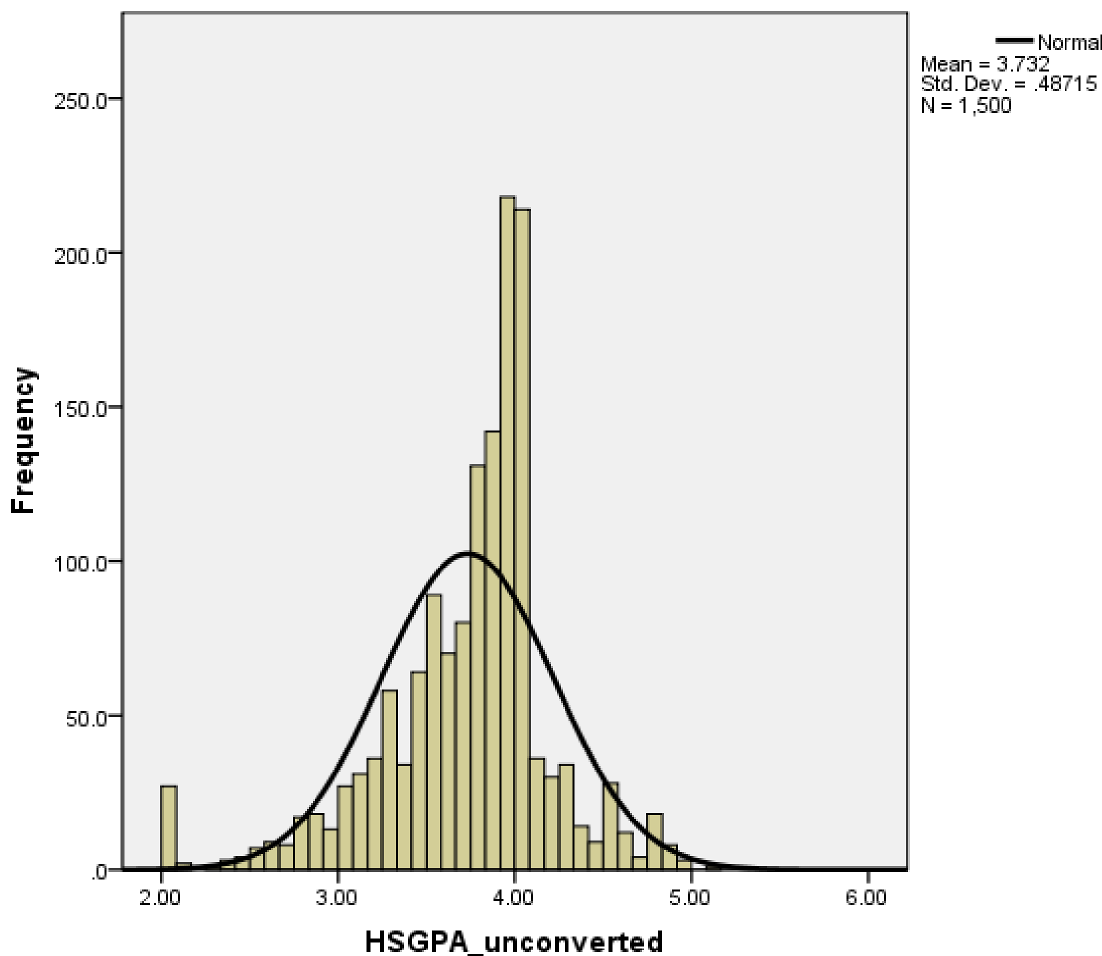


Figure 18: The histogram shows the distribution of unconverted high school GPAs (HSGPA_unconverted) for students in organic chemistry I (CHEM 624) from 2008 till 2010. This distribution fits into a normal curve.

ACT composite scores can be a good predictor of prior background knowledge (Thompson Ross, 2004). The ACT score data was collected from the university records to determine if ACT composite scores correlate with student performance in Organic Chemistry I. Out of the students who enrolled in the organic chemistry I course, approximately 85-90% of the students reported their ACT score to the university. The average ACT composite score is 26.83 with a standard deviation of 3.76. Figure 19 shows the values, and it can be concluded that this variable is normally distributed within the group of enrolled students.

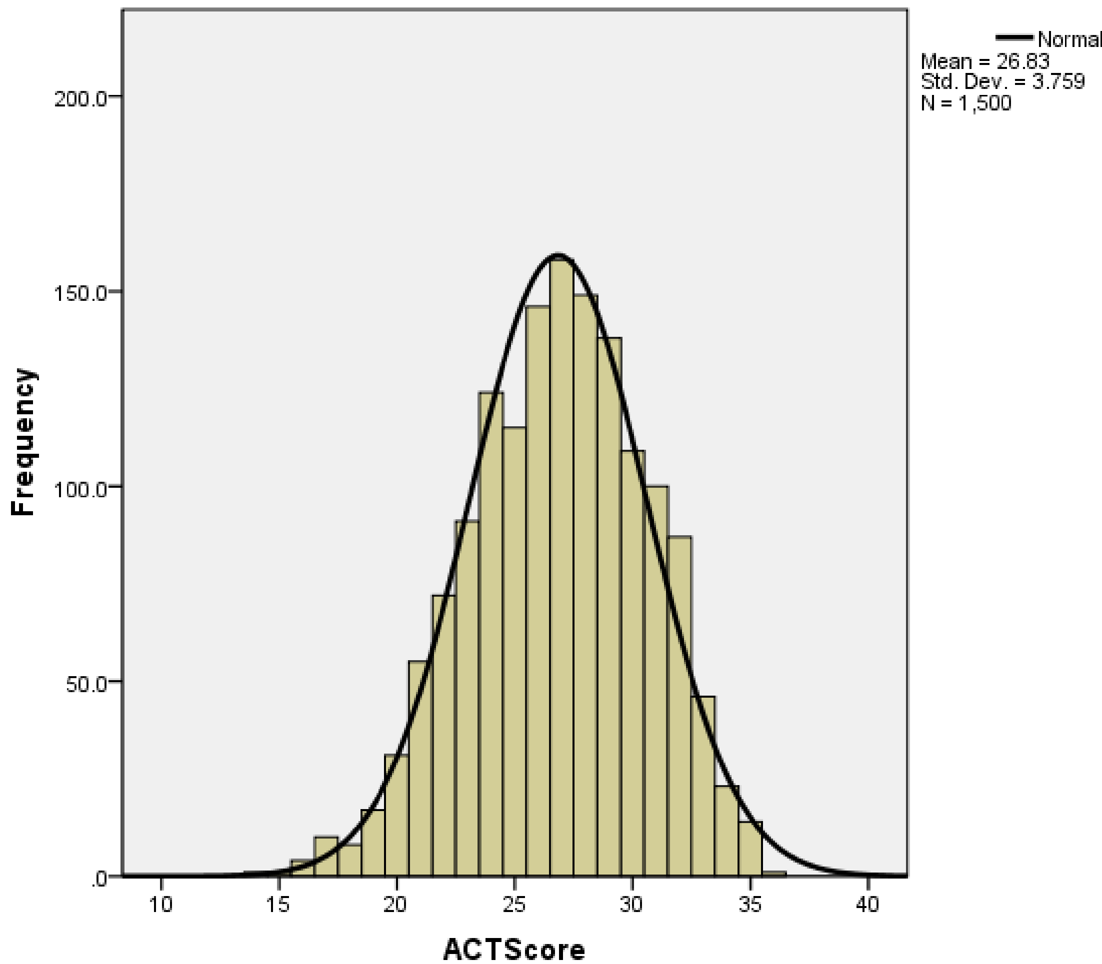


Figure 19: The histogram shows the distribution of ACT scores for students in organic chemistry I (CHEM 624) from 2008 till 2010. This distribution does fit into a normal curve.

Course performance based on final grades

Course performance for the first semester organic chemistry (organic chemistry I) course was analyzed based on the final grades of students obtained from the university records. The mean grade for students enrolled in organic chemistry I (N = 1500) was 2.88, with a standard deviation of 1.05. The grades ranged from A (4.0) through F (0.0). The histogram for student grades was negatively skewed. Both the skewness (-0.82) and kurtosis (-0.25) values were less than ±1.0. If both the skewness and kurtosis are between ±1.0 then the curve can be generalized as normal distribution. Other than grades of A through F, grading options also included credit (CR), no-credit (NC), and withdrawal (W). Students with those grades were excluded from the sample data because they did not successfully complete the course. Furthermore, these students did not fit the research question that was being solved in this study. Figure 20 shows the histogram that defines the course performance based on final grades. The figure also lists the mean, standard deviation, and plots the idealized normal curve for the data set.

The organic chemistry I course was taught by different professors in 2008 and 2009-2010. The mean grade for students enrolled in organic chemistry I in 2008 (N = 545) was 2.6, with a standard deviation of 1.1, and for students enrolled in 2009-2010 (N = 955) the mean grade was 2.8 with a standard deviation of 1.2. The histograms for student grades were negatively skewed. Both the skewness (-0.6 and -0.7) and kurtosis (-0.7 and -0.2) values were less than ±1.0 for both 2008 and 2009-2010. The skewness and kurtosis values signify that both the curves could be generalized as normal distributions and were comparable. For this study the student population was mixed together from 2008 till 2010, as the grade distributions for all the years were comparable and had normal distributions. Figure 21 shows the histogram that defines the course performance based on grades in 2008 and Figure 22 shows the histogram that defines the course performance based on grades in 2009-2010.

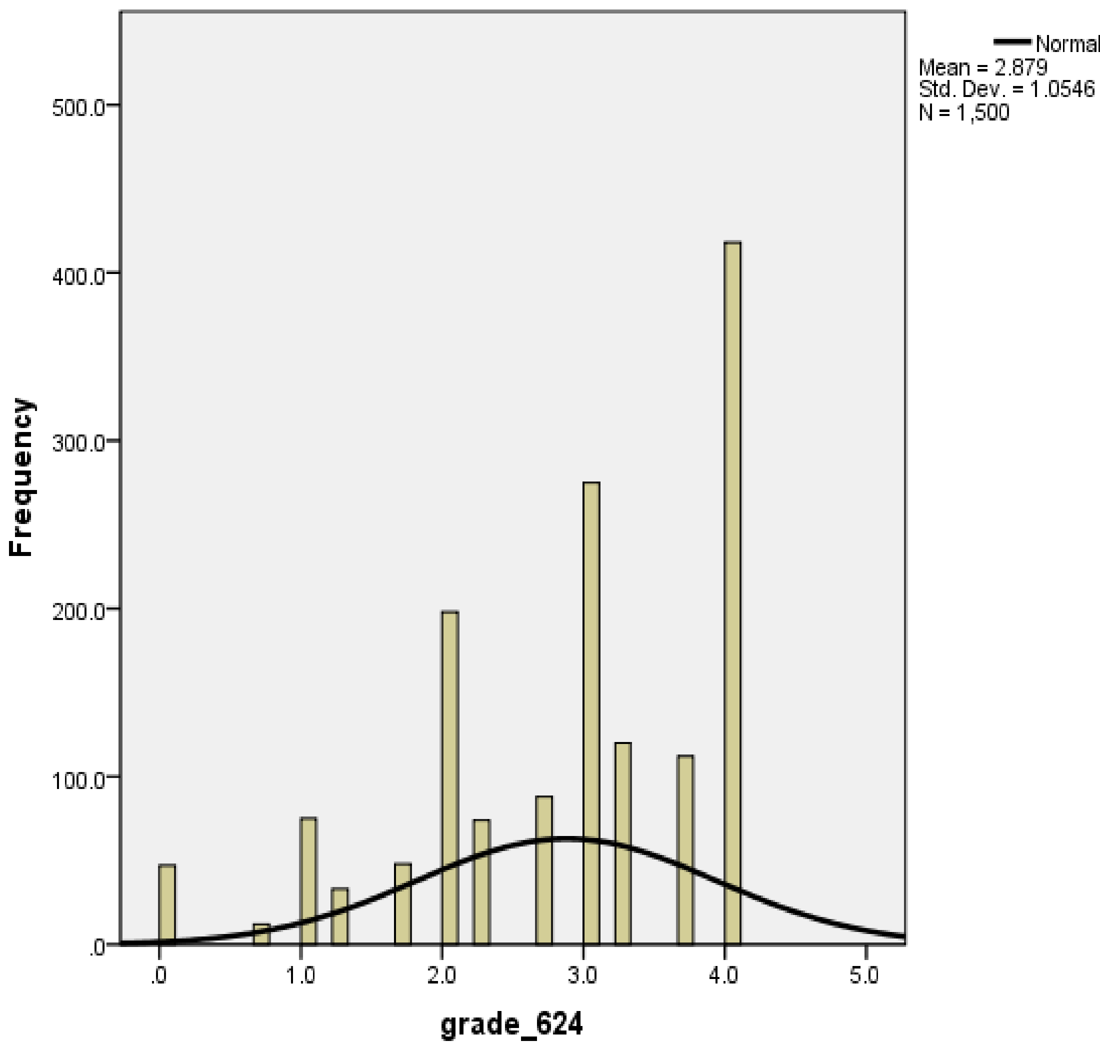


Figure 20: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry I (CHEM 624) from 2008 till 2010. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

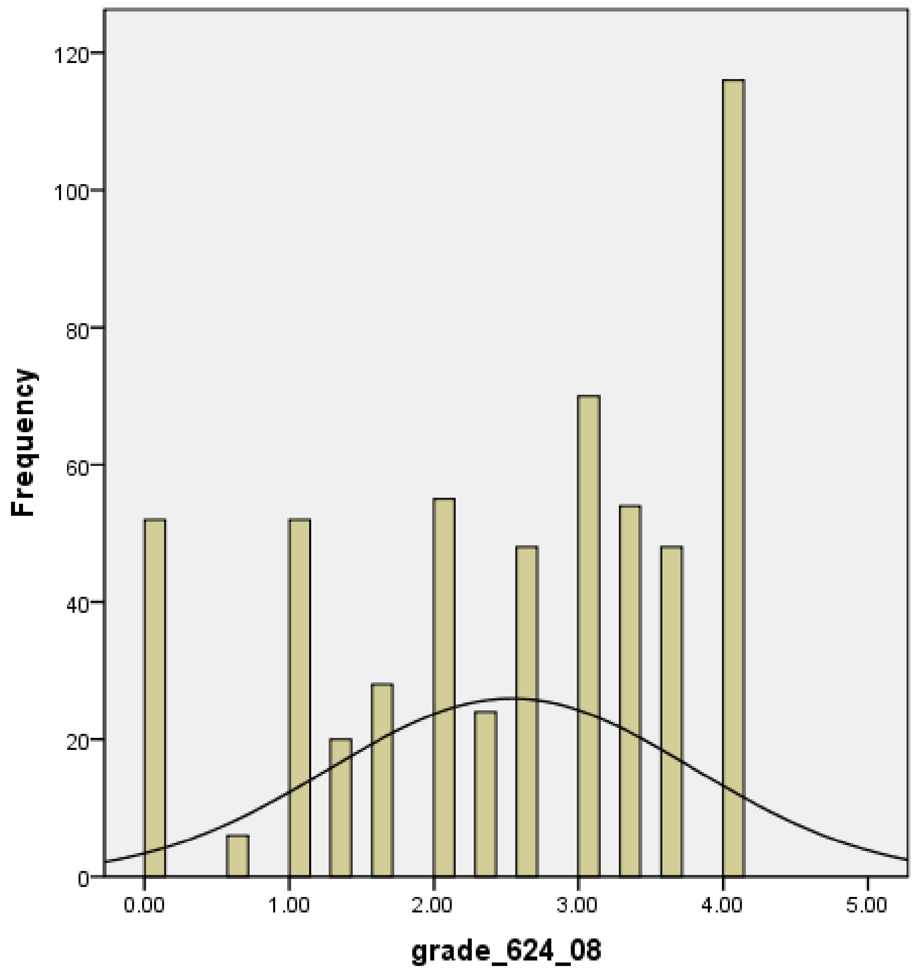


Figure 21: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry I (CHEM 624) in 2008. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

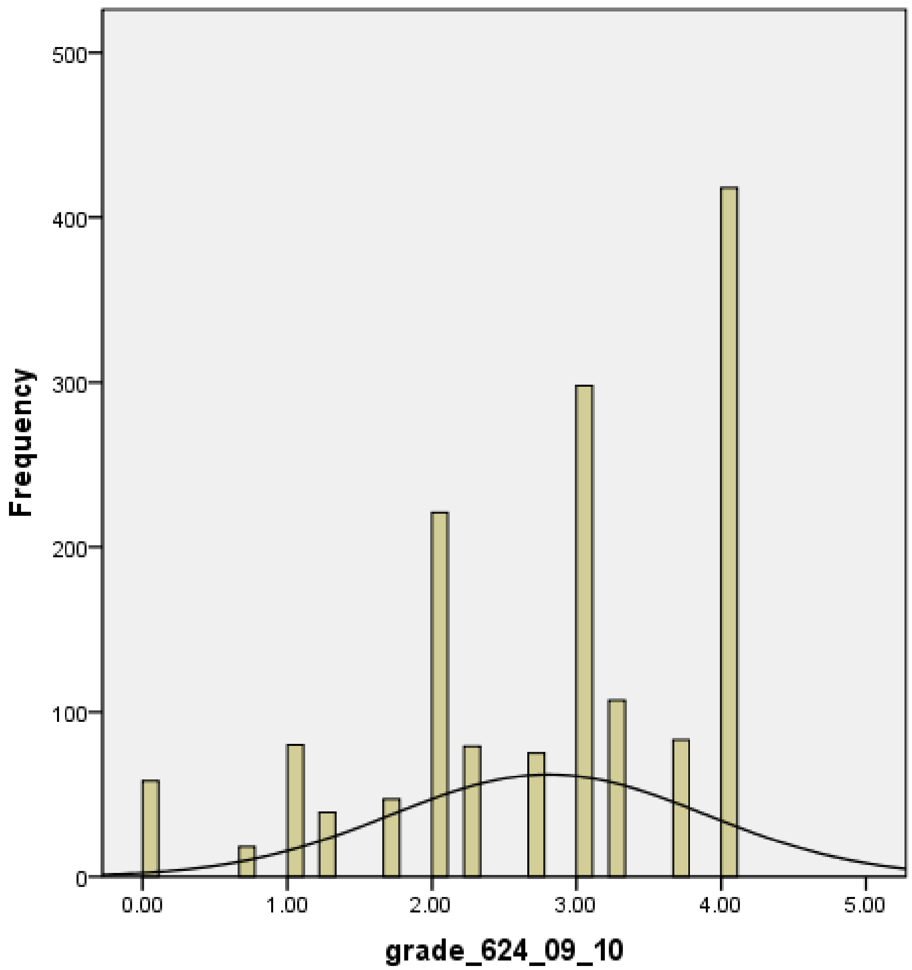


Figure 22: The histogram shows the distribution of lecture grades for students enrolled in organic chemistry I (CHEM 624) in 2009-2010. This distribution is negatively skewed but the skewness and kurtosis values suggest that it can be generalized as a normal curve.

Methods of analysis

Like in the previous chapter (chapter 3), the analysis of student performance in Organic Chemistry I (CHEM 624) included statistical analysis of final lecture grades from spring 2008 to spring 2010, using SPSS (Statistical Package for the Social Sciences) software. Statistical analysis included correlations, partial correlation, one-way analysis of variance (ANOVA), T-tests, and multiple linear regressions.

Results of the statistical analysis for measuring student performance in CHEM 624, 2008-2010

A correlation analysis was performed to understand the relationship between two interval level variables. This study was performed to examine the relationship between the *independent variable* (taking lab and lecture together vs. separate) and the *dependent variable* (grades obtained in CHEM 624), along with the relationship between the *dependent variable* and the *covariates or antacedents* (demographic and academic information). Students who were enrolled in the laboratory and lecture course together, the *concurrent-lab group* ($N = 1212$) had a mean score of 2.91 with standard deviation of 1.05, and students enrolled for just the lecture course, the *no-lab group* ($N = 288$) had a mean score of 2.74 with standard deviation of 1.04. The correlation between the no-lab group and the grades obtained by the students in CHEM 624, $r(1498) = -0.064$, $p < 0.05$ is negative and weak, but is significant at 0.05 level of significance (α). The level of significance established as a benchmark for this research study was 0.05 (α). When correlation analysis was performed among the covariates and the grades obtained in CHEM 624, significant correlation was observed among the academic background information, ACT score $r(1498) = 0.24$, $p < 0.01$, and HSGPA $r(1498) = 0.21$, $p < 0.01$ respectively. One of the demographic information, male gender, had a significant correlation with grades obtained in CHEM 624, $r(1498) = 0.086$, $p < 0.01$. Table 7 shows that all the other demographic information (ethnicity and major) did not have any significant correlation with the grades of CHEM 624.

Table 7: Correlation Table for CHEM 624, 2008-2010

Grade 624 r	Male Gender	Ethnicity	ACT score	HSGPA	Major	Concurrent lab group vs. No-lab group
	.086**	-.029	.240**	.207**	.037	-.064*

*signifies statistical significance at 0.05 level

**signifies statistical significance at 0.01 level

A partial correlation was performed to measure the effect of sequencing on student performance after controlling for the significant confounding variables, like the ACT score, HSGPA, and male gender. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for ACT score showed, $r(1497) = -0.041$, $p < 0.05$. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for HSGPA gave, $r(1497) = -0.051$, $p < 0.05$. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for male gender resulted in, $r(1497) = -0.067$, $p < 0.05$.

To determine whether the results included any significant effect of demographic information and academic background on student grades obtained in CHEM 624 separate one-way ANOVAs were performed. The academic background (ACT score, HSGPA, and major) and demographic information (gender and ethnicity) were used as the independent variable, and the student grade in CHEM 624 as the dependent variable. Ethnicity categories constituting of 3% or less of the groups of interest were determined to have insufficient power to stand alone as independent variables. Consequently, these categories were combined together in a category labeled *others*, also the major category constituting of 3% or less of the groups of interest were combined together in a category labeled *others*. All these background variables which were interval level or dichotomous, like the gender, did not have to be altered prior to the ANOVA analysis, whereas, the nominal or ordinal level variables had to be altered into interval level, like the ACT score, before performing the analysis. In total 5 confounding variables were analyzed for their effects on student performance.

Table 8 presents the percentages of students in each group along with ANOVA results obtained by comparing these groups of interest for the 5 confounding variables. Levene's test was performed prior to each ANOVA on the interval level variable and the dichotomous variable to test the homogeneity of variance among the groups of interest. When Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and their statistical significance was better described by Welch-F statistic rather than traditional F-statistic. The Welch-F statistic is a robust test of equality that can be used in a modification of the traditional version of ANOVA that does not assume homogeneity of variance among the variables. The ANOVA results in Table 8 clearly identifies the variables for which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore requiring the application of a significance test based on Welch-F statistic.

Whether there is a difference in performance between students enrolled in the concurrent lab group and the no-lab group, one-way ANOVA was also performed. Students enrolled in concurrent lab group and no-lab group being the independent variable and the student grades in CHEM 624 as the dependent variable. From the ANOVA test it was found that there is a significant difference between the students enrolled in the concurrent lab group (N = 1212) and the no-lab group (N = 288). The mean grades for the concurrent lab group (M = 2.91, SD = 1.05) and for the no-lab group (M = 2.74, SD = 1.04). There was found to be a significant difference between the two groups, $F (1, 1498) = 6.23$, $p = 0.013 < 0.05$, hence significant at 0.05. Prior to conducting the ANOVA, Levene's test of homogeneity showed that the variables conformed to homogeneity of variance, $p = 0.993 > 0.05$.

Figure 23 illustrates the difference in mean grades between the two groups (concurrent lab group and no-lab group) with regards to gender. Figure 24 shows the distribution of students enrolled in CHEM 624 based on gender. Figure 25 illustrates the difference in mean grades between the two groups (concurrent lab group and no-lab group) with regards to ethnicity. Figure 26 shows the distribution of students enrolled in CHEM 624 based on ethnicity. Figure 27 explains the difference in mean grades between the two groups with regards to the major information obtained from the students. Figure 28 shows the distribution of students enrolled in CHEM 624 based on major information. Ethnicity, major, and gender information is not significantly different for the two groups.

Table 8: Summary Statistics and ANOVA table of CHEM 624, 2008-2010

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) from spring of 2008-2010			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 1212)	No- lab group (N = 288)
Gender	Female	81.8	18.2
	Male	79.8	20.2
ANOVA	Gender*	F (1, 1498) = 1.35, p = 0.26 > 0.05	
Ethnicity	White	82.1	17.9
	Hispanic	60.7	39.3
	African-American	73.8	26.2
	Asian	80.1	19.9
	Others	85.7	14.3
ANOVA	Ethnicity*	F (1, 1498) = 1.25, p = 0.24 > 0.05	
Major	Biochemistry	77.9	22.1
	Chemistry BS	81.7	18.3
	Chemistry BA	78.8	21.2
	Biology	80.3	19.7
	Pre-pharmacy	85.4	14.6
	Pre-Med	81.7	18.3
	Engineering	79.3	20.7
	Others	81.8	18.2
ANOVA	Major*	F (1, 1498) = 1.99, p = 0.15 > 0.05	
ACT score		81.5	18.5
ANOVA	ACT score	F (1, 1498) = 1.79, p = 0.18 > 0.05	
HSGPA		75.9	24.1
ANOVA	HSGPA*	F (1, 1498) = 1.03, p = 0.34 > 0.05	

Bolded ANOVA results are significant; * signifies variables are homogenous (Levene's Test)

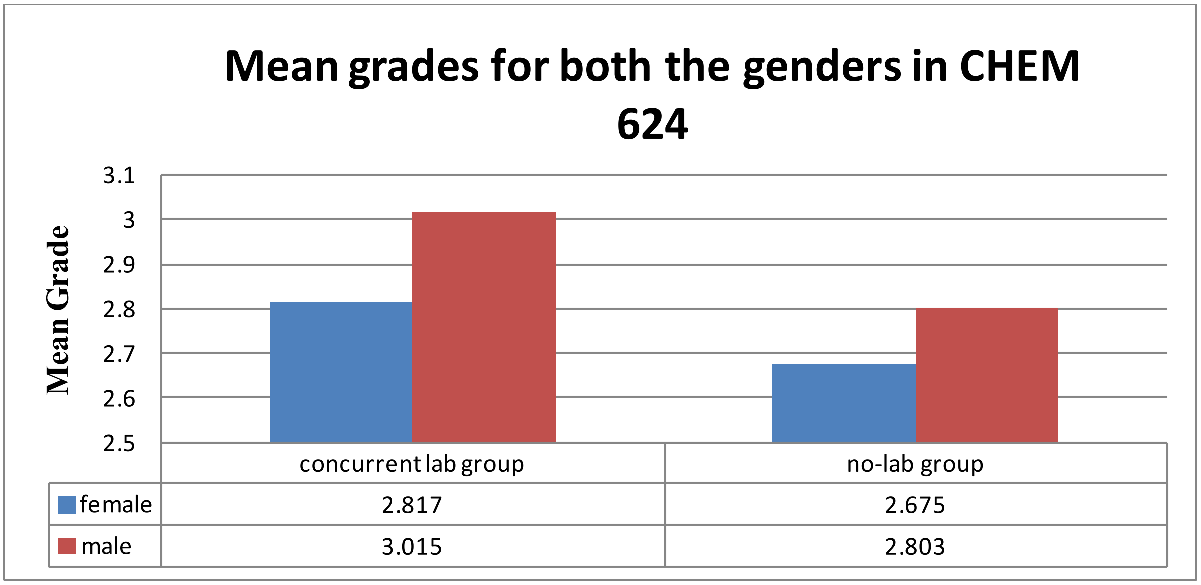


Figure 23: Gender difference in mean grades between two groups (concurrent lab group and no-lab group)

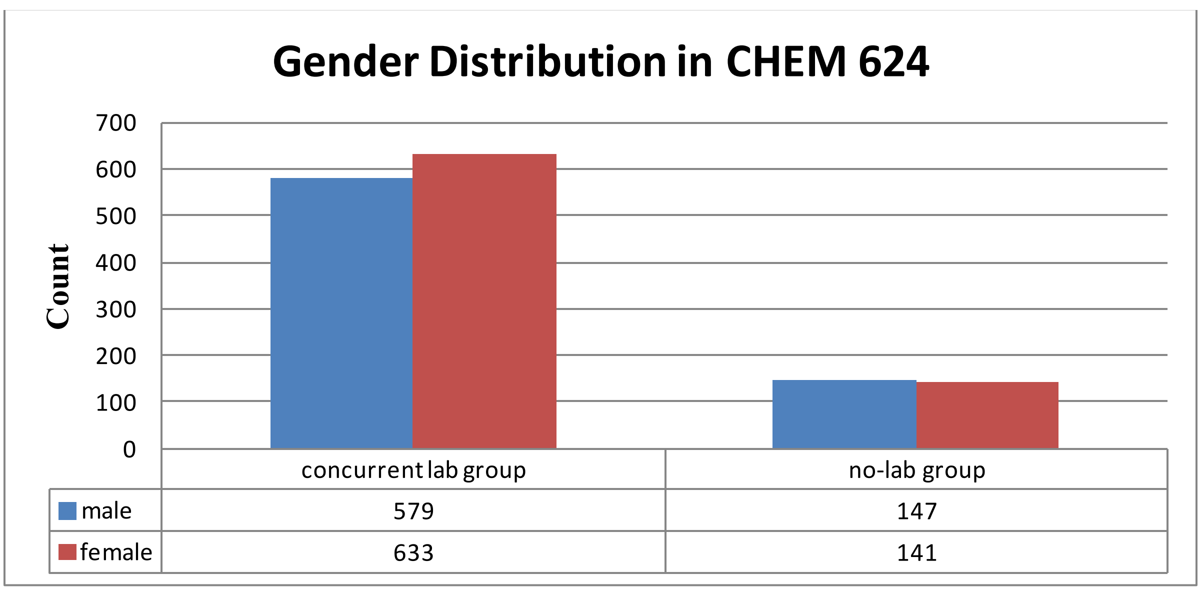


Figure 24: Gender distribution for both the groups (concurrent lab group and no-lab group) in CHEM 624

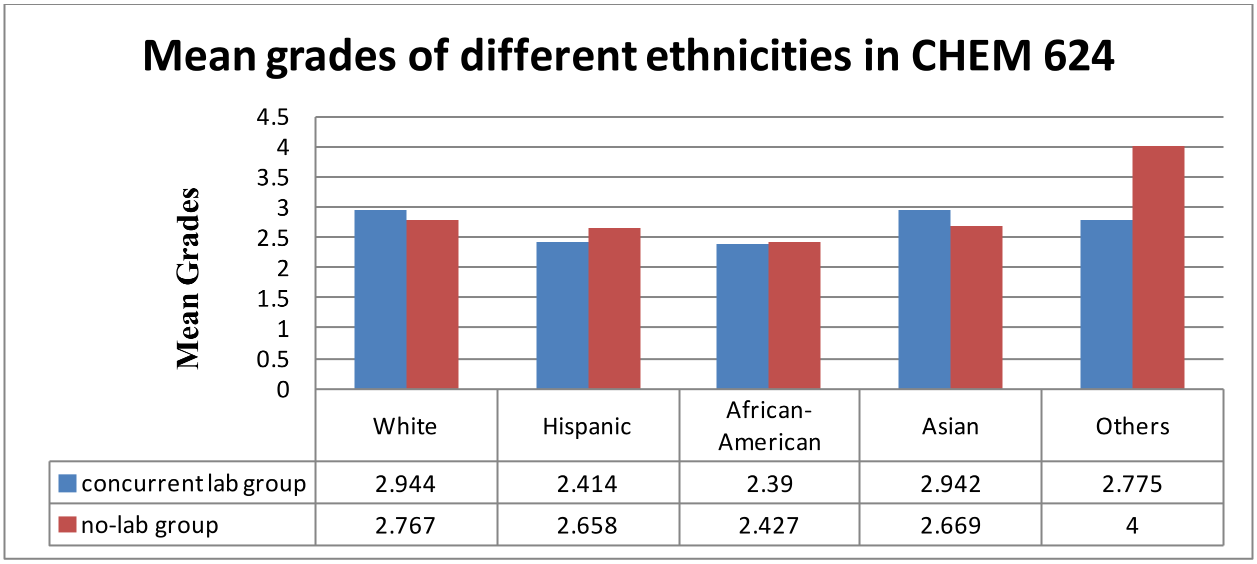


Figure 25: Ethnicity difference in mean grades between two groups (concurrent lab group and no-lab group)

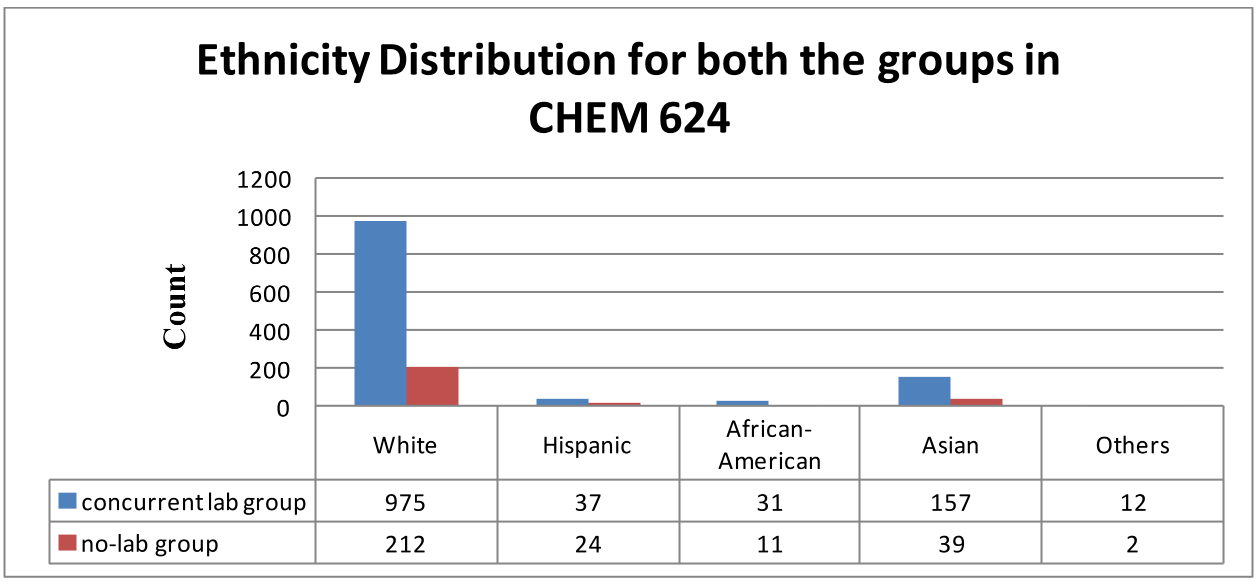
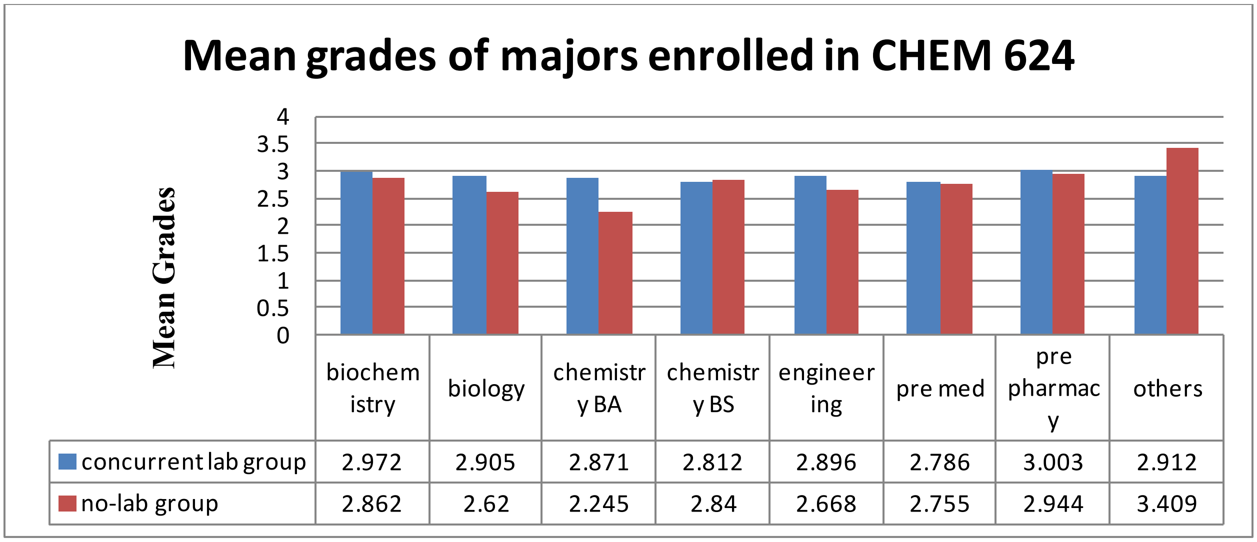
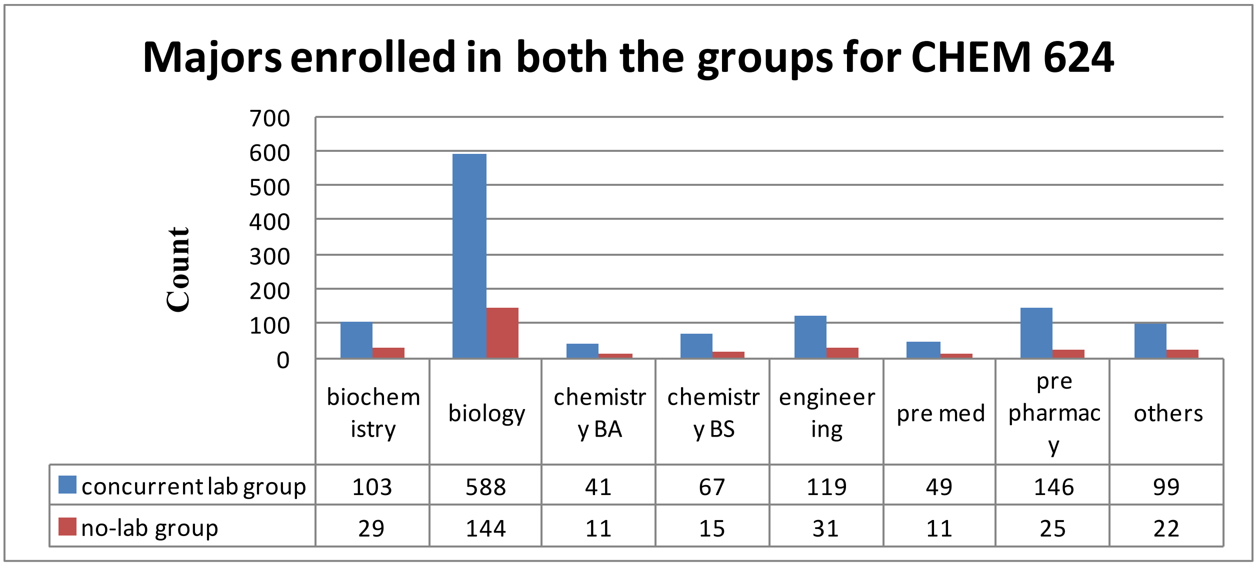


Figure 26: Ethnicity distribution for two groups (concurrent lab group and no-lab group) in CHEM 624



	biochemistry	biology	chemistry BA	chemistry BS	engineering	pre med	pre pharmacy	others
concurrent lab group	2.972	2.905	2.871	2.812	2.896	2.786	3.003	2.912
no-lab group	2.862	2.62	2.245	2.84	2.668	2.755	2.944	3.409

Figure 27: Major information difference in mean grades among the two groups (concurrent lab group and no-lab group)



	biochemistry	biology	chemistry BA	chemistry BS	engineering	pre med	pre pharmacy	others
concurrent lab group	103	588	41	67	119	49	146	99
no-lab group	29	144	11	15	31	11	25	22

Figure 28: Distribution of majors in both the groups (concurrent lab group and no-lab group) in CHEM 624

In Figure 29, the difference between the two groups, concurrent lab group and no-lab group is illustrated based on the mean grades of students obtained in CHEM 624 from 2008 till 2010.

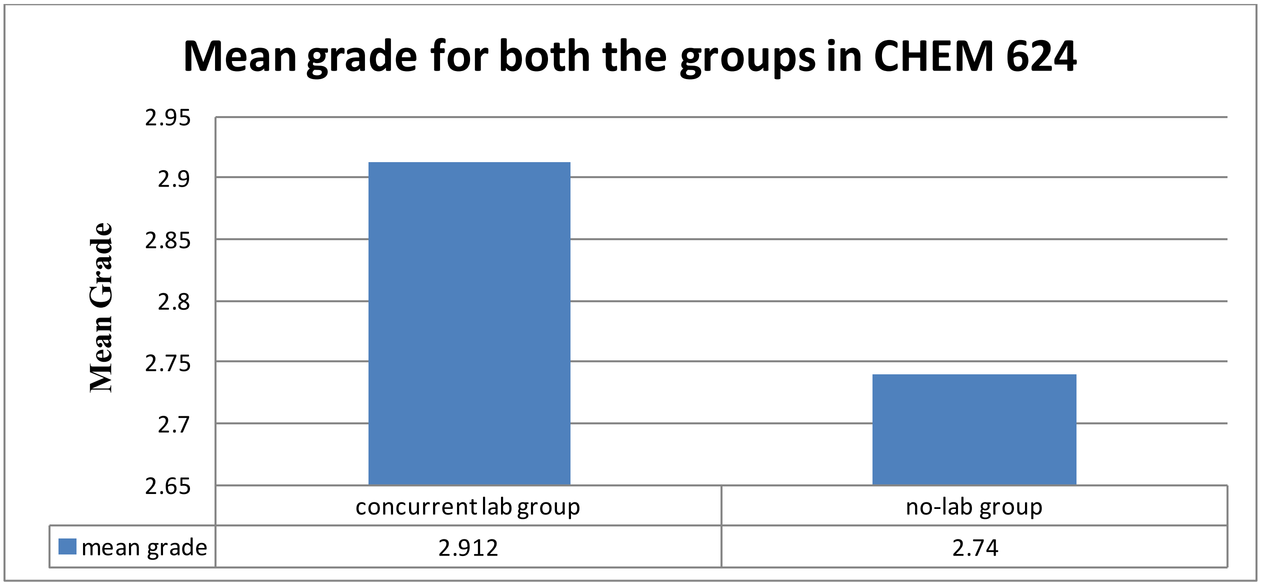


Figure 29: Difference in mean grades obtained by the concurrent lab group and the no-lab group in CHEM 624, 2008-2010.

A multiple linear regression (MLR) was conducted to predict the final exam grades (student performance) from demographic and academic background information along with lecture and laboratory sequencing information. The analysis showed that these predictor variables accounted for a significant amount of the final exam grades points, $R^2 = 0.087$ (adj. $R^2 = 0.084$), $F (5, 1494) = 26.27$, $p < 0.05$ (Model 1, Table 9).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted final exam grades over and above the background and academic information variables. A significant amount of the final exam grades were accounted by the sequence in which students enrolled for the laboratory and lecture course, after controlling for the effects of background knowledge and demographic information variables, $R^2 = 0.090$ (adj. $R^2 = 0.086$), $F (1, 1493) = 4.38$, $p < 0.05$ (Model 2, Table 9).

Equation 7:

CHEM 624 final grades = -0.257 + 0.223 (Male gender)* + 0.019 (Ethnicity) + 0.051 (ACT score)* + 0.445 (HSGPA)* - 0.002 (Major) – 0.2 (No-lab group)*

Table 9: Model Summary of CHEM 624 grades – MLR, 2008-2010

	Model Summary for Organic Chemistry I (CHEM 624) grades MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.296[a]	.087	.084	1.0148	.087	26.270	5	1494	.000
2	.301[b]	.090	.086	1.0135	.003	4.380	1	1493	.037

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry grade 624

Table 10: Coefficients of CHEM 624 grades – MLR, 2008-2010

Coefficients of Organic Chemistry I (CHEM 624) grades						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.341	.310		-1.100	.271
	ACT score	.052	.008	.186	6.548	.000
	HSGPA	.449	.079	.162	5.647	.000
	Male Gender	.221	.057	.104	3.915	.000
	Ethnicity	.018	.025	.019	.709	.478
	Major	-.002	.014	-.003	-.113	.910
2	(Constant)	-.257	.312		-.822	.411
	ACT score	.051	.008	.181	6.345	.000
	HSGPA	.445	.079	.160	5.598	.000
	Male Gender	.223	.056	.105	3.947	.000
	Ethnicity	.019	.025	.020	.752	.452
	Major	-.002	.014	-.004	-.174	.862
	No-lab group	-.200	.070	-.054	-2.093	.037

Dependent Variable: chemistry grade 624

Figure 30 shows that the MLR assumption of normally distributed residuals was met for this analysis. The relatively good fit of the data to the diagonal line in Normal P-P plot shown in Figure 31 explains that variables involved describe all cases relatively well. Figure 32 shows that all levels of the criterion variable and range of the residuals have similar ranges and all this indicates that MLR analysis met the homogeneity of residual error assumption.

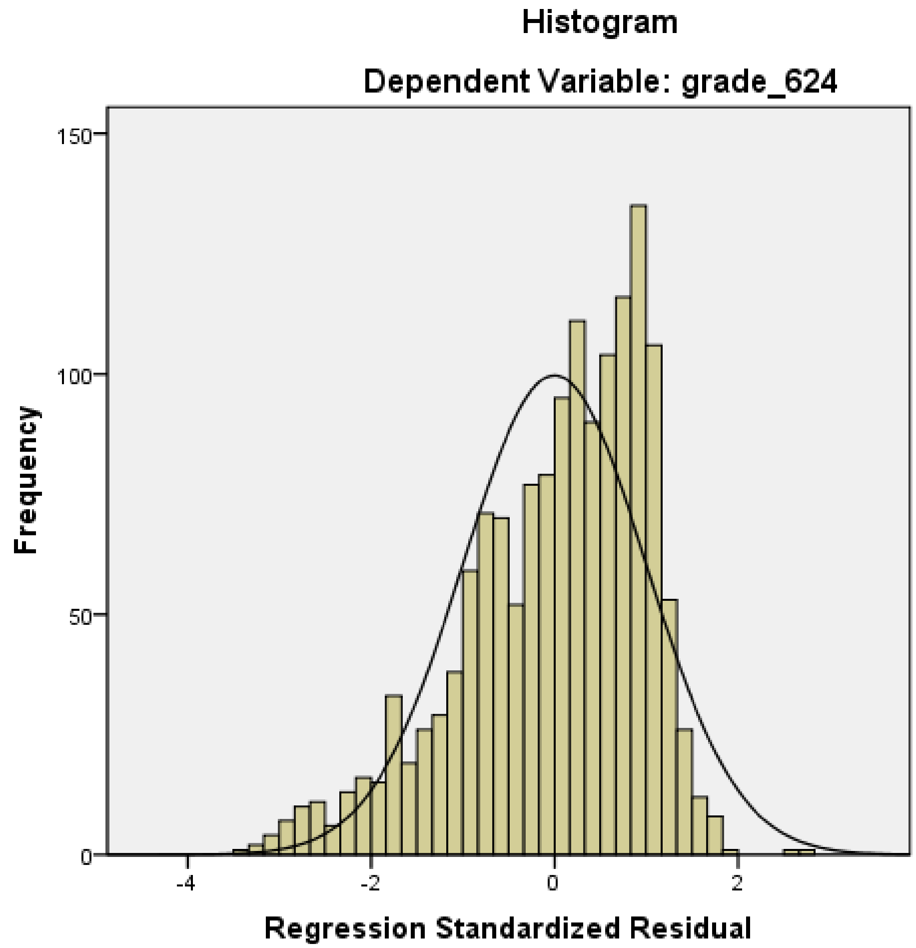


Figure 30: Normally distributed residual plot resulting from the MLR analysis using background variables and sequence of lecture and laboratory course of CHEM 624 (described in Table 9 and Equation 7) to predict final exam grade in CHEM 624 from spring 2008-fall 2010. The residual values were obtained by subtracting observed final exam grades from predicted final exam grades.

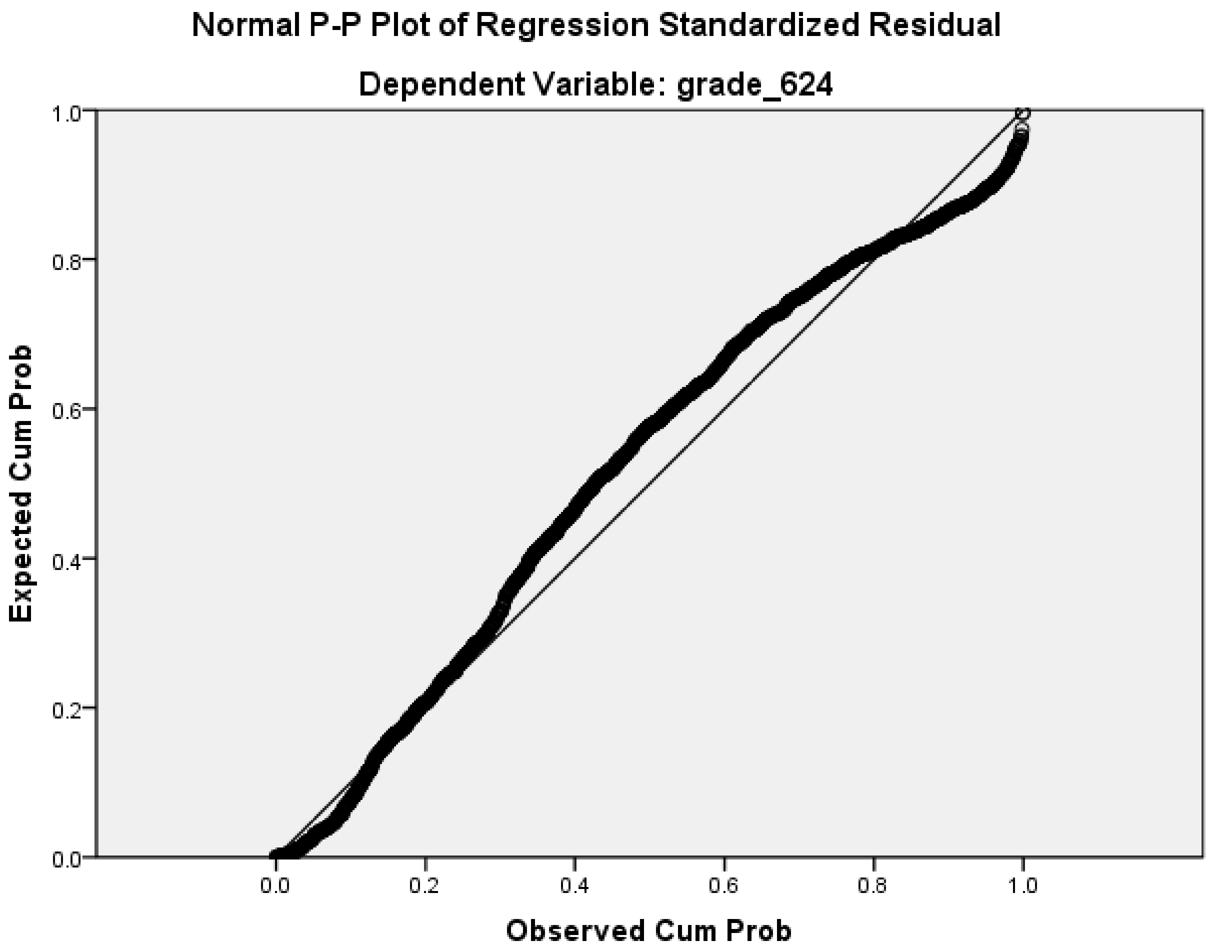


Figure 31: Normal P-P plot of regression standardized residuals confirmed that the residuals for 2008-2010 were well modeled by the normal curve. The diagonal line represents the relationship that would be expected if the predicted distribution was perfectly normal. Small deviations from this diagonal are acceptable. Therefore, predicted distribution produced by Equation 7 models the expected normal distribution for final exam grades in CHEM 624.

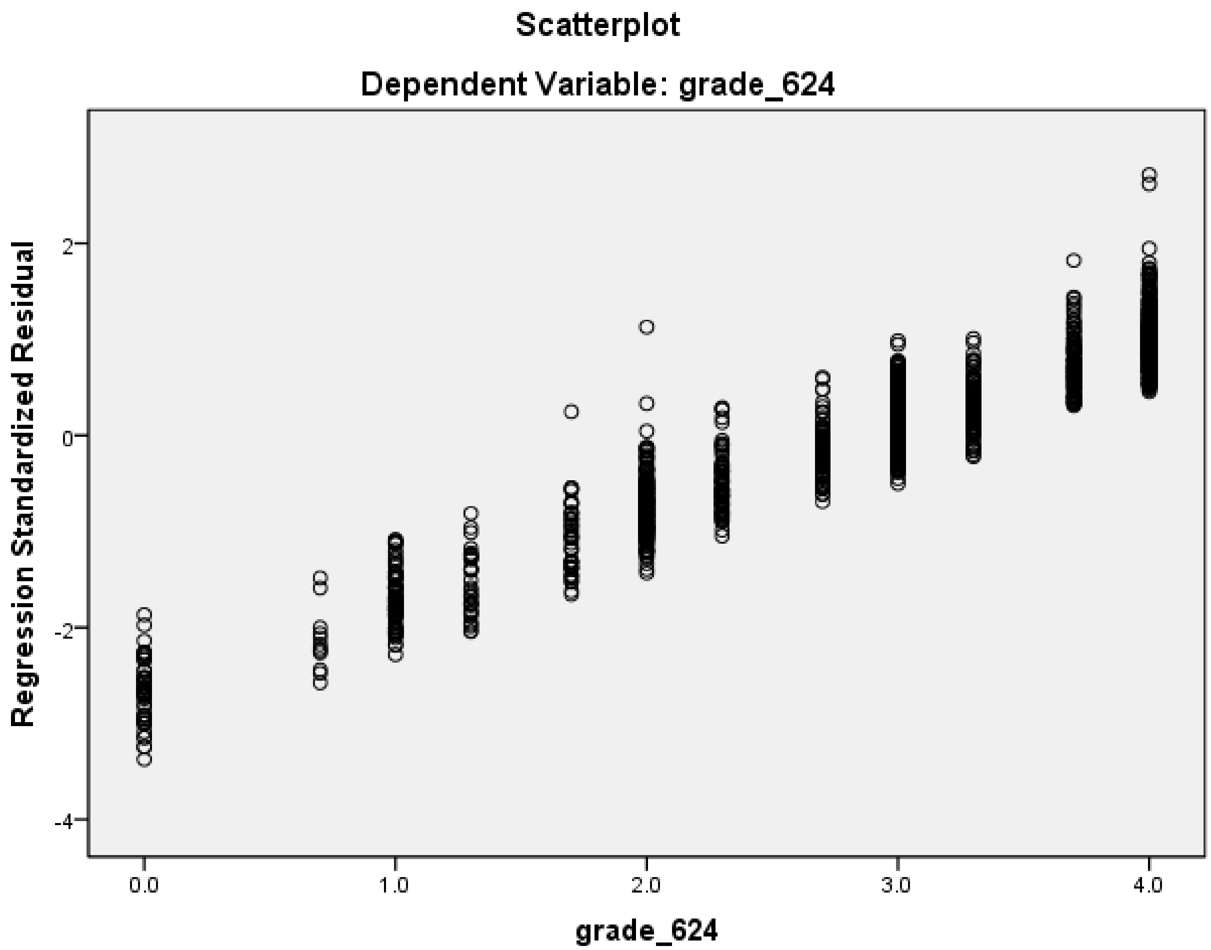


Figure 32: Scatterplot of regression standardized residual versus exam grades in CHEM 624 for 2008-2010. This plot illustrates that the MLR assumption of residual homoscedasticity was met for this model of final exam grade in CHEM 624 based on student background variables and sequencing of lecture and laboratory instruction, as measured by the sequencing of lecture and laboratory instruction. The variances of residuals are equal across the range of the dependent variable.

Discussion of statistical analysis

Prior to starting this experiment, the level of significance was decided to be 0.05 (α). The correlation study, of grades obtained in for students concurrently enrolled in CHEM 626 with the laboratory course and students enrolled in just the lecture showed a negative and weak correlation existed among the two variables. This negative number signifies when one variable increases the other variable decreases, they have an inverse relationship. In this study, even though the correlation was weak, it was observed to be significant at $\alpha = 0.05$ level. For the other confounding variables, academic background variables and one of the demographic variable the correlation value was significant at $\alpha = 0.01$ level. The correlation between ACT scores and grade obtained by students in CHEM 624 was positive and medium in strength and between HSGPA and grade obtained in CHEM 624 was again positive and medium. Positive correlation signifies when one variable increases the other variable also increases, that means they have a direct relationship. The correlation among male gender and grade obtained in CHEM 624 is positive and weak, but statistically significant at a 0.01 level ($\alpha = 0.01$ level means there is only 1% chance for Type I error or rejecting the null hypothesis when it is actually true). For the other demographic information variables like ethnicity, the correlation was negative and very weak, and for the majors the correlation was positive and very weak. Both the correlations of the variables with the grade were not statistically significant.

A partial correlation was performed to measure the effect of sequencing on student performance after controlling for the significant confounding variables, like the ACT score, HSGPA, and male gender. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for ACT score signifies that the correlation dropped from 0.064 to 0.041. Approximately 2.3% of the correlation was actually due to the significant ACT score and not the no-lab group. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for HSGPA signifies that the correlation dropped from 0.064 to 0.051, and 1.3% of the correlation was due to the HSGPA and not the no-lab group by itself. The partial correlation between no-lab group and the grades obtained in CHEM 624 after controlling for male gender signifies that the correlation went up from 0.064 to 0.067, and 0.3% of the correlation was actually due to no-lab group which was mistaken to be due to the male gender. Even after controlling for the covariates, the relationship between the no-lab group and grades obtained in CHEM 624 are statistically significant at 0.05 (α) level.

To determine any significant effect of demographic information and academic background on student grades obtained in CHEM 624, separate one-way ANOVAs were performed. The academic background (ACT score, HSGPA, and major) and demographic information (gender and ethnicity) were used as the dependent variable, and the student grade in CHEM 624 as the independent variable. To demonstrate that there is a difference in performance between students enrolled in the concurrent lab group and the no-lab group, one-way ANOVA was also performed. In this study, students enrolled in concurrent lab group and no-lab group were used as the independent variable and the student grades obtained in CHEM 624 were assigned as the dependent variable. Due to unequal sample sizes between the concurrent lab group and the no-lab group, Levene's test of homogeneity was conducted prior to conducting the ANOVAs. When the Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and then the statistical significance is based on Welch-F statistic rather than traditional F-statistic.

ANOVA results shown in Table 8, illustrates no significant difference between the two groups (concurrent lab group and no-lab group) based on gender differences at $\alpha = 0.05$ level.

Also Levene's test of homogeneity was not statistically significant, indicating that the two groups were homogeneous and the traditional F statistic was applicable. The one-way ANOVA results showed no significant difference between the concurrent lab group and the no-lab group for different ethnicity groups at $\alpha = 0.05$ level, but the Levene's test of homogeneity was not statistically significant either and hence traditional F statistic was used. There was no significant difference between the concurrent lab group and no-lab group for different academic majors at $\alpha = 0.05$ level, and the Levene's test of homogeneity was not statistically significant and hence traditional F statistic was used for this test. There was no significant difference between the concurrent lab group and no-lab group for the ACT score at $\alpha = 0.05$ level, but the Levene's test of homogeneity was statistically significant and hence the Welch's F statistic was used. For the last covariate, there was no significant difference between the concurrent lab group and no-lab group based on the HSGPAs at $\alpha = 0.05$ level, and the Levene's test of homogeneity was not statistically significant and hence the traditional F statistics was used. Also when the two groups, the concurrent lab group and the no-lab group, were tested for their performance, statistically significant difference was observed between the two groups (concurrent lab group and no-lab group) on their performance (final grade of CHEM 624) at $\alpha = 0.05$ level, hence the null hypothesis was rejected.

Figure 23 illustrates there was no significant difference between the two groups (concurrent lab group and no-lab group) even though the male population performed better in CHEM 624 compared to females. Figure 25 illustrates that there was no significant difference between the two groups, concurrent lab group and no-lab group, but the no-lab group performed lower than the concurrent lab group for some of the ethnicities compared to the others. For White and Asian ethnicities, the concurrent lab group performed better than the no-lab group, whereas for the Hispanics and Others, the no-lab group performed better than the concurrent lab group, and for the African-Americans, there was no difference between the two groups. The African-American and Hispanic population had the lowest performance, whereas Asian and White population were a little higher and lied close to each other in their performances. The “Others” group of ethnicity performed higher compared to the rest of the ethnicities, but there was no significant difference among the different ethnicities and their performances. Figure 27 shows that there was no significant difference between the two groups based on student major information. Student in each category of major performed lower in the no-lab group than students in the corresponding major in the concurrent lab group. Students in the “Others” group, where the no-lab group performed better than the concurrent lab group, were the exceptions. Students in the Chemistry BS, Pre-Med, and Pre-Pharmacy, the two groups were very close to each other in their performances. Overall there was no significant difference between the groups. Figure 24, 26, and 28 shows the distribution of students enrolled in both the groups (concurrent lab group and no-lab group) in CHEM 624, based on gender, ethnicity, and major information respectively for 2008 till 2010.

Figure 29 illustrates the difference between the concurrent lab group and no-lab group as explained by the mean grades of students obtained in CHEM 624. The concurrent lab group had a higher mean grade compared to the no-lab group.

Figure 30 shows that the MLR assumption of normally distributed residuals was met for this analysis. Figure 31 shows that variables involved describe all cases relatively well from the relatively good fit of the data to the diagonal line in the Normal P-P plot. Figure 32 shows that all levels of the criterion variable and range of the residuals have similar ranges and all these indicate that MLR analysis met the homogeneity of residual error assumption.

A multiple linear regression (MLR) was conducted to predict the final exam grades (student performance) from demographic and academic background information along with lecture and laboratory sequencing information. From Table 9 it could be determined that the predictor variables which included all the covariates accounted for a significant amount of the final exam grades of CHEM 624. On the second analysis, it was observed that significant amount of the final exam grades were accounted by the sequence in which students enrolled for the laboratory and lecture course, after controlling for the effects of background knowledge and demographic information variables (covariates).

The data shown in Table 10, an MLR equation was determined for unstandardized coefficients B (Equation 7). According to the equation, one point change in the ACT score on average results in statistically significant 0.051 point change in the final grade. For every one point change in the HSGPA there will on average be 0.445 point change in the final grade for the course and it is also significant. Students of male gender will on average receive 0.223 points higher than the females in their final grade of CHEM 624 and it is significant. Both ethnicity and major contribute an average of 0.02 and 0.002 points change in the final exam grade respectively and both are not statistically significant. For the ethnicity it is a positive change whereas for the major the change is negative. Finally, students in the no-lab group on an average experience a 0.2 points decrease in the final grade point compared to the students in the concurrent lab group, and it is significant. This preliminary analysis helped to confirm the preliminary hypothesis of this study.

Conclusion

The data analyzed in this chapter confirmed that there is a statistically significant difference in student performance among the concurrent lab group and the no-lab group in CHEM 624 (Organic chemistry I). Based on the MLR analysis, students in the no-lab group are likely to achieve close to a half a letter grade lower course grade than the concurrent lab group. The approximate letter grade performance of 0.3 points lower for the no lab group corresponds with a half a letter grade (from A to A- etc.) difference in final grade performance. This result controls for potential confounding effects of background information. This data supports the conclusion that students, as measured by final grades, benefit from enrollment in the laboratory and lecture course simultaneously rather than enrolling for them separately. Also, the students enrolled in CHEM 626 (Organic chemistry II) are a subset of students from CHEM 624 (Organic chemistry I) course, and for both the courses it has been observed that sequencing does affect student performance, more definitely in organic chemistry II rather than in organic chemistry I as seen in the previous chapter.

Chapter 5- Effect of Sequence on Learning in Organic Chemistry I lecture course: Fall 2011

Purpose and Overview

Based on the preliminary study on the effect of lecture and laboratory sequence on student performance data was collected from 2008 till 2010 for both the first and second semester organic chemistry course (CHEM 624 and CHEM 626 respectively), and a difference was observed between, the concurrent lab group and the no-lab. The results obtained from the previous studies lead to an expansion of this study where the effect of lecture and laboratory sequence on student learning was measured in fall 2011. Demographic and academic background information (to measure prior knowledge of the student) was collected for the students enrolled in Organic Chemistry I course (CHEM 624/625) at the University of Kansas (KU) from fall of 2011 from university records. Organic chemistry I is offered at KU during both the fall and spring semesters, but for this study only fall 2011 data was used. The preliminary study quantitatively determined the difference between students enrolled in both the laboratory and lecture with students enrolled in just the lecture and how this sequence of enrollment in courses affects student performance in the lecture. The preliminary study was performed to understand if sequencing was involved with just students' performance determined by their final grades in the lecture course or with in-depth understanding of the concepts from the course. These factors correlated with student learning concepts or conceptual learning in Organic Chemistry I course.

Data obtained from university records on demographic and academic backgrounds of students enrolled in the lecture course to measure student learning in Organic Chemistry I lecture course. Data was collected from university records to check if a student enrolled in the lecture course was also enrolled in the laboratory. The data helped in grouping the students into the concurrent lab group (students enrolled in both laboratory and lecture) and the no-lab group (students enrolled in just the lecture). The data obtained from university records were coded with non-specific student identifiers. This was performed to maintain the students privacy on any data obtained from university records. During the course of the analysis, all the identifying information was removed. The results from this study was purely used to better describe the overall student population enrolled for Organic Chemistry I in fall 2011 and their concept learning process.

The professor teaching Organic Chemistry I lecture course (CHEM 624) in fall 2011 collaborated the research group on this project and provided student data from his exams that measured student concept learning in Organic Chemistry I course. For both the groups, the grades obtained in the conceptual questions from the lecture exams corresponded with the concepts learned in the laboratory, and meaningful difference between the two groups was analyzed. This study helped in answering the research question, is there any difference in student learning among the concurrent lab group and the no-lab group.

Course Structure for Lecture and Laboratory

The first semester Organic Chemistry course (CHEM 624), taught in fall 2011, was selected for this study. For the fall 2011 semester the professor used the textbook, *Organic Chemistry, 3rd edition, by Janice G. Smith*, and the structure of both the laboratory and lecture course was similar to that of the previous years. For the fall 2011 semester the course structure included 50-minutes lecture class that met three days per week and five-hour laboratory that met once per week. Along with the five-hour laboratory sessions there was a separate laboratory lecture conducted for an hour and fifteen minutes once per week. One lecture professor was responsible for the lecture course, and a separate professor responsible for the laboratory-lecture course. Different graduate teaching assistants were responsible for teaching the various laboratory sections and these students are usually conducting graduate work in organic chemistry. All the students enrolled for the lecture met in a single large group in an auditorium for their classes, and students who also enrolled for laboratory were divided into groups of 20 or less for their individual lab sections.

As before, the most important factor leading to sequencing issues involving laboratory and lecture is that students are not required to enroll for both laboratory and lecture during the same semester, though many self-select themselves into group who are simultaneously enrolled in laboratory. During the fall 2011 semester approximately 511 students enrolled for the lecture course, and among these 441 students completed the course for a grade, and had demographic and academic background information available with the university. For this study, the students who enrolled for both the laboratory and lecture course, called the concurrent lab group, included 332 students. The students who just enrolled for the lecture and not the laboratory, called the no-lab group, included 109 students.

Student grades for the lecture and laboratory course are assigned separately and are independent of each other. For the lecture, students can earn a maximum of 560 points, and for the laboratory, students can earn a maximum of 580 points. The lecture grade was determined by four one-hour exam scores worth, 100 points each, out of which only the three best scores was considered for the final grade, along with top six quiz scores which are worth 10 points each, and the final exam worth 200 points. These assignments sum up to 560 total points for the final lecture grade. The laboratory grade consisted of two exam scores (a midterm and a final) worth 100 points, along with 10 quiz scores worth 8 points each, laboratory techniques worth a total of 25 points, and finally 11 graded laboratory notebook sections and reports on laboratory experiments which are worth 25 points each. These sums up to 580 total points for the final laboratory grade. All of the lecture exam grades were collected along with individual conceptual question grades from each of the exams with permission from the professor teaching the lecture course and human subjects committee at Lawrence to measure student learning. The course final grade is given to the students in form of A, A-, B+, B, B-, C+, C, C-, D+, D, D-, and F, where getting above a 93% is an A and getting below 60% is a F grade.

The resources available to students during the course included assigned textbook, instructor office hours, laboratory and lecture TA office hours, along with emailing system between the students and the instructors. The only pre-requisite for enrolling in the lecture course is that students should have completed two semesters of general chemistry (CHEM 184 and CHEM 188) courses successfully. To enroll for the laboratory the pre-requisites state that a student must have completed two semesters of general chemistry laboratories (CHEM 184 and CHEM 188) and should have been concurrently enrolled or completed organic chemistry I lecture course (first semester organic chemistry). This gives a student choice of whether to enroll for the laboratory and lecture simultaneously or separately.

Lecture and laboratory are treated as separate courses with separate grades. The concepts that were introduced in the laboratory had similarity to some concepts introduced in the lecture course. The common topics introduced in both lecture and laboratories were acid-base chemistry, boiling point and melting point concepts, racemic mixtures, dehydration, and hydroboration. Some of these concepts were introduced in the laboratory before they were introduced in the lecture and some other concepts were introduced in the lecture before being introduced in the laboratories; however all of these particular concepts were introduced in both the lecture and laboratory. Exposure to concepts twice in a row for students enrolled in both the laboratory and lecture courses compared with learning concepts once for the students enrolled in just the lecture should affect student understanding of the concepts, and hence their grades obtained in the conceptual questions in all of the exams during the semester.

Selection of Student Groups for analysis

Data obtained from the university records and the lecture professor consisted of approximately 511 students who were enrolled for the first semester organic chemistry lecture course in fall 2011. Some of the students were concurrently enrolled for the laboratory and some of them were not enrolled for the laboratory. Out of these students some of the students were enrolled for the lecture course for the second time. Therefore, to eliminate the possibility of the effect of prior exposure to the lecture material might have on student concept learning, such students were eliminated from the student sample data. Some students had the laboratory grade but no lecture grade, and this group of students also removed from the sample data. This is due to the fact that those students enrolled for both laboratory and lecture but withdrew from the lecture course in between the semester. The sample for this study included students who were enrolled for the lecture and laboratory or just the lecture course for the first time and earned a grade of A through F in the course.

Demographic data included gender, ethnicity and academic major, and prior academic background knowledge information which was characterized by ACT score and high-school GPA were collected from the university records. Some of the student data did not have all the records and had to be removed from the sample data to maintain equality and homogeneity in student data during the analysis. Some students dropped out of individual exams because only three best exam scores are counted towards the final grade. Therefore, those students had to be removed from the analysis due to missing data from some conceptual questions. Approximately 70 students were removed from the sample based on the above criterions. The remaining students were part of the sample data (N = 441) for the fall 2011 semester. The concurrent lab group (students enrolled for both the laboratory and lecture) total sample size was N = 332, and the no-lab group (students enrolled for the lecture only) total sample size was N = 109. This data was used to analyze student learning organic chemistry concepts based on sequence of the lecture and laboratory instruction.

Overview of Data from OIRP

Demographic data

The demographic information obtained from the university records included gender, ethnicity, and academic major. Table 11 shows the demographic data for the first semester Organic Chemistry course (CHEM 624) in fall 2011, where the number of females was more than the males by 3.4%. There were 228 females and 213 males in the student population. There was little diversity among the ethnicities. Approximately 77% of the students applying to KU self-identified themselves as white. Other ethnicities included African-American, Hispanic, Asian, and others (which included students from international background/non-Asians, and who identified themselves as multi-ethnicity and non-specific). Minority students include African-American and Hispanics population with 3.2% and 5.7% respectively as stated in Table 11.

Student majors included chemistry, biology, biochemistry, self-identified pre-med, self-identified pre-pharmacy, and engineering students, also including some health science majors (others). Biology majors were 32.4% of the population. Following them were the pre-med and the pre-pharmacy majors with 15.9% and 18.1% of the population, respectively. The population description and percentages are included in Table 11. Most of the students enrolled for this course were in their sophomore or junior year. Although, detailed information about the student's number of years of enrollment at KU was not collected from the university.

Table 11: Demographic Information Table of CHEM 624, fall 2011

Demographic Information Table			
Variables		N	Percent
Gender	Male	213	48.3
	Female	228	51.7
Ethnicity	White	341	77.3
	Hispanic	25	5.7
	African-American	14	3.2
	Asian	34	7.7
	Others	27	6.1
Major	Biochemistry	21	4.8
	Biology	143	32.4
	Chemistry	21	4.8
	Engineering	46	10.4
	Pre- Med	70	15.9
	Pre- Pharmacy	80	18.1
	Others	60	13.6

Academic background

Academic background data collected from university records included ACT score and high-school grade point averages (HSGPA). Of those enrolled for first semester organic chemistry course approximately 85-90% of the students reported their high-school GPA and ACT score. Different school districts apply different methods for reporting high-school grade point averages. Some of the schools report grade point averages on an un-weighted scale, which means grades in all courses are worth equal points, while other schools report grade point averages on a weighted scale, meaning that grades in advanced courses are awarded more points than standard-level courses. The HSGPA of the students enrolled for the first semester organic chemistry course ranged from 4-point un-weighted, 4-point weighted, 5-point un-weighted, 5-point weighted, 100-point un-weighted, and 100-point weighted. On some weighted scales, for students taking advanced coursework it is possible to obtain values above the value used in the scale. For example, a student getting A in an advanced course can get 4.2 rather than 4.0 in a weighted scale. During admission to KU, the university converts all the weighted HSGPAs that range above the scale of 4.0. In this process all the weighted HSGPAs ranging above 4.0 are reported as a 4.0 value. As a consequence the HSGPA's for students enrolled in first semester organic chemistry ranged from 2.0 to 4.0.

The truncated HSGPA graph tends to give a negatively skewed curve as observed from the preliminary studies, which is not useful for this study, and hence the unconverted HSGPA was requested from the university records. The high school grade point average that was used for the analysis was the un-converted high-school GPA. The HSGPA included the original HSGPA values from un-weighted 4.0 to weighted 4.0 scales. The new distribution resembles a normal curve (Figure 33). The HSGPA has a mean of 3.78 with a standard deviation of 0.51. The unconverted HSGPA is more useful for standard statistical methods due to its normal distribution.

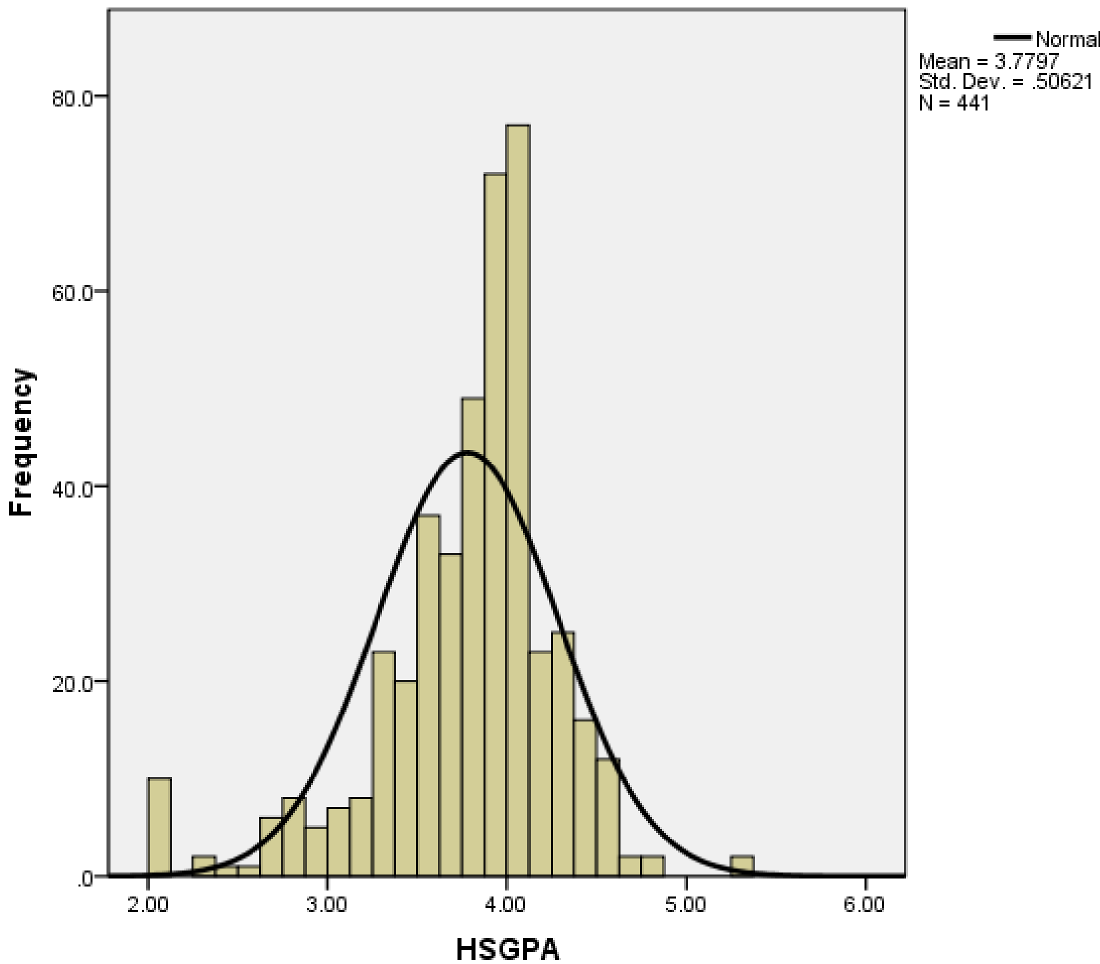


Figure 33: The histogram shows the distribution of unconverted high school GPAs (HSGPA_unconverted) for students in organic chemistry I (CHEM 624) for fall 2011. This distribution fits into a normal curve.

ACT composite scores can be a good predictor of prior background knowledge (Thompson Ross, 2004). The ACT score data was collected from the university records to determine if ACT composite scores correlate with student learning in Organic Chemistry I course. Out of the students who enrolled in the organic chemistry I course, approximately 85-90% reported their ACT score to the university. The average ACT composite score is 27.13 with a standard deviation of 3.63. Figure 34 shows the values, and it can be concluded that this variable is normally distributed within the group of enrolled students.

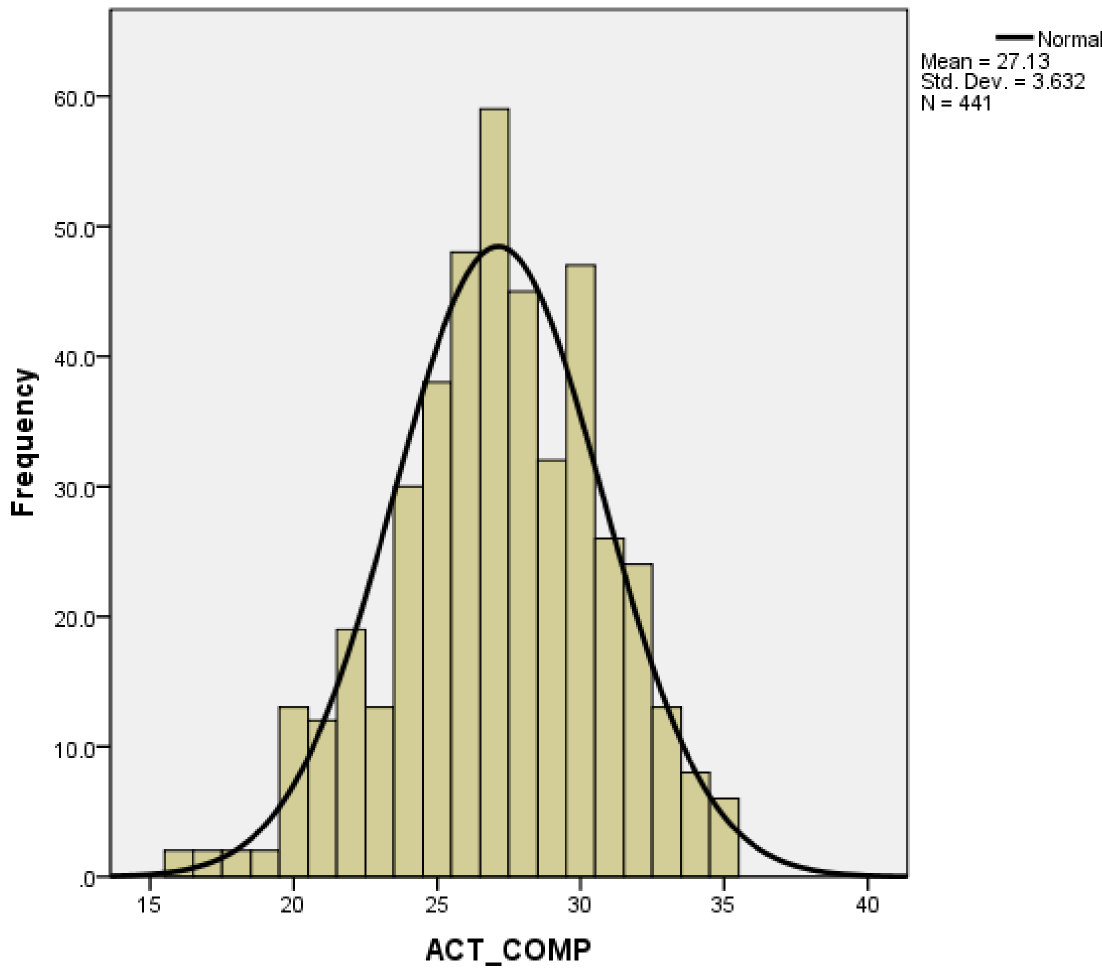


Figure 34: The histogram shows the distribution of ACT scores for students in organic chemistry I (CHEM 624) for fall 2011. This distribution does fit into a normal curve.

Overview of Data obtained from the Lecture course

Data from the lecture course was collected to analyze the effect of lecture and laboratory sequence on student learning. The concepts that were introduced in the laboratory had similarity with some concepts introduced in the lecture course. The common topics introduced in both lecture and laboratories were acid-base chemistry, boiling point and melting point concepts, racemic mixtures, dehydration, and hydroboration. Some of these concepts were introduced in the laboratory before it was introduced in the lecture and some other concepts were introduced in the lecture before being introduced in the laboratories, but all these concepts were introduced in both the lecture and laboratory. This concept learning twice in a row for students enrolled in both the laboratory and lecture course compared to learning it once for the students enrolled in just the lecture could affect their learning of organic chemistry concepts.

Student grades were collected based on their response to conceptual questions on all of the four exams and the final. The conceptual questions were multiple choice, three points for a correct answer and zero points for an incorrect response. For exam I, there was one question on boiling point and melting point concepts. For exam II, there was one question based on hydrogen elimination or dehydration concept. For exam III, there was no conceptual question that resembled concepts learned in the laboratory. For exam IV, there were two questions, one based on hydroboration concept, and the other on addition of hydrogen ions. For the final exam, there were five relevant questions, three questions based on acid-base theory, one on boiling point and melting point theory, and the last one on dehydration. All these concepts were introduced in both the laboratory and the lecture, hence students enrolled in both the laboratory and lecture group has seen the same concepts twice (in practical and theoretical environments) and students enrolled in the lecture only has seen the concepts only once (only in a theoretical environment).

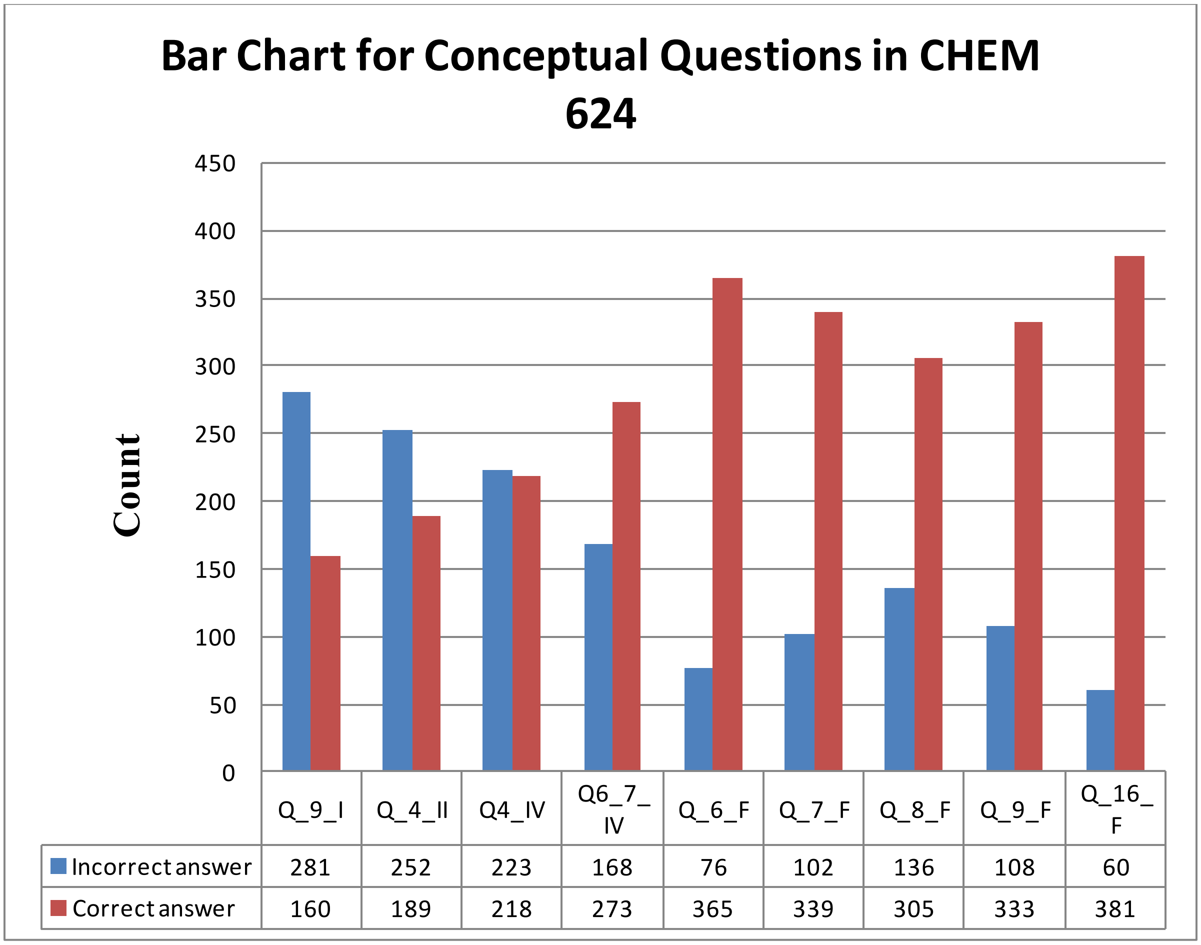


Figure 35: Bar chart of student responses to conceptual questions in all the exams in CHEM 624

The overall grades were also collected for all the exams in CHEM 624 (four exams and the final), and the difference between the two groups, concurrent lab group and no-lab group were analyzed based on the exam grades. This data helped in analyzing the effect of sequencing lecture and laboratory instruction on student learning.

Methods of analysis

The analysis of student learning in Organic Chemistry I (CHEM 624) included statistical analysis of conceptual question grades from 4 exams and 1 final exam in fall 2011, using SPSS (Statistical Package for the Social Sciences) software. Statistical analysis included correlations, partial correlation, one-way analysis of variance (ANOVA), T-tests, and multiple linear regressions and the methods are discussed in the previous chapter (Chapter 3).

Results of the statistical analysis for measuring student learning in CHEM 624, fall 2011

To analyze the effect of sequencing on student learning nine conceptual multiple choice questions were selected from the exams conducted in CHEM 624 (Organic Chemistry I) throughout the semester (fall 2011). A correlation analysis was performed to understand the relationship between two variables. This study was performed to examine the relationship between the *independent variable* (concurrent lab group vs. no-lab group) and the *dependent variables* (grades obtained in multiple choice conceptual questions in CHEM 624), along with the relationship between the *dependent variables* and the *covariates or antecedents* (demographic and academic information). The correlation results illustrate the covariates that had statistically significant effect on the grades obtained by students in each of the conceptual questions. Partial correlation shows the effect of sequencing on student learning after controlling for the significant covariates or confounding variables. The correlations and partial correlations are listed in the Table 12.

Table 12: Correlation and Partial Correlation Table of CHEM 624, fall 2011

Correlations and Partial Correlations of CHEM 624 (Fall 2011)						
	Concurrent lab group vs. No lab group	ACT	HSGPA	Gender	Ethnicity	Major
Q9_ExamI r partial r	.016	.101*	.079	.082	-.017	-.011
Q4_ExamII r partial r	-.124**	-.003	.079	.016	-.048	-.044
Q4_ExamIV r partial r	-.072	.046	-.018	-.012	-.052	-.020
Q6/7_ExamIV r partial r (HSGPA) (Ethnicity)	-.135** -.127** -.131**	.090	.117*	.001	-.110*	.070
Q6_Final r partial r	-.114*	.090	.022	.069	-.043	-.019
Q7_Final r partial r	-.222**	-.005	.011	-.008	.034	.019
Q8_Final r partial r (ACT)	-.164** -.172**	.104*	.050	-.042	.049	-.062
Q9_Final r partial r (Gender)	-.138** -.153**	.071	.018	.128**	-.028	-.010
Q16_Final r partial r	-.079	.107*	-.006	.079	.004	.001

** Correlation is significant at 0.01 level

*Correlation is significant at 0.05 level

The overall exam grades were also analyzed (four 1-hour exams and one final) to measure the effect of laboratory and lecture course sequence on student performance on individual exams. Students enrolled in the laboratory and lecture course together, the *concurrent-lab group* (N = 332), and students enrolled for just the lecture course, the *no-lab group* (N = 109) had different means and standard deviations for each of the exams listed in Table 13. Figure 36 explains the differences in the average (mean) grades obtained in all the exams by the two groups, concurrent lab group and the no-lab group.

Table 13: Descriptive Statistics Table of CHEM 624, fall 2011

Descriptive Statistics of CHEM 624 Exams and Final grades (Fall 2011)		
	Mean	Standard deviation
Exam I (100 points)		
Concurrent lab group	80.12	14.43
No-lab group	75.85	14.10
Exam II (100 points)		
Concurrent lab group	82.27	13.43
No-lab group	72.55	23.73
Exam III (100 points)		
Concurrent lab group	80.38	16.63
No-lab group	73.24	20.83
Exam IV (100 points)		
Concurrent lab group	58.03	23.53
No-lab group	48.37	26.49
Final (200 points)		
Concurrent lab group	144.34	39.54
No-lab group	119.83	51.01

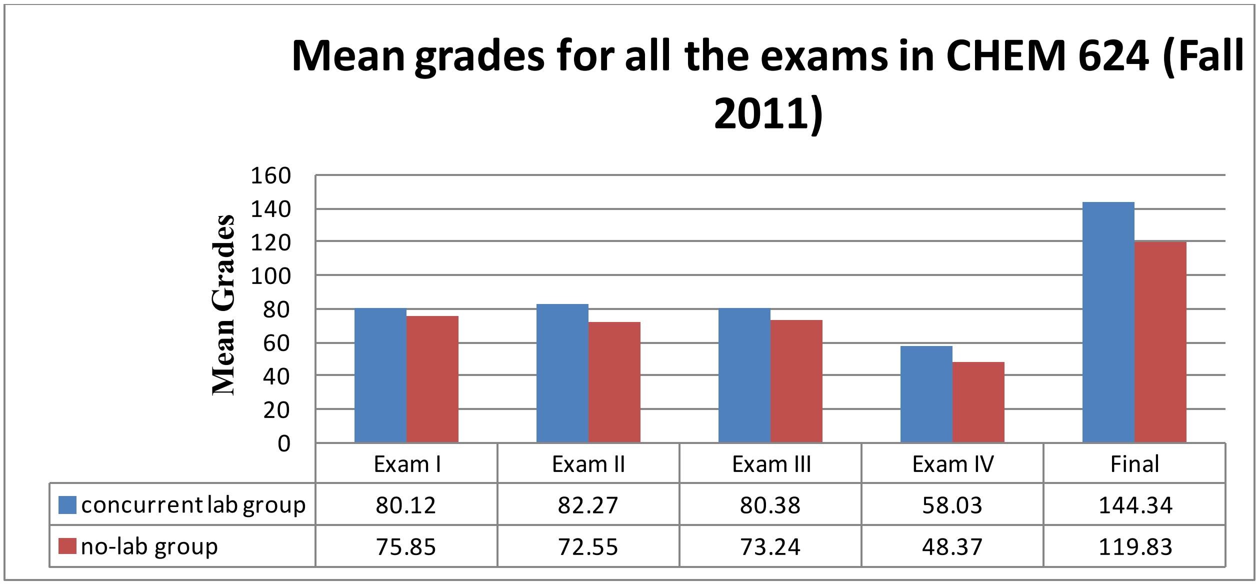


Figure 36: Mean grades obtained by students in CHEM 624 exams

To determine the significant effect of sequencing lecture and laboratory instruction on student grades in individual exams conducted in CHEM 624, separate one-way ANOVAs were performed. Levene's test was performed prior to each ANOVA on the interval level variable and the dichotomous variable to test the homogeneity of variance among the groups of interest. When the Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and their statistical significance was better described by the Welch-F statistic rather than traditional F-statistic. The Welch-F statistic is a robust test of equality of means that can be used in a modification of the traditional version of ANOVA that does not assume homogeneity of variance among the variables. The ANOVA results in Table 14 clearly identifies the variables on which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore requiring the application of a significance test based on Welch-F statistic. The level of significance for this study was chosen to be 0.05 (α).

Table 14: ANOVA results table of CHEM 624, fall 2011

ANOVA results from CHEM 624 Exams (Fall 2011)		
ANOVA	Exam I*	**$F (1, 439) = 7.26$, $p = .007 < 0.05$**
ANOVA	Exam II*	**$F (1, 439) = 28.26$, $p = .000 < 0.05$**
ANOVA	Exam III*	**$F (1, 439) = 13.29$, $p = .000 < 0.05$**
ANOVA	Exam IV*	**$F (1, 439) = 12.99$, $p = .000 < 0.05$**
ANOVA	Finals*	**$F (1,439) = 27.09$, $p = .000 < 0.05$**

*Levene's Test not significant

Bolded ANOVA results are statistically significant

The correlation analysis illustrates which conceptual questions had statistical significance based on the sequence of the lecture and laboratory course. To determine any significant effect of demographic information and academic background information on student grades obtained in six of the conceptual questions (significant from the correlation study) in CHEM 624 separate one-way ANOVAs were performed. The academic background (ACT score, HSGPA, and major) and demographic information (gender and ethnicity) were used as the independent variable, and the student grades were assigned as the dependent variable. Ethnicity categories constituting of 3% or less of the groups of interest were combined together in a category labeled *others*. Also the major category constituting of 3% or less of the groups of interest were determined to have insufficient power to stand alone as independent variables. Consequently, these categories were combined together in a category labeled *others*. All of the background variables which were interval level or dichotomous, like the gender, did not have to be altered prior to the ANOVA analysis, whereas, the nominal or ordinal level variables had to be altered into interval level, like the ACT score, before performing the analysis. In total, 5 confounding variables were analyzed for their effects on student learning.

Table 15 shows, the percentages of students in each group along with ANOVA results obtained by comparing the two groups of interest (concurrent lab group and no-lab group) for the 5 confounding variables. ANOVA results in Table 15 clearly shows the variables on which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore having a significance test based on Welch-F statistic.

A significant difference between the two groups based on the grades in the conceptual question 4 from exam II was observed, $F(1,439) = 6.90$, $p = .009 < 0.05$, hence significant at 0.05 level. Levene's test of homogeneity showed that the variables conformed to homogeneity of variance, $p = 0.993 > 0.05$. A significant difference between the two groups based on their grades in the conceptual question 6 from exam IV was shown, $F(1,439) = 8.16$, $p = .004 < 0.05$, at a significance level of 0.05. Levene's test of homogeneity was showed that the variables conformed to homogeneity of variance, $p = 0.998 > 0.05$. A significant difference between the two groups based on their grades in the conceptual question 6 from finals was illustrated, $F(1,439) = 5.82$, $p = .016 < 0.05$, at a significance level of 0.05. Levene's test of homogeneity was performed before the ANOVA and it was found to be, $p = 0.987 > 0.05$, hence Levene's test is not statistically significant and the variable maintains the homogeneity of variance. A significant difference between the two groups based on their grades in the conceptual question 7 from finals was identified, $F(1,439) = 22.7$, $p = .000 < 0.05$, at a significance level of 0.05. Levene's test of homogeneity was showed that the variables conformed to homogeneity of variance, $p = 0.956 > 0.05$. A significant difference between the two groups based on their grades in the conceptual question 8 from finals was illustrated, $F(1,439) = 12.1$, $p = .001 < 0.05$, at a significance level of 0.05. Levene's test of homogeneity was showed that the variables conformed to homogeneity of variance, $p = 0.966 > 0.05$. A significant difference between the two groups based on their grades in the conceptual question 9 from finals was observed, $F(1,439) = 8.55$, $p = .004 < 0.05$, at a significance level of 0.05. Levene's test of homogeneity was showed that the variables conformed to homogeneity of variance, $p = 0.958 > 0.05$.

Table 15: Summary Statistics and ANOVA table of CHEM 624, fall 2011

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) in Fall 2011			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 332)	No- lab group (N = 109)
Gender	Female Male	54.5 45.5	43.1 56.9
ANOVA	Gender*	F (1, 439) = .129, p = 0.72 > 0.05	
Ethnicity	White Hispanic African-American Asian Others	76.5 68.0 71.4 73.5 70.3	23.5 32.0 28.6 26.5 29.7
ANOVA	Ethnicity*	F (1, 439) = .416, p = 0.797 > 0.05	
Major	Biochemistry Chemistry Biology Pre-pharmacy Pre-Med Engineering Others	61.9 57.1 73.4 91.2 78.6 65.2 73.3	38.1 42.9 26.6 8.8 21.4 34.8 26.67
ANOVA	Major	F (1, 439) = .476, p = 0.826 > 0.05	
ACT score		81.5	18.5
ANOVA	ACT score*	F (1, 439) = .479, p = 0.830 > 0.05	
HSGPA		75.9	24.1
ANOVA	HSGPA*	F (1, 439) = .426, p = 0.800 > 0.05	

Bolded ANOVA results are significant

*signifies that Levene's test of homogeneity was not significant, hence variables are homogeneous

A multiple linear regression (MLR) was conducted to predict the question 4 exam II score (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a non-significant amount of the exam grade points, $R^2 = 0.011$ (adj. $R^2 = 0.000$), F (5, 435) = .986, $p > 0.05$ (Model 1, Table 16).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 4 in exam II above and beyond the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for the effects of background knowledge and demographic information variables, $R^2 = 0.026$ (adj. $R^2 = 0.013$), F (1, 434) = 6.80, $p < 0.05$ (Model 2, Table 16).

Equation 8:

CHEM 624 Q4 exam II scores = 1.208 + 0.116 (Male gender) - 0.030 (Ethnicity) - 0.01 (ACT score) + 0.162 (HSGPA) - 0.041 (Major) – 0.432 (No-lab group)*

Table 16: Summary table Q4 (Exam II) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q4_Exam II scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.106[a]	.011	.000	1.486	.011	.986	5	435	.426
2	.163[b]	.026	.013	1.477	.015	6.800	1	434	.009

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q4 exam II

Table 17: Coefficients of Q4 (Exam II) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q4_Exam II grades						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.115	.623		1.788	.074
	ACT score	-.014	.019	-.036	-.710	.478
	HSGPA	.184	.108	.088	1.704	.089
	Male Gender	.085	.144	.029	.589	.556
	Ethnicity	-.034	.060	-.028	-.574	.566
	Major	-.034	.031	-.052	-1.087	.278
2	(Constant)	1.208	.620		1.949	.052
	ACT score	-.010	.019	-.026	-.529	.597
	HSGPA	.162	.107	.078	1.513	.131
	Male Gender	.116	.144	.039	.808	.419
	Ethnicity	-.030	.059	-.025	-.503	.615
	Major	-.041	.031	-.064	-1.319	.188
	No-lab group	-.432	.166	-.125	-2.608	.009

Dependent Variable: chemistry score_Q4 exam II

A multiple linear regression (MLR) was conducted to predict the question 6 exam IV grade (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a significant amount of the exam grade points, R^2 = 0.031 (adj. R^2 = 0.019), F (5, 435) = 2.74, $p < 0.05$ (Model 1, Table 18).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 6 in exam IV over and above the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for

the effects of background knowledge and demographic information variables, $R^2 = 0.046$ (adj. $R^2 = 0.033$), $F(1, 434) = 7.09$, $p < 0.05$ (Model 2, Table 18).

Equation 9:

CHEM 624 Q6 exam IV scores = 0.568 + 0.049 (Male gender) - 0.099 (Ethnicity)* - 0.033 (ACT score) + 0.132 (HSGPA)* + 0.042 (Major) – 0.428 (No-lab group)*

Table 18: Summary table of Q6 (Exam IV) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q6_Exam IV scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.175[a]	.031	.019	1.444	.031	2.737	5	435	.019
2	.215[b]	.046	.033	1.434	.016	7.095	1	434	.008

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q6 exam IV

Table 19: Coefficients of Q6 (Exam IV) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q6_Exam IV scores						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.475	.606		.784	.433
	ACT score	.029	.019	.076	1.538	.125
	HSGPA	.153	.105	.075	1.461	.045
	Male Gender	.018	.140	.006	.128	.898
	Ethnicity	-.104	.058	-.087	-1.792	.044
	Major	.049	.030	.077	1.603	.110
2	(Constant)	.568	.602		.943	.346
	ACT score	.033	.019	.086	1.733	.084
	HSGPA	.132	.104	.064	1.266	.036
	Male Gender	.049	.139	.017	.350	.726
	Ethnicity	-.099	.058	-.084	-1.727	.046
	Major	.042	.030	.065	1.373	.170
	No-lab group	-.428	.161	-.127	-2.664	.008

Dependent Variable: chemistry score_Q6 exam IV

A multiple linear regression (MLR) was conducted to predict the question 6 final exam grade (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a non-significant amount of the exam grade points, $R^2 = 0.014$ (adj. $R^2 = 0.002$), $F (5, 435) = 1.19$, $p > 0.05$ (Model 1, Table 20).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 6 in the final exam over and above the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for

the effects of background knowledge and demographic information variables, $R^2 = 0.030$ (adj. $R^2 = 0.016$), $F(1, 434) = 7.244$, $p < 0.05$ (Model 2, Table 20).

Equation 10:

CHEM 624 Q6 final exam scores = 1.808 + 0.169 (Male gender) – 0.030 (Ethnicity) + 0.027 (ACT score) – 0.014 (HSGPA) – 0.01 (Major) – 0.339 (No-lab group)*

Table 20: Summary table of Q6 (final) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q6_Final Exam scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.116[a]	.014	.002	1.133	.014	1.192	5	435	.312
2	.172[b]	.030	.016	1.125	.016	7.244	1	434	.007

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q6 final exam

Table 21: Coefficients of Q6 (final) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q6_Final Exam scores						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.808	.475		3.805	.000
	ACT score	.025	.015	.083	1.660	.098
	HSGPA	.002	.082	.001	.029	.977
	Male Gender	.144	.110	.064	1.313	.190
	Ethnicity	-.033	.045	-.036	-.734	.463
	Major	-.004	.024	-.008	-.163	.870
2	(Constant)	1.881	.472		3.982	.000
	ACT score	.027	.015	.093	1.857	.064
	HSGPA	-.014	.082	-.009	-.174	.862
	Male Gender	.169	.109	.074	1.542	.124
	Ethnicity	-.030	.045	-.032	-.662	.508
	Major	-.010	.024	-.019	-.400	.689
	No-lab group	-.339	.126	-.129	-2.691	.007

Dependent Variable: chemistry score_Q6 final exam

A multiple linear regression (MLR) was conducted to predict the question 7 final exam grade (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a non-significant amount of the exam grade points, $R^2 = 0.002$ (adj. $R^2 = -.009$), $F (5, 435) = .173$, $p > 0.05$ (Model 1, Table 22).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 7 in the final exam over and above the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for

the effects of background knowledge and demographic information variables, $R^2 = 0.051$ (adj. $R^2 = 0.038$), $F(1, 434) = 22.655$, $p < 0.05$ (Model 2, Table 22).

Equation 11:

CHEM 624 Q7 final exam scores = 2.267 + 0.039 (Male gender) + .047 (Ethnicity) + 0.004 (ACT score) + 0.004 (HSGPA) – 0.001 (Major) – 0.663 (No-lab group)*

Table 22: Summary table Q7 (final) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q7_Final Exam scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.045[a]	.002	-.009	1.272	.002	.173	5	435	.973
2	.227[b]	.051	.038	1.242	.050	22.655	1	434	.000

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q7 final exam

Table 23: Coefficients of Q7 (final) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q7_Final Exam scores					
Model	Unstandardized Coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	2.122	.533		3.979	.000
ACT score	-.002	.017	-.006	-.115	.908
HSGPA	.037	.092	.021	.400	.689
Male Gender	-.009	.123	-.003	-.070	.945
Ethnicity	.040	.051	.039	.790	.430
Major	.010	.027	.018	.374	.709
2 (Constant)	2.267	.522		4.346	.000
ACT score	.004	.016	.011	.218	.827
HSGPA	.004	.090	.003	.050	.960
Male Gender	.039	.121	.015	.325	.745
Ethnicity	.047	.050	.046	.946	.345
Major	-.001	.026	-.002	-.037	.971
No-lab group	-.663	.139	-.226	-4.76	.000

Dependent Variable: chemistry score_Q7 final exam

A multiple linear regression (MLR) was conducted to predict the question 8 final exam grade (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a non-significant amount of the exam grade points, $R^2 = 0.019$ (adj. $R^2 = .008$), $F (5, 435) = 1.705$, $p > 0.05$ (Model 1, Table 24).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 8 in the final exam over and above the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for

the effects of background knowledge and demographic information variables, $R^2 = 0.049$ (adj. $R^2 = 0.036$), $F(1, 434) = 13.7$, $p < 0.05$ (Model 2, Table 24).

Equation 12:

CHEM 624 Q8 final exam scores = 1.084 – 0.071 (Male gender) + .074 (Ethnicity) + 0.038 (ACT score)* + 0.044 (HSGPA) – 0.040 (Major) – 0.565 (No-lab group)*

Table 24: Summary table of Q8 (final) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q8_Final Exam scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.139[a]	.019	.008	1.382	.019	1.705	5	435	.132
2	.222[b]	.049	.036	1.362	.030	13.703	1	434	.000

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q8 final exam

Table 25: Coefficients of Q8 (final) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q8_Final Exam scores						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.961	.579		1.659	.098
	ACT score	.033	.018	.092	1.852	.065
	HSGPA	.072	.100	.037	.719	.472
	Male Gender	-.112	.134	-.040	-.836	.403
	Ethnicity	.068	.055	.060	1.231	.219
	Major	-.030	.029	-.050	-1.049	.295
2	(Constant)	1.084	.572		1.896	.059
	ACT score	.038	.018	.105	2.135	.033
	HSGPA	.044	.099	.023	.448	.654
	Male Gender	-.071	.132	-.026	-.538	.591
	Ethnicity	.074	.055	.065	1.355	.176
	Major	-.040	.029	-.066	-1.385	.167
	No-lab group	-.565	.153	-.176	-3.702	.000

Dependent Variable: chemistry score_Q8 final exam

A multiple linear regression (MLR) was conducted to predict the question 8 final exam grade (measuring student learning) from demographic and academic background information along with lecture and laboratory sequencing information. The results of this analysis indicated that these predictor variables accounted for a non-significant amount of the exam grade points, $R^2 = 0.021$ (adj. $R^2 = .010$), $F(5, 435) = 1.901$, $p > 0.05$ (Model 1, Table 26).

A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the score on question 8 in the final exam over and above the background and academic information variables. A significant amount of the exam scores were accounted for the sequence in which students enrolled for the laboratory and lecture course, after controlling for

the effects of background knowledge and demographic information variables, $R^2 = 0.045$ (adj. $R^2 = 0.032$), $F(1, 434) = 10.94$, $p < 0.05$ (Model 2, Table 26).

Equation 13:

CHEM 624 Q9 final exam scores = 1.586 + 0.362 (Male gender)* - .014 (Ethnicity) + 0.024 (ACT score) + 0.007 (HSGPA) - 0.008 (Major) – 0.471 (No-lab group)*

Table 26: Summary table Q9 (final) scores – MLR

	Model Summary for Organic Chemistry I (CHEM 624) Q9_Final Exam scores MLR								
Model	R	R square	Adj. R	Std. Error of Estimate	R Square change	F change	df1	df2	Sig. F change
1	.146[a]	.021	.010	1.285	.021	1.901	5	435	.093
2	.213[b]	.045	.032	1.271	.024	10.935	1	434	.001

a. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA
b. Predictors: (Constant), major, ACT score, male gender, ethnicity, HSGPA, no-lab group
c. Dependent Variable: chemistry score_Q9 final exam

Table 27: Coefficients of Q9 (final) scores – MLR

Coefficients of Organic Chemistry I (CHEM 624) Q9_Final Exam scores						
Model		Unstandardized Coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.484	.539		2.754	.006
	ACT score	.020	.017	.060	1.197	.232
	HSGPA	.030	.093	.016	.319	.750
	Male Gender	.328	.124	.127	2.638	.009
	Ethnicity	-.019	.052	-.018	-.361	.718
	Major	-.001	.027	-.001	-.024	.981
2	(Constant)	1.586	.534		2.973	.003
	ACT score	.024	.017	.071	1.441	.150
	HSGPA	.007	.092	.004	.072	.942
	Male Gender	.362	.123	.140	2.934	.004
	Ethnicity	-.014	.051	-.013	-.270	.787
	Major	-.008	.027	-.015	-.314	.754
	No-lab group	-.471	.142	-.157	-3.307	.001

Dependent Variable: chemistry score_Q9 final exam

Discussion of statistical analysis

Prior to starting this experiment, the level of significance was decided to be 0.05 (α). To analyze the hypothesis, that there is a difference in student mastery of organic chemistry concepts between the concurrent lab group and the no-lab, various statistical analyses were run using Statistical Package for the Social Sciences (SPSS) including correlation, ANOVA, and linear regressions. To analyze the hypothesis, multiple choice items covered in both organic chemistry I (CHEM 624) lecture and laboratory were used as the dependent variables. The grading system for the multiple choice question included 0 points for the incorrect answer and 3 points for the correct answer. Item analysis was performed to check the reliability of the questions. Nine multiple choice question grades were used to analyze this study, and all these questions had concepts which were learned in the laboratory along with the lecture. The concepts included boiling point/melting point concept questions, H-addition or removal, dehydration, hydroboration, racemic mixture, and acid-base chemistry.

A correlation analysis was performed to understand the relationship between two variables. The *independent variable* being concurrent lab group vs. no-lab group and the *dependent variables* being grades obtained in multiple choice conceptual questions in CHEM 624, along with this analysis the relationship between the *dependent variables* and the *covariates or antecedents* (demographic and academic information) were also analyzed. Table 12 shows, that question 9 from exam I, based on boiling point/melting point concept, had no correlation with any of the variables other than ACT score, $r (439) = 0.101$, $p < 0.05$, correlation was positive and weak. There was no significant difference between the concurrent lab group and no-lab group for question 9. For grades in question 4 from exam II, based on hydrogen elimination concept, there was a negative and weak correlation, $r (439) = -.124$, $p < 0.01$, with the independent variable (concurrent lab group vs. no-lab group). Negative correlation signifies that when one variable increases the other variable decreases, and according to the coding of the variables, it signifies that when more students enroll for the no-lab group their grade in question 4 tend to decrease. There was no significant correlation between the grades in question 4 and the covariates or confounding variables. There was no question from exam III that had concepts taught in the laboratory. For grades in question 4 from exam IV, based on hydroboration concept, there was no significant correlation between the grades and the independent variable or with the covariates. For question 6 from exam IV, based on hydrogen ion addition concept, there was a significant correlation between the grades and concurrent lab group vs. no-lab group, $r (439) = -.135$, $p < 0.01$, the correlation is negative and weak. There was also correlation between grade in question 6 and HSGPA, $r (439) = .117$, $p < 0.05$, positive and weak correlation, and grade in question 6 and ethnicity, $r (439) = -.110$, $p < 0.05$, negative and weak correlation. According to coding performed in the variable "ethnicity", it is illustrated that African-American ethnicity gets lower score compared to rest of the ethnicity groups. For question 6 on the final exam, based on acid-base concepts, there was a significant correlation between the grades and concurrent lab group vs. no-lab group, $r (439) = -.114$, $p < 0.05$, the correlation was negative and weak. There was no correlation between the grades in question 6 from finals and the covariates. For question 7 on the final exam, based on acid-base concepts, there was a significant correlation between the grades and concurrent lab group vs. no-lab group, $r (439) = -.222$, $p < 0.01$, the correlation was negative and weak. There was no correlation between the grades in question 7 from finals and the covariates. For question 8 on the final exam, based on acid-base concepts, there was a significant correlation between the grades and concurrent lab group vs. no-lab group, $r (439) = -.164$, $p < 0.01$, the correlation was negative and weak. There was correlation between the grades in question 8 from finals and the ACT score, $r(439) = .104$, $p < 0.05$, correlation was positive and weak. There was no correlation with rest of the covariates. For question 9 on the final exam, based on boiling point/ melting point concepts, there was a significant correlation between the grades and concurrent lab group vs. no-lab group, $r(439) = -.138$, $p < 0.01$, the correlation was negative and weak. There was correlation between the grades in question 9 from finals and the gender, $r(439) = .128$, $p < 0.01$, correlation was positive and weak. The male gender tends to perform better in the above question. There was no correlation with rest of the covariates. For question 16 from the final exam, based on dehydration concept, has no correlation with any of the variables other than ACT score, $r(439) = .107$, $p < 0.05$, correlation is positive and weak. There was no significant difference between the concurrent lab group and no-lab group for question 16 and also no correlation between the grades and the covariates. All the negative correlations between the grades and concurrent lab group vs. no lab group signify that with more students enrolling in the no –lab group, there was a decrease in the grades of the questions that had similar organic chemistry concepts from the laboratory and the lecture course. Students were more likely to succeed in concept questions when they enrolled for lecture and laboratory simultaneously rather than separately.

A partial correlation was performed to measure the effect of sequencing on student learning after controlling for the significant covariates or confounding variables. Partial correlation was not performed on questions 9 (exam I), 4 (exam II), 4 (exam IV), 6 (final), 7 (final), and 16 (final) because there was no correlation between the dependent variable and the covariates for any of the above listed questions. For questions 6 (exam IV), the correlation between grade and concurrent lab group vs. no-lab group, after controlling for HSGPA dropped from 0.135 to 0.127, hence on average, 0.8% of the grade was due to HSGPA. The correlation between grade and concurrent lab group vs. no-lab group, after controlling for ethnicity dropped from 0.135 to 0.131; hence on average, 0.4% of the grade was contributable to ethnicity. For question 8 on the final exam, the correlation between grade and concurrent lab group vs. no-lab group, after controlling for ACT score increased from 0.164 to 0.172, hence on average, 0.8% of the grade was contributable to the concurrent lab group vs. no lab group and not for ACT score. For question 9 on the final exam, the correlation between grade and concurrent lab group vs. no-lab group, after controlling for gender increased from 0.138 to 0.153, hence on average, 1.5% of the grade was contributable to concurrent lab group vs. no-lab group and not due to the gender. Overall, there was a significant correlation between question scores and sequence of enrollment after controlling for the confounding variables.

Along with the concept questions based on both laboratory and lecture course, the overall lecture grades were also analyzed to measure the effect of sequencing lecture and laboratory course on student performance. Table 13 and Figure 36, provides the mean score and standard deviations for each of the exams conducted in the lecture course of CHEM 624 in fall 2011. The mean score for exam I, II, III, and the finals were close for both the concurrent lab group and the no-lab group. The mean score for exam IV was drastically lower compared to the other exams for both the groups. This may have been due to the content of the lecture course covered in Exam 4, which included reaction mechanisms and functional group transformations like hydroboration. Students tend to struggle with these advanced concepts. The one-way ANOVA performed on the exam grades showed a significant difference between the concurrent lab group vs. the no-lab group for exam grades on all the four exams and the final (Table 14).

Separate one-way ANOVAs were performed on the grades obtained in each of the questions with 5 covariates (demographic information and academic background information), which included ACT score, HSGPA, gender, ethnicity, and major information. From the correlation study, the questions that did not show any correlation with the covariates and the independent variable, concurrent lab group vs. no lab group, one-way ANOVA study was excluded for them. Levene's test was performed prior to each ANOVA on the interval level variable and the dichotomous variable to test the homogeneity of variance among the groups of interest. When the Levene's Test is statistically significant, it means that the variable lacked homogeneity showed and their statistical significance was better described by Welch-F statistic rather than traditional F-statistic. The Welch-F statistic is a robust test of equality that can be used in modification of the traditional version of ANOVA that does not assume homogeneity of variance.

Table 15 explains the one-way ANOVAs performed on student demographics and academic information. There was no significant difference between the concurrent lab group and no-lab group for any of the covariates (gender, ethnicity, major, ACT score, and high school GPA) at $\alpha = 0.05$. There was a significant difference between the two groups, concurrent lab group and no-lab group, based on student grades in the conceptual question 4 from exam II, $F(1,439) = 6.90$, $p = .009 < 0.05$, hence significant at 0.05. There was a significant difference between the two groups based on student grades in the conceptual question 6 from exam IV, $F(1,439) = 8.16$, $p = .004 < 0.05$, hence significant at 0.05. There was a significant difference between the two groups based on student grades in the conceptual question 6 from the finals, $F(1,439) = 5.82$, $p = .016 < 0.05$, hence significant at 0.05. There was a significant difference between the two groups based on student grades in the conceptual question 7 from the finals, $F(1,439) = 22.7$, $p = .000 < 0.05$, hence significant at 0.05. There was a significant difference between the two groups based on student grades in the conceptual question 8 from the finals, F

(1,439) = 12.1, p = .001< 0.05, hence significant at 0.05. There was a significant difference between the two groups based on student grades in the conceptual question 9 from the finals, F (1,439) = 8.55, p = .004 < 0.05, hence significant at 0.05. The Levene's test of homogeneity was performed and for all these tests the two groups (concurrent lab group and the no-lab group) were homogeneous, non-significant Levene's test.

A multiple linear regression (MLR) was conducted to predict the question grades (student learning) from demographic and academic background information along with lecture and laboratory sequencing information. A second MLR analysis was conducted to evaluate whether sequencing of laboratory and lecture predicted the question grades above and beyond the background and academic information variables. Table 16 through 27 provides the data from the MLR analysis from which the equations 8 through 13 were developed. Equation 8, predicted that for the no-lab group on an average there was a decrease in the grade for question 4 (exam II) by 0.432, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), on an average students enrolled in the no-lab group could get the answer incorrect. In equation 9, with every White population enrolled in the lecture course there on an average was a 0.01 point decrease in the grade of question 6 (exam IV). Also, with one unit change in the HSGPA on an average there was an increase in the grade by 0.132. This signifies that the White ethnicity on an average can get question 6 incorrect and higher HSGPA on an average can get the question correct. In question 6 (exam IV) for the no-lab group on an average there was a decrease in the grade by 0.428, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), students enrolled in the no-lab group gets the answer incorrect. In equation 10, for question 6 from the final exam, for the no-lab group on an average there was a decrease in the grade by 0.339, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), students enrolled in the no-lab group gets the answer incorrect. In equation 11, for question 7 from the final exam, for the no-lab group on an average there was a decrease in the grade by 0.663, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), the students enrolled in the no-lab group gets the answer incorrect. In equation 12, for question 8 from the final exam, for the no-lab group on an average there was a decrease in the grade by 0.565, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), students enrolled in the no-lab group gets the answer incorrect. Also, with one unit change in the ACT score on an average there was an increase in the grade for question 8 by 0.038, which means higher ACT score on average has higher chance of getting the answer correct. In equation 13, for question 9 from the final exam, for the no-lab group on an average there was a decrease in the grade by 0.471, which means because the exam is a multiple choice exam (3 for correct answer, 0 for incorrect answer), students enrolled in the no-lab group gets the answer incorrect. Also, for the male gender on average there was a higher chance of getting 0.362 points increase in the grade which literarily means that male gender on average gets the answer correct in question 9 compared to the females. Therefore, overall students enrolled in laboratory and lecture course simultaneously are more likely to succeed in concept questions compared to students enrolled separately.

Conclusion

The analysis outlined above supports the conclusion that there is a significant difference in student learning organic chemistry concepts between the concurrent lab group and the no-lab group in CHEM 624 (organic chemistry I). Concepts that are introduced in both the laboratory and the lecture were analyzed and students enrolled in the concurrent lab group seemed to have benefited from the observation of similar concepts twice (practical in laboratory and theoretical in lecture) rather than just once as for the no-lab group. This conclusion can be drawn from the MLR analysis that the no-lab group on an average is more likely to incorrectly answer the multiple choice question. Based on all of the MLR analyses, overall the confounding variables or covariates (demographic and academic information) do not play a significant role in determining the grades of the concept questions. The mean grade on Exam IV was lower compared to the other exam grades, and a potential reason could be that students do not understand the concepts learned during that period of the semester and hence the exam content seems to be meaningless and difficult for them. Students experience great difficulty with concepts such as hydroboration and reaction mechanisms. Another potential reason for getting lower grades in exam IV could be that one exam is dropped when accounting for the final grade in the lecture course hence motivation to succeed in this exam is low compared to other exams. Students enrolled in the concurrent lab group clearly have a better understanding of concepts including acid-base chemistry, and H-elimination and addition reactions than the no-lab group. Students are exposed to acid-base concepts in general chemistry courses before enrolling in organic chemistry I course, hence prior knowledge from a previous course could potentially influence student scores in related to one concept in this study. At present, it is beyond the scope of this study to examine potential interference from this source. One concept that the concurrent lab group clearly develops a better understanding of than the no-lab group during the course is the boiling point/melting point concept. Question 9 from exam I showed no significant difference between the groups, but question 9 on the final exam indicated that there was a difference in knowledge between the groups. There was no significant difference between the two groups while answering the concept question on hydroboration, and a potential reason could be that students do not understand the more extensive mechanistic rules involved in the hydroboration process. Therefore, based on these item analyses of concepts included in the four midterm tests and the final, it is possible to conclude that student learning of chemical concepts benefits from enrolling in the laboratory and lecture courses simultaneously rather than taking these courses during separate semesters. Student enrolled in lecture and laboratory simultaneously can actively discuss concepts with other peers while performing peer-led experiments in the laboratory. Also, learning samples on exam performance has been observed to be consistently being picked up by students enrolled in laboratory and lecture simultaneously than students enrolled separately. These added factors could possibly influence better student learning for those enrolled in the lecture and laboratory simultaneously compared to the students enrolled separately.

Chapter 6- Effect of Sequence on Motivation in Organic Chemistry I lecture course: Chemistry Motivational Questionnaire, Fall 2011

Background of questionnaire

Chemistry Motivational Questionnaire (CMQ) was used in this study to measure students' motivation to learn chemistry. Although there are many other well researched motivational questionnaires, the CMQ was chosen because of the high reliability and validity of the questionnaire in measuring student motivation to learn chemistry. Glynn in 2007 first introduced this questionnaire to measure student motivation in different sciences which included chemistry, biology, and physics. CMQ measures student motivation which has a direct influence on their achievement, and hence it can be correlated with the grades obtained in the chemistry lecture (Glynn, et al., 2007; Glynn, Taasoobshirazi, & Brickman, 2009).

The questionnaire reports intrinsically motivated science learning (items 1, 16, 22, 27, and 30), extrinsically motivated science learning (items 3, 7, 10, 15, and 17), relevance of learning science to personal goals (items 2, 11, 19, 23, and 25), responsibility or self-determination for learning science (items 5, 8, 9, 20, and 26), confidence or self-efficacy in learning science (items 12, 21, 24, 28, and 29), and anxiety about science assessment (items 4, 6, 13, 14, and 18). Students answer 30 randomly ordered items on a 5- point Likert scale ranging from 1 (never) to 5 (always) (Glynn, et al., 2007, 2009). The maximum total score obtained in this questionnaire is 150 and minimum is 30. A score in the range of 30-59 is relatively low, 60-89 is moderate, 90-119 is high, and 120-150 is very high (Glynn, et al., 2007, 2009). The anxiety questions should be reverse scored when added to the total, such that high score means low anxiety. CMQ has high reliability in terms of internal consistency (coefficient alpha = 0.93) and has high validity in terms of positive correlations with college students' science grades, interest in science, and number of science courses taken (Glynn, et al., 2007).

Motivation is dependent on an individual's behavior and characteristics, gender, and interaction with environment like in chemistry lecture classroom or chemistry laboratory. In the social-cognitive framework, students are "viewed as self-regulating system that affects beliefs and aids in the development of motivation that enables behavior cognitively and affectively" (Glynn, et al., 2007, 2009). There are five constructs within the self-regulatory system which affects student's overall motivation to learn and they are *intrinsic and extrinsic motivation*, *goal orientation, self-efficacy, and assessment anxiety.* The *Chemistry Motivational Questionnaire* (CMQ) accounts for all the five constructs of motivation and for this study help us to determine student motivation in learning chemistry.

Validity and Reliability of questionnaire

The CMQ has a high content validity and also high reliability (internal consistency) - Cronbach coefficient alpha reliability of 0.93 (Glynn, et al., 2007, 2009). The construct validity of CMQ includes measuring the construct for this questionnaire which is measuring student motivation to learn chemistry. It also includes measuring science majors learning chemistry in a course that satisfies core-curriculum requirements and empirically it is measured by the means or averages of the items. Criterion validity of CMQ is satisfied because it is used to measure student grades in chemistry courses. It also measures student beliefs in relevance to sciences in their individual careers. From previous studies the correlation between total item score and chemistry GPA was found to be $r (140) = 0.56$, $p < 0.01$, and relevance to one's career it was $r (140) = 0.51$, $p < 0.01$, using the CMQ (Glynn, et al., 2007, 2009).

Selection of Student Groups for analysis

Student motivation could be determined by administering the CMQ to both the concurrent lab group and the no-lab group. The CMQ is a Likert scale questionnaire, and the data collected was ordinal level but was transformed into interval level for the data analysis (Glynn, et al., 2007). This questionnaire was conducted after the midterm and before the finals, and students enrolled in both the laboratory and lecture and students enrolled in just the lecture got the chance to answer the questionnaire. The questionnaire consists of 30 questions which reflect student's motivation towards learning chemistry, and it took ~ 15 to 20 minutes for the students to complete the questionnaire. The questionnaire was conducted online through Blackboard and was offered as a voluntary option for the students. Students were informed about the questionnaire through an announcement made online on Blackboard along with emails sent to the students requesting that they take the questionnaire for this study. The first questionnaire was open for the students for a two weeks period right after the midterm exam (Exam II) in October. The second questionnaire was open for two weeks before the final exam in December. After the questionnaire was conducted 140 students completed the first questionnaire and 138 students completed the second questionnaire. Different groups of students answered the questionnaire both the times.

Demographic data which included gender, ethnicity and major information, and prior academic background knowledge information which was characterized by ACT score was collected from the students during the questionnaire with their consent and maintaining the privacy act of the college. Human Subjects Committee at Lawrence (HSCL) approved collection of this data along with conducting the questionnaire to the organic chemistry I students in fall 2011. In both the first and second questionnaire some students did not provide their ACT score, and some others did not provide their major. Few others did not complete the questionnaire, and all those cases had to be removed from the final data analysis due to missing data and therefore maintain homogeneity in the data. As the questionnaire was voluntary we could not get all the students enrolled in CHEM 624 during fall 2011 to answer the questionnaire. Approximately 3 to 5 students were removed from the samples based on the criterions noted above. The remaining students were part of the sample data (N = 135) for both the first and second questionnaire conducted in the fall 2011 semester. For the first questionnaire, the concurrent lab group (students enrolled for both the laboratory and lecture) total sample size was N = 109, and the no-lab group (students enrolled for the lecture only) total sample size was N = 26. For the second questionnaire, the concurrent lab group (students enrolled for both the laboratory and lecture) total sample size was N = 110, and the no-lab group (students enrolled for the lecture only) total sample size was N = 25. All of this data was used to analyze student motivation to learn organic chemistry based on sequence of the lecture and laboratory instruction.

Overview of questionnaire responses- after Midterm and before Finals

The responses from the questionnaire were coded as “Always” being 5, “Usually” being 4, “Sometimes” being 3, “Rarely” being 2, and “Never” being 1. The questions related to *intrinsic motivation* (1, 16, 22, 27, and 30) was analyzed along with overall motivation because intrinsic motivation measures a students’ motivation to learn chemistry due to the learning experience and not due to any external or personal goals. Table 28 provides the Means and the Standard Deviations of each of the responses related to intrinsic motivation during both first and the second questionnaire.

Table 28: Mean and Standard Deviation table of Intrinsic Motivation from CMQ, fall 2011

Means and Standard Deviations of Intrinsic Motivation Questions from CMQ in fall 2011		
Questions	Mean	Standard Deviation
I enjoy learning the chemistry: Before Midterm After Finals	 3.97 3.67	 .938 1.105
The chemistry I learn is more important to me rather than the grades I receive: Before Midterm After Finals	 2.97 3.01	 .977 1.04
I find learning chemistry interesting: Before Midterm After Finals	 4.01 3.81	 .837 1.00
I like chemistry that challenges me: Before Midterm After Finals	 3.81 3.80	 .856 1.01
Understanding chemistry gives me a sense of accomplishment Before Midterm After Finals	 4.41 4.25	 .694 .808

In both the CMQs conducted after midterm and before finals, for the extrinsic motivation questions (3, 7, 10, 15, and 17) the means were approximately 4.55, for the relevance of learning science to personal goals (2, 11, 19, 23, and 25) the means were approximately 3.65, for the responsibility or self-determination for learning science (5, 8, 9, 20, and 26) the means were approximately 3.80, for the confidence or self-efficacy in learning science (12, 21, 24, 28, and 29) the means were approximately 3.60 , and for the anxiety about science assessment (4, 6, 13, 14, and 18) the means were approximately 3.40. This data indicates that overall student motivation responses were weighted towards "Sometimes", while extrinsic motivation student responses were weighted towards "Always."

The demographic data for the students responding to the questionnaire in fall 2011, for both the after midterm CMQ and before finals CMQ illustrates that the number of females were more than the males by 20% as shown in Table 34 and 35 respectively. There were 81 females and 54 males in the student population. There was little diversity among the ethnicities. For the after midterm CMQ, approximately 82% of the students applying at KU self-identified themselves as white. Other ethnicities included African-American, Hispanic, Asian, and Others (which included students from international background/non-Asians, and who identified themselves as multi-ethnicity and non-specific). Minority students included African-American and Hispanics with 4.4% and 3.7% respectively of the population as stated in Table 29. The before finals CMQ shows approximately 78% of the students as white population when applying at KU. Other ethnicities included African-American, Hispanic, Asian, and Others (which included students from international background/non-Asians, and who identified themselves as multi-ethnicity and non-specific). Minority students included African-American and Hispanics with 4.4% and 4.4% respectively of the population as stated in Table 30.

The academic majors included chemistry, biology, biochemistry, self-identified pre-med, self-identified pre-pharmacy, and engineering students, also including some health majors (others). The after midterm CMQ shows, the biology major students were 41.5% of the population. Following them were the engineering and the pre-pharmacy major students with 8.9% and 22.2% of the population respectively. The population description and percentages are included in Table 29. The before finals CMQ shows, the biology major students were 40.7% of the population. Following them were the engineering and the pre-pharmacy major students with 8.9% and 20.7% of the population respectively. The population description and percentages are included in Table 30. Most of the students enrolled for this course included students who are in their sophomore or junior year. Although, detailed information about the student's years of enrollment at KU was not collected from the university.

Table 29: Demographic Information for After Midterm CMQ, fall 2011

Demographic Information Table For After Midterm CMQ in Fall 2011			
Variables		N	Percent
Gender	Male	54	40
	Female	81	60
Ethnicity	White	111	82.2
	Hispanic	5	3.7
	African-American	6	4.4
	Asian	7	5.2
	Others	6	4.4
Major	Biochemistry	8	5.9
	Biology	56	41.5
	Chemistry	5	3.7
	Engineering	12	8.9
	Pre- Med	8	5.9
	Pre- Pharmacy	30	22.2
	Others	16	11.9

Table 30: Demographic Information for Before Finals CMQ, fall 2011

Demographic Information Table For Before Finals CMQ in Fall 2011			
Variables		N	Percent
Gender	Male	54	40
	Female	81	60
Ethnicity	White	106	78.5
	Hispanic	6	4.4
	African-American	6	4.4
	Asian	10	7.4
	Others	7	5.2
Major	Biochemistry	8	5.9
	Biology	55	40.7
	Chemistry	5	3.7
	Engineering	12	8.9
	Pre- Med	10	7.4
	Pre- Pharmacy	28	20.7
	Others	17	12.6

Figure 37 shows responses from both the genders for the intrinsic motivation questions from the CMQ (Mean of the Sum of the questions) after midterm and before finals. In both the instances the average response of the male gender was higher compared to the females suggesting higher intrinsic motivation among the males. Similarly, Figure 38 and 39 explains the difference in intrinsic motivation questions (Mean of the Sum of the questions) from after midterm and before finals CMQ based on ethnicity and academic major information. Figure 38 illustrates that the Hispanic population had the least intrinsic motivation for both the CMQs and following them were the African-Americans. Figure 39 illustrates that the Biology majors had lower intrinsic motivation compared to others for both the CMQs.

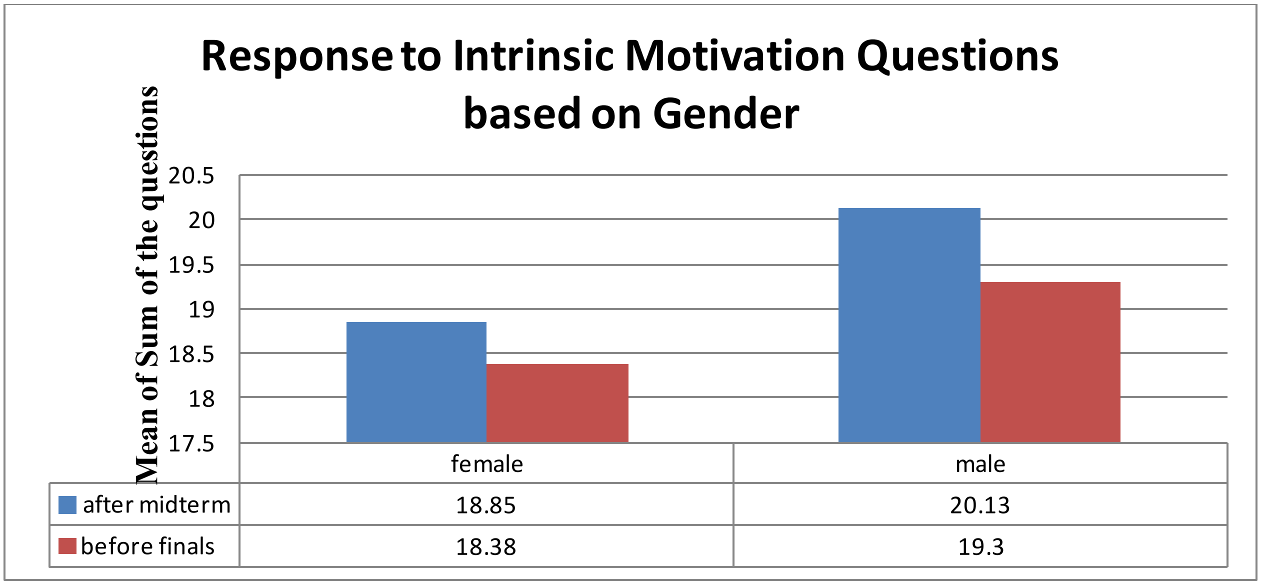


Figure 37: Response to Intrinsic Motivation questions based on Gender

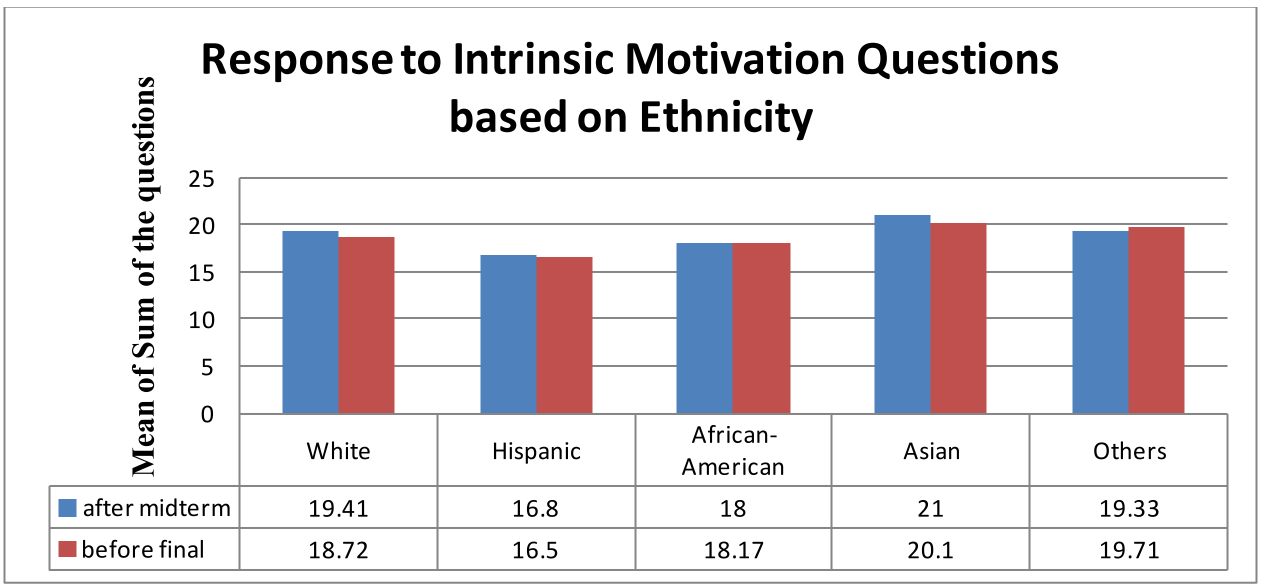


Figure 38: Response to Intrinsic Motivation questions based on Ethnicity

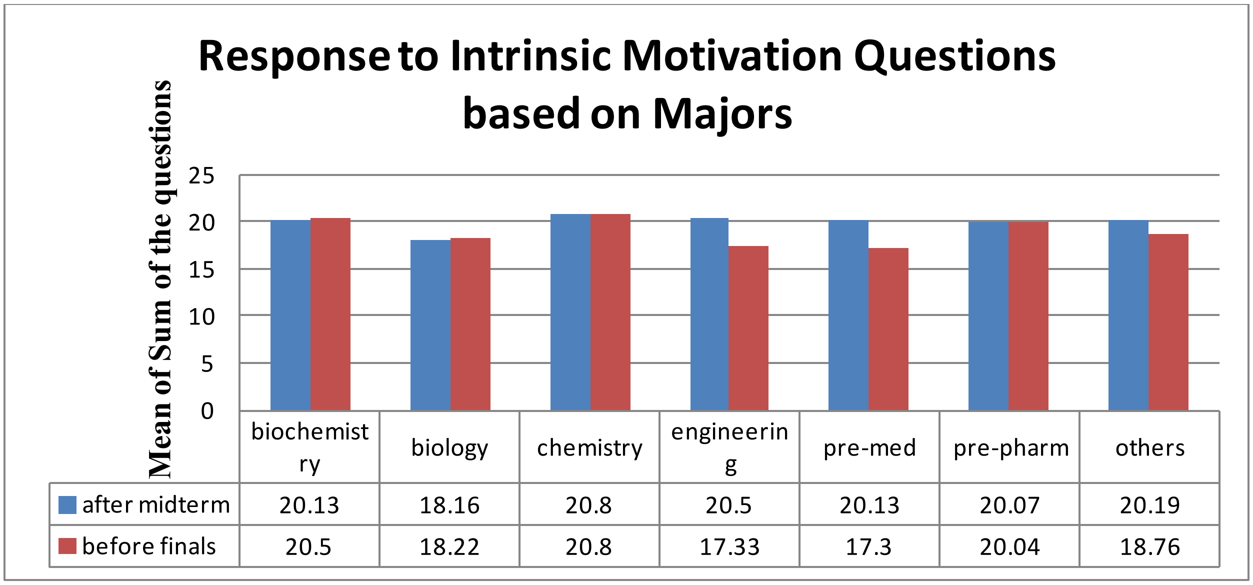


Figure 39: Response to Intrinsic Motivation questions based on student Majors

Figure 40 shows the responses for both the genders for the overall motivation questions from the CMQ (Mean of the Sum of the questions) after midterm and before final exam. In both the instances the average response of the male gender was higher compared to the females. This suggests higher overall motivation among the males. Similarly, Figure 41 and 42 illustrates the difference in overall motivation questions for the CMQ (Mean of the Sum of the questions) after midterm and before final exam based on ethnicity and major information. Figure 41 shows that the African-American population had the least overall motivation for the after midterm CMQ, and the Hispanics had the least overall motivation for the before finals CMQ. Figure 42 illustrates that the Biology majors and the Others group had lower overall motivation compared to others in the after midterm CMQ, whereas Engineering and Pre-Med majors had lower overall motivation compared to others in the before finals CMQ.

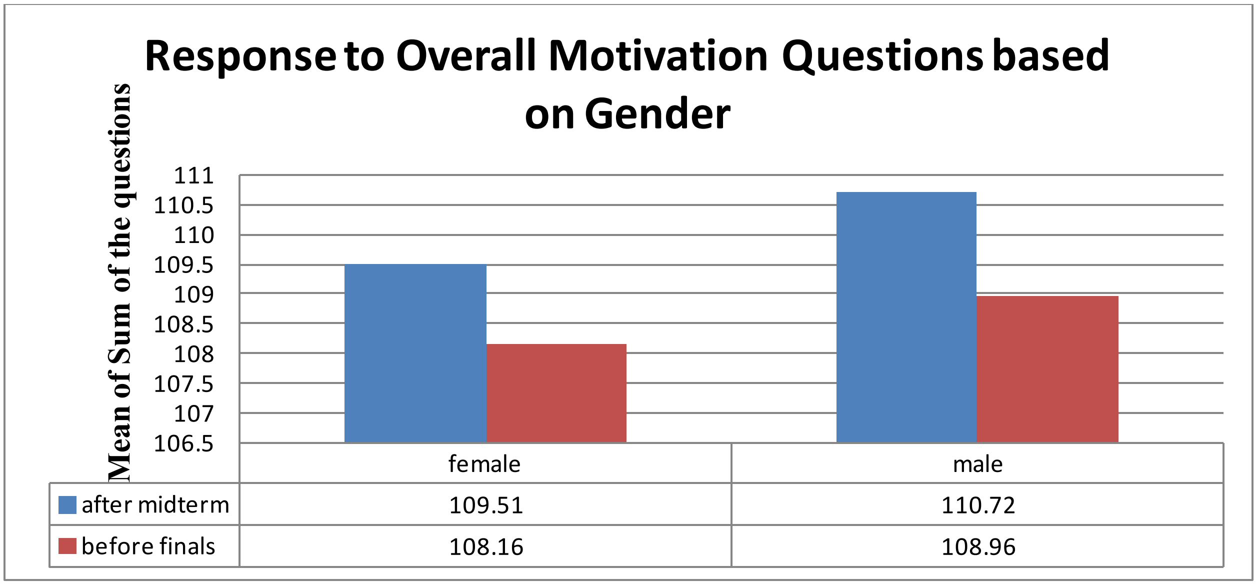


Figure 40: Response to Overall Motivation questions based on gender

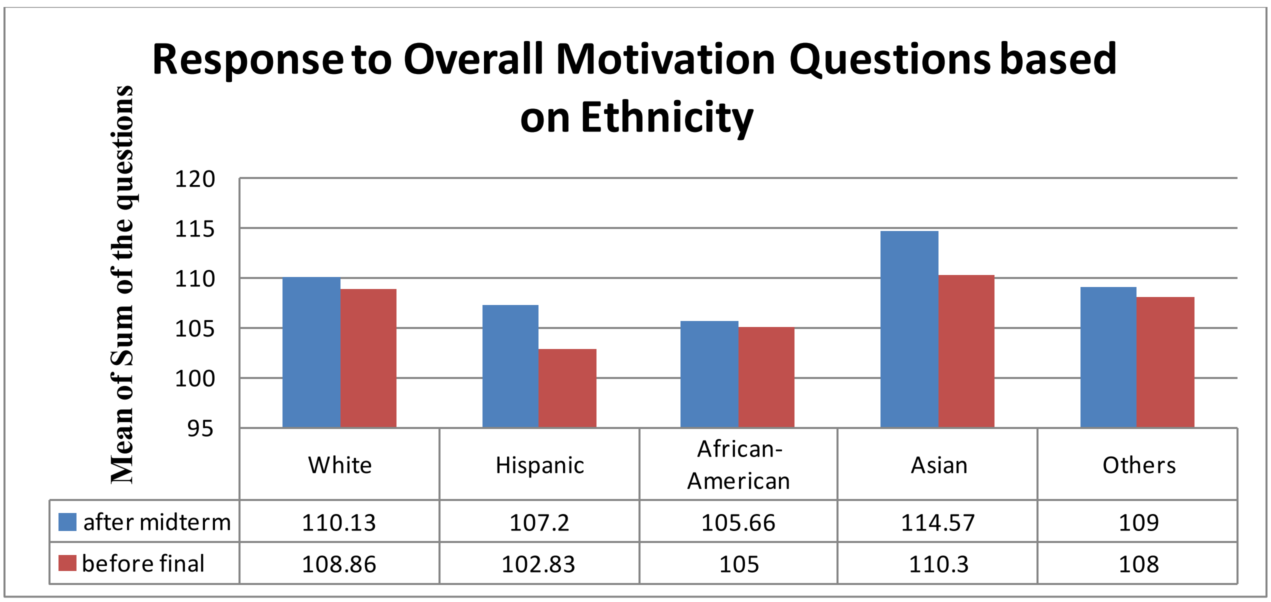


Figure 41: Response to Overall Motivation questions based on Ethnicity

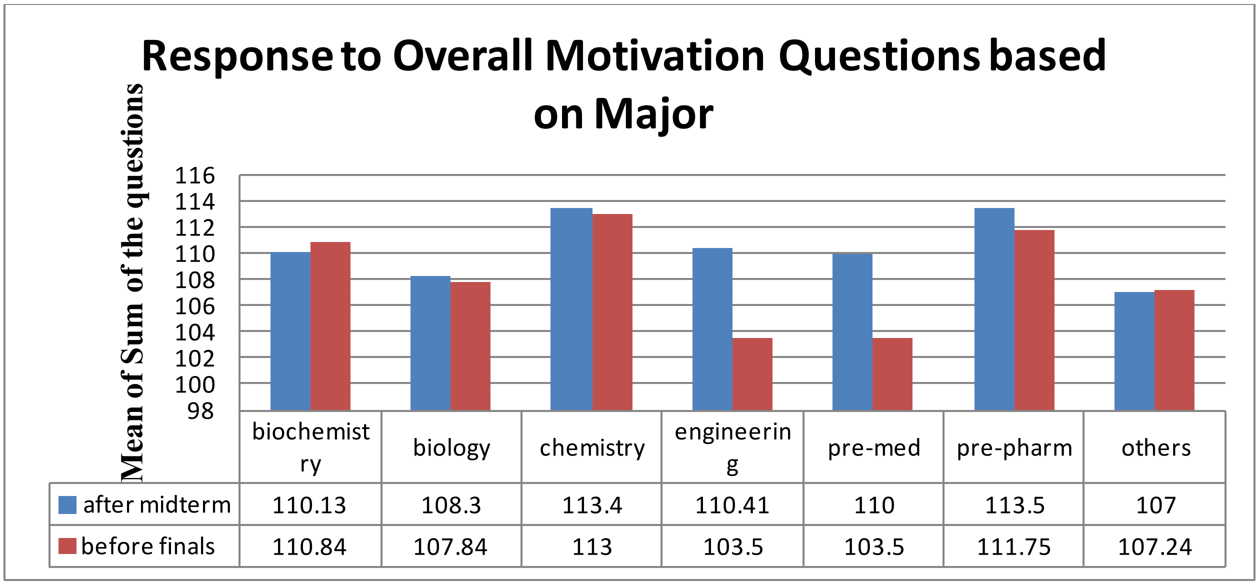


Figure 42: Response to Overall Motivation Questions based on Major information of students

The students taking the CMQs had an average ACT score of 27.19 for the after midterm CMQ with a standard deviation of 3.69. For the before finals CMQ, the average ACT score was 27.73 with a standard deviation of 3.36. ACT score was used as a measure of prior knowledge for students taking the CMQ, and was used to determine its effects on student motivation.

Methods of analysis

The analysis of student motivation in Organic Chemistry I (CHEM 624) was measured by analyzing student responses to the *Chemistry Motivational Questionnaire* (CMQ) during after midterm and before finals in fall 2011. Statistical analysis included correlations, partial correlation, one-way analysis of variance (ANOVA), T-tests, and multiple linear regressions and the methods are discussed in the previous chapter (Chapter 3).

Results of the statistical analysis for measuring student motivation, fall 2011

To analyze the effect of sequencing on student motivation *chemistry motivational questionnaire* (CMQ) was conducted on students enrolled in CHEM 624/625 (organic chemistry I) in fall 2011. A correlation analysis was performed to understand the relationship between two variables. This study was conducted to determine the relationship between the *independent variable* (concurrent lab group vs. no-lab group) and the *dependent variables* (sum of the CMQ responses after midterm and before finals for overall motivation and intrinsic motivation questions), along with the relationship between the *dependent variables* and the *covariates or antecedents* (demographic and academic information). From the correlation results the covariates that had statistically significant effect on the sum of CMQ responses given by the students were observed. In order to examine the relationship between grades and motivation, correlation studies were also performed on grades obtained in midterm (EXAM II) and finals with the sum of the CMQ scores obtained after midterm and before finals respectively for both the overall and the intrinsic motivation questions. The correlations are listed in Table 31 and Table 32 for after midterm CMQ and before final exam CMQ, respectively.

Table 31: Correlation table for After Midterm CMQ, fall 2011

Correlation Data for After Midterm CMQ						
	Concurrent lab group vs. No- lab group	Gender	Ethnicity	Major	ACT score	Grade in EXAM II
SUM-Overall	-.074	.086	.029	.147	.008	.032
SUM-Intrinsic	-.090	.240**	.025	.273**	.056	.131

** Correlation is significant at 0.01

Table 32: Correlation table for Before Finals CMQ, fall 2011

Correlation Data for Before Finals CMQ						
	Concurrent lab group vs. No- lab group	Gender	Ethnicity	Major	ACT score	Grade in Final Exam
SUM-Overall	-.192*	.047	.026	.051	.145	.019
SUM-Intrinsic	-.011	.146	.096	.113	.086	.030

* Correlation is significant at 0.05

Table 33 and 34, for after midterm CMQ (overall and intrinsic motivation) presents the percentages of students in each group along with ANOVA results obtained by comparing these groups of interest for the 4 confounding variables. The ANOVA results in Table 33 and 34 clearly identifies the variables on which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore requiring the application of a significance test based on Welch-F statistic. A non-significant difference between the two groups based on the sum of responses given by the students for overall motivation was illustrated, $F(1,133) = .72$, $p = .396 > 0.05$, hence non-significant at 0.05 level. A non-significant difference between the two groups based on the sum of responses given by the students for intrinsic motivation was illustrated, $F(1,133) = 1.08$, $p = .301 > 0.05$, hence non-significant at 0.05 level. The Levene's test of homogeneity was performed before the ANOVA and it was found to be, $p = 0.734 > 0.05$ and $p = .382 > 0.05$ respectively, indicating that the variables maintain homogeneity.

Table 33: Summary Statistics and ANOVA table for After Midterm (Overall) CMQ, fall 2011

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) for After Midterm CMQ (Overall Motivation) in Fall 2011			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 109)	No- lab group (N = 26)
Gender	Female	54.5	43.1
	Male	45.5	56.9
ANOVA	Gender*	F (1, 133) = .981, p = 0.324 > 0.05	
Ethnicity	White	76.5	23.5
	Hispanic	68.0	32.0
	African-American	71.4	28.6
	Asian	73.5	26.5
	Others	70.3	29.7
ANOVA	Ethnicity*	F (1, 133) = 1.63, p = 0.171 > 0.05	
Major	Biochemistry	61.9	38.1
	Chemistry	57.1	42.9
	Biology	73.4	26.6
	Pre-pharmacy	91.2	8.8
	Pre-Med	78.6	21.4
	Engineering	65.2	34.8
	Others	73.3	26.67
ANOVA	Major*	F (1, 133) = 1.43, p = 0.186 > 0.05	
ACT score		81.0	19.0
ANOVA	ACT score*	F (1, 133) = .715, p = .783 > 0.05	

*signifies that Levene's test of homogeneity was not significant, hence variables are homogeneous

Table 34: Summary Statistics and ANOVA table for After Midterm (Intrinsic) CMQ, fall 2011

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) for After Midterm CMQ (Intrinsic Motivation) in Fall 2011			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 109)	No- lab group (N = 26)
Gender	Female Male	54.5 45.5	43.1 56.9
ANOVA	Gender*	F (1, 133) = 1.15, p = 0.198 > 0.05	
Ethnicity	White Hispanic African-American Asian Others	76.5 68.0 71.4 73.5 70.3	23.5 32.0 28.6 26.5 29.7
ANOVA	Ethnicity*	F (1, 133) = 1.57, p = 0.185 > 0.05	
Major	Biochemistry Chemistry Biology Pre-pharmacy Pre-Med Engineering Others	61.9 57.1 73.4 91.2 78.6 65.2 73.3	38.1 42.9 26.6 8.8 21.4 34.8 26.67
ANOVA	Major*	F (1, 133) = 1.91, p = 0.23 > 0.05	
ACT score		81.0	19.0
ANOVA	ACT score*	F (1, 133) = .647, p = .848 > 0.05	

*signifies that Levene's test of homogeneity was not significant, hence variables are homogeneous

Table 35 and 36, for the before final exam administration of the CMQ (overall and intrinsic motivation) shows the percentages of students in each group along with ANOVA results obtained by comparing these groups of interest for the 4 confounding variables. The ANOVA results in Table 35 and 36 clearly identifies the variables on which the groups of interest differed significantly ($p < 0.05$) and those which did not differ significantly, as well as variables lacking homogeneity of variance and therefore requiring the application of a significance test based on Welch-F statistic. A significant difference between the two groups based on the sum of responses given by the students for overall motivation was illustrated, $F(1,133) = 5.11$, $p = .025 < 0.05$, hence significant at 0.05 level. A non-significant difference between the two groups based on the sum of responses given by the students for intrinsic motivation was illustrated, F (1,133) = .02, p = .903 > 0.05, hence non-significant at 0.05 level. The Levene's test of homogeneity was performed before the ANOVA and it was found to be, p = 0.321 > 0.05 and p = .988 > 0.05 respectively, indicating that the variables maintain homogeneity.

Table 35: Summary Statistics and ANOVA table for Before Finals (Overall) CMQ, fall 2011

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) for Before Finals CMQ (Overall Motivation) in Fall 2011			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 110)	No- lab group (N = 25)
Gender	Female Male	53.0 56.6	47.0 43.4
ANOVA	Gender*	F (1, 133) = .29, p = 0.591 > 0.05	
Ethnicity	White Hispanic African-American Asian Others	78.5 62.0 61.4 70.5 65.3	21.5 38.0 38.6 29.5 34.7
ANOVA	Ethnicity*	F (1, 133) = 1.10, p = 0.360 > 0.05	
Major	Biochemistry Chemistry Biology Pre-pharmacy Pre-Med Engineering Others	60.9 52.1 63.4 81.2 72.6 65.2 63.3	39.1 47.9 36.6 18.8 27.4 34.8 36.7
ANOVA	Major*	F (1, 133) = 2.07, p = 0.061 > 0.05	
ACT score		78.0	22.0
ANOVA	ACT score*	F (1, 133) = .547, p = .948 > 0.05	

*signifies that Levene's test of homogeneity was not significant, hence variables are homogeneous

Table 36: Summary Statistics and ANOVA table for Before Finals (Intrinsic) CMQ, fall 2011

Summary Statistics and ANOVA results of Organic Chemistry I (CHEM 624) for Before Finals CMQ (Intrinsic Motivation) in Fall 2011			
Demographic and Academic Information		**Percent of students in each group**	
Variable	Variable categories	Concurrent lab group (N = 110)	No- lab group (N = 25)
Gender	Female Male	53.0 56.6	47.0 43.4
ANOVA	Gender*	F (1, 133) = 1.88, p = 0.192 > 0.05	
Ethnicity	White Hispanic African-American Asian Others	78.5 62.0 61.4 70.5 65.3	21.5 38.0 38.6 29.5 34.7
ANOVA	Ethnicity*	F (1, 133) = 1.52, p = 0.298 > 0.05	
Major	Biochemistry Chemistry Biology Pre-pharmacy Pre-Med Engineering Others	60.9 52.1 63.4 81.2 72.6 65.2 63.3	39.1 47.9 36.6 18.8 27.4 34.8 36.7
ANOVA	Major*	F (1, 133) = 1.89, p = 0.191 > 0.05	
ACT score		78.0	22.0
ANOVA	ACT score*	F (1, 133) = .747, p = .948 > 0.05	

*signifies that Levene's test of homogeneity was not significant, hence variables are homogeneous

Discussion of statistical analysis

Prior to starting this experiment, the level of significance was decided to be 0.05 (α). In this study, to measure the difference in student motivation between the concurrent lab group and the no-lab group; various statistical analyses were run using Statistical Package for the Social Sciences (SPSS) including correlation and ANOVA. *Chemistry Motivational Questionnaire* (CMQ) was used to analyze student motivation for both the groups. Students answered to total 30 randomly ordered items on a 5- point Likert scale ranging from 1 (never) to 5 (always) (Glynn, et al., 2007, 2009). The maximum total score that can be obtained in this questionnaire is 150 and minimum is 30. A score in the range of 30-59 is relatively low, 60-89 is moderate, 90-119 is high, and 120-150 is very high (Glynn, et al., 2007, 2009). The questionnaire reports intrinsically motivated science learning, extrinsically motivated science learning, relevance of learning science to personal goals, responsibility or self-determination for learning science, confidence or self-efficacy in learning science, and anxiety about science assessment.

A correlation analysis was performed to understand the relationship between two variables. In this study, the relationship between the *independent variable* (concurrent lab group vs. no-lab group) and the *dependent variables* (sum of the CMQ responses after midterm and before finals for overall motivation and intrinsic motivation questions), along with the relationship between the *dependent variables* and the *covariates or antacedents* (demographic and academic information) was measured. From the correlation results the covariates that had statistically significant effect on the sum of the CMQ responses given by the students were observed. Correlation was also performed on grades obtained in midterm (EXAM II) and finals with the sum of the CMQ scores obtained after midterm and before finals respectively for both the overall and the intrinsic motivation questions to examine the relationship between grades and motivation.

Table 31 shows, that there was no significant correlation between sum of the overall CMQ (after midterm) and the concurrent lab group vs. the no-lab group. The correlation was negative which suggests that each person enrolled in the no-lab group has a negative correlation with the sum of the overall CMQ (after midterm), one variable increases and the other variable decreases, but the effect is not significant. There was also no significant correlation between the covariates (academic background and demographic information) and the sum of the overall CMQ (after midterm). No significant correlation was found between sum of the overall CMQ (after midterm) and the grades obtained by students in Exam II, which was the midterm exam. Table 31 shows, that there was no significant correlation between sum of the intrinsic CMQ (after midterm) and the concurrent lab group vs. no-lab group. The correlation was negative which suggests that on average each person enrolled in the no-lab group has a negative correlation with the sum of the intrinsic CMQ (after midterm), one variable increases and the other variable decreases, but the effect is not significant. There was significant correlation between the sum of intrinsic CMQ (after midterm) with the gender, $r(133) = 0.24$, $p < 0.01$, and the majors, $r(133) = 0.27$, $p < 0.01$. Both the correlations are positive and medium in strength which suggests as one variable increases the other variable also increases. The other covariates and the grades obtained by students in Exam II did not have any significant correlation with the sum of intrinsic CMQ (after midterm).

Table 32 shows, that there was a significant correlation between sum of overall CMQ (before finals) and the concurrent lab group vs. no-lab group, $r(133) = -.19$, $p < 0.05$. The correlation was weak and negative which suggests that enrollment will have negative correlation with the sum of overall CMQ (before finals) based on the coding performed on the variables. The covariates and the final exam grades did not have any significant correlation with the sum of overall CMQ (before finals). Table 32 shows, that there was no significant correlation between sum of intrinsic CMQ (before finals) and the concurrent lab group vs. no-lab group. The correlation was negative which suggested that on average each person enrolled in the no-lab group has a negative correlation with the sum of the intrinsic CMQ (before finals), one variable increases and the other variable decreases, but the effect was not significant. The covariates and the final exam grades did not have any significant correlation with the sum of intrinsic CMQ (before finals).

Separate one-way ANOVAs were performed on the sum of overall and intrinsic CMQ (after midterm and before finals) with 4 covariates (demographic information and academic background information), which included ACT score, gender, ethnicity, and major information. Levene's test was performed prior to each ANOVA on the interval level variable and the dichotomous variable to test the homogeneity of variance among the groups of interest. When Levene's Test is statistically significant, it means that the variable lacked homogeneity of variance, and the statistical significance is based on Welch-F statistic rather than traditional F-statistic. The Welch-F statistic is a robust test of equality of means that was chosen because it modified the traditional version of ANOVA that does not assume homogeneity of variance.

Table 33 illustrates, which analyzes the overall CMQ after midterm, that there was no significant difference between the two groups (concurrent lab group and the no-lab group) based on the ACT score, gender, ethnicity, and major information. Levene's test of homogeneity was performed and for each of the ANOVAs Levene's test was not statistically significant and hence the variables maintained the homogeneity of variance. There was a non-significant difference between the two groups based on the sum of responses given by the students for overall motivation, F (1,133) = .72, p = .396 > 0.05, hence non-significant at 0.05. Levene's test of homogeneity was performed before the ANOVA and it was found to be, p = 0.734 > 0.05, the variable maintains its homogeneity.

Table 34, which analyzes the intrinsic CMQ after midterm, shows that there was no significant difference between the two groups, concurrent lab group and no-lab group, based on gender, major information, ACT score and ethnicity. There was a non-significant difference between the two groups based on the sum of responses given by the students for intrinsic motivation, F (1,133) = 1.08, p = .301 > 0.05, hence non-significant at 0.05. Levene's test of homogeneity was performed before the ANOVA and it was found to be p = .382 > 0.05, the variable maintains its homogeneity.

Similarly, ANOVA Tables 35 and 36 analyze CMQ (overall and intrinsic motivation) before the final exam. Table 35, analyzes overall CMQ before finals, shows that there was no significant difference between the two groups (concurrent lab group and the no-lab group) based on the ACT score, gender, ethnicity, and major information. Levene's test of homogeneity was performed and for each of the ANOVAs Levene's test was not statistically significant and hence the variables maintained the homogeneity of variance. There was a significant difference between the two groups based on the sum of responses given by the students for overall motivation before the finals, F (1,133) = 5.11, p = .025 < 0.05, hence significant at 0.05. Table 36, analyzes intrinsic CMQ before finals, shows that there was no significant difference between the two groups based on major information, gender, ethnicity, and ACT score. Levene's test of homogeneity was performed and for each of the ANOVAs Levene's test was not statistically significant and hence the variables maintained the homogeneity of variance. There was a non-significant difference between the two groups based on the sum of responses given by the students for intrinsic motivation before finals, $F(1,133) = .02$, $p = .903 > 0.05$, hence non-significant at 0.05. Levene's test of homogeneity was performed before the ANOVA and it was found to be $p = .988 > 0.05$, the variable maintains its homogeneity.

During the semester the overall motivation increased for the concurrent lab group compared to the no-lab group and there was significant difference between the two groups at the end of the semester, but there was no change in the intrinsic motivation over the semester for both the concurrent lab group and the no-lab group. Therefore, overall it can be concluded that motivation does not seem to be a factor influencing student learning during the semester, but it is the sequence of enrollment that influences student learning.

Conclusion

The above analysis draws a conclusion that over the semester student's overall motivation towards learning organic chemistry increases, and there was a significant difference between the concurrent lab group and the no-lab group at the end of the semester which was not observed during the mid-semester. This signifies that students in both the concurrent lab group and the no-lab group had similar level of motivation during mid-semester, and hence the difference in student learning that was observed in the previous chapter (chapter 5) question 4 from exam II was not due to difference in motivation but due sequencing of the laboratory and lecture course instruction. At the end of the semester the overall motivation does increase and there was a difference between the concurrent lab group and the no-lab group which signifies that the concurrent lab group were more motivated at the end of the semester and that could have affected their learning process which can be observed from the results in chapter 5 from the four different questions asked in the finals. The intrinsic motivation does not change over the semester, and there was no significant difference between the concurrent lab group and the no-lab group based on their intrinsic motivation during the period of the whole semester. During the mid-semester CMQ, males were more intrinsically motivated compared to females, but before the finals the intrinsic motivation between both the genders were not found to be different. For both the after midterm and before final CMQ, the chemistry and biochemistry majors were more intrinsically motivated compared to the other majors. Therefore, overall it can be concluded that motivation does not seem to be a factor influencing student learning during the semester, but it is the sequence of enrollment that influences student learning.

Chapter 7- Conclusion and Future Directions

Conclusions

This research was conducted to analyze the effect of sequencing lecture and laboratory instruction on student learning and motivation towards learning chemistry. In a variety of studies over the past 20 years, researchers have tried to integrate laboratory and lecture in sciences and engineering so that they can combine practical and theoretical knowledge for better conceptual understanding (ref). Little research has been done to analyze the programs across the country where asynchronous learning is prevalent. Students at University of Kansas (KU) are not required to enroll for the laboratory and lecture course simultaneously in a semester. Students who are enrolled in both laboratory and lecture course during the same semester are introduced to chemical concepts from organic chemistry in both the laboratory and the lecture with a short time lag which leads to an asynchronous learning environment. The students enrolled for just the lecture course are introduced to chemical concepts in just the lecture, and this leads to a difference of being introduced to concepts once rather than twice for the students enrolled in just the lecture course. Therefore, it would be desirable to know how common practices in scheduling the lecture and laboratory course affects student learning and motivation which is analyzed in this research study.

Preliminary research was conducted to measure the effect of sequencing laboratory and lecture course on student performance and the hypothesis stated that there would be difference between the concurrent lab group and the no-lab group based on their lecture course performance. Different statistical analysis were run including correlations, ANOVA, and linear regressions for the students enrolled in the second semester organic chemistry (CHEM 626), and a significant difference in student performance was observed among the concurrent lab group and the no-lab group. From the linear regression analysis it was concluded that the no-lab group on average perform half a letter grade lower than the concurrent lab group, after considering the effects of confounding variables (demographic information and academic background information). For the first semester organic chemistry (CHEM 624) it was also concluded that there was a significant difference in student performance between the concurrent lab group and the no-lab group. From the linear regression analysis it was concluded that the no-lab group on average perform close to half a letter grade lower than the concurrent lab group, after considering the effects of confounding variables (demographic information and academic background information). Therefore, it is beneficial for students in terms of their performance, measured by their final grades, to enroll for the laboratory and lecture course simultaneously rather than enrolling for them separately. Also, the students enrolled in CHEM 626 (Organic chemistry II) are a subset of students from CHEM 624 (Organic chemistry I) course, and for both the courses it was observed that sequencing does affect student performance.

In fall 2011 effect of sequencing on student learning and motivation was analyzed using the data obtained from organic chemistry I lecture course at KU. Student learning was measured using the grades of conceptual multiple choice questions given in each exam during the semester. The questions tested were related to the concepts learned in both the laboratory and lecture course. Hence the students taking both the laboratory and lecture get exposed to similar concepts twice compared to students taking just the lecture who get exposed to the concept only once. Student motivation was measured by conducting a questionnaire named chemistry motivational questionnaire (CMQ) during the middle and the end of the semester. This was to measure any motivational change over the course of the semester. Two research hypotheses were formed, there would be significant difference between the concurrent lab group and the no-lab group in the student learning of the lecture material, and there would be significant difference between the concurrent lab group and no-lab group in student motivation to learn chemistry.

Different statistical analysis were run including correlations, partial correlations, ANOVA, and linear regressions, and it was concluded that there was a significant difference in student learning organic chemistry concepts between the concurrent lab group and the no-lab group in organic chemistry I (CHEM 624). Concepts that were introduced in both the laboratory and the lecture were analyzed and students enrolled in the concurrent lab group seemed to have benefited from the fact that they observe similar concepts twice (practical in laboratory and theoretical in lecture) rather than just once as for the no-lab group. The linear regression analysis illustrates that the no-lab group on average answers the concept questions incorrectly compared to the concurrent lab group. From all the linear regression equations it was also concluded that the confounding variables or covariates (demographic and academic information) does not affect the scores of the concept questions. The concepts that students enrolled in the concurrent lab group on average answer correctly than the no-lab group was acid-base concepts, and H-elimination and addition concepts. Students get exposed to acid-base concepts in general chemistry courses before enrolling for organic chemistry I course, hence prior knowledge from a previous course can influence student learning, but was beyond our scope of analysis as that data could not be collected from the university. Concepts that the concurrent lab group on average answer correctly over the semester than the no-lab group was the boiling point/melting point concept, because there was no significant difference between the groups when question 9 from exam I was analyzed but there was a difference between the groups when question 9 from the finals was analyzed. There was no significant difference between the two groups when answering the concept question on hydroboration, and a possible reason could be that students do not understand the higher mechanist rules involved in the hydroboration process. Therefore, overall it is beneficial for students to enroll for laboratory and lecture course simultaneously rather than separately when learning chemical concepts. A possible reason for the concurrent lab group to learn concepts better than the no-lab group could be that students enrolled in lecture and laboratory simultaneously can actively discuss concepts with other peers while performing peer-led experiments in the laboratory. Also, learning samples on exam performance has been observed to be consistently being picked up by students enrolled in laboratory and lecture simultaneously than students enrolled separately. These added factors could possibly influence better student learning for those enrolled in the lecture and laboratory simultaneously compared to the students enrolled separately.

From the different statistical analysis which included correlations and ANOVA it was concluded that over the semester student's overall motivation towards learning organic chemistry increases, and there was significant difference between the concurrent lab group and the no-lab group at the end of the semester which was not observed during the mid-semester. This signifies that students in both the concurrent lab group and the no-lab group had similar level of motivation during mid-semester, and hence the difference in student learning that is observed in the previous chapter (chapter 5) question 4 from exam II was not due to difference in motivation but due to sequencing of the laboratory and lecture course instruction. At the end of the semester the overall motivation does increase and there was difference between the concurrent lab group and the no-lab group which signified that the concurrent lab group were more motivated at the end of the semester and that might have affected their learning process which was observed from the results in chapter 5 from the four different questions asked in the finals. The intrinsic motivation does not change over the semester, and there was no significant difference between the concurrent lab group and the no-lab group based on their intrinsic motivation during the period of the whole semester. During the mid-semester CMQ, males were more intrinsically motivated compared to females, but before the finals the intrinsic motivation between both the genders was not found to be statistically different. For both the after midterm and before final CMQ, the chemistry and biochemistry majors were more intrinsically motivated compared to the other majors. Therefore, overall it can be concluded that motivation does not seem to be a factor influencing student learning during the semester, but it is the sequence of enrollment that influences student learning.

Future Directions

In this research study, the effect of sequencing lecture and laboratory course on student learning and motivation to learn chemistry in lecture course was analyzed. For future study, it can be desirable to study the effect of sequencing lecture and laboratory course on student learning and motivation to learn in a laboratory course. Laboratory and lecture course have separate grades, hence the future analysis can be done by using grades from the laboratory. This will give us perspective towards learning and motivation from both the lecture and laboratory course, and also help compare the two mediums of education (theoretical learning and practical learning). Also, this study was performed on students from organic chemistry I course (CHEM 624) at KU, but this study can be extended to different courses especially to higher-level chemistry courses and also to different universities around the globe. That will help further generalize the study for different courses and also for different universities.

The Chemistry Motivational Questionnaire (CMQ) was voluntary, and hence it wasn't possible to get responses on the questionnaire from all the students enrolled in the course, but making the questionnaire compulsory would help get more responses to the questionnaire. The data obtained from this research study (N = 135, for both questionnaires) gave a power of 0.80 and effect size of 0.35 which means the data well represents the entire population, therefore the conclusions drawn were reasonable, but more data can be beneficial for future study. Also, controlling student behavior while they are taking the survey can prove beneficial for the future. Student behavior outside classroom cannot be controlled which sometimes leads to not so meaningful responses to the questionnaire from the students which have to be removed from the analysis, hence controlling student behavior can provide more meaningful data. Also, performing in-depth qualitative analysis by conducting interviews added to the CMQs with students from both the concurrent lab group and the no-lab group can be beneficial in determining student motivation towards learning chemistry. Building a new motivation questionnaire to analyze student motivation could be a possible change in this study. In this study, students can self-select into the concurrent lab group and no-lab group which if restricted for future study can provide a better experimental group and comparison group based on demographics. These are the suggested modifications that can be done to this study for the future work.

Appendix I

Chemistry Motivation Questionnaire (CMQ)

In order to better understand what you think and feel about your college chemistry courses, please respond to each of the following statements from the perspective of: "When I am in a college chemistry course…"

01. I enjoy learning the chemistry.
O Never O Rarely O Sometimes O Usually O Always
02. The chemistry I learn relates to my personal goals.
O Never O Rarely O Sometimes O Usually O Always
03. I like to do better than the other students on the chemistry tests.
O Never O Rarely O Sometimes O Usually O Always
04. I am nervous about how I will do on the chemistry tests.
O Never O Rarely O Sometimes O Usually O Always
05. If I am having trouble learning the chemistry, I try to figure out why.
O Never O Rarely O Sometimes O Usually O Always
06. I become anxious when it is time to take a chemistry test.
O Never O Rarely O Sometimes O Usually O Always
07. Earning a good chemistry grade is important to me.
O Never O Rarely O Sometimes O Usually O Always
08. I put enough effort into learning the chemistry.
O Never O Rarely O Sometimes O Usually O Always
09. I use strategies that ensure I learn the chemistry well.
O Never O Rarely O Sometimes O Usually O Always
10. I think about how learning the chemistry can help me get a good job.
O Never O Rarely O Sometimes O Usually O Always
11. I think about how the chemistry I learn will be helpful to me.
O Never O Rarely O Sometimes O Usually O Always
12. I expect to do as well as or better than other students in the chemistry course.
O Never O Rarely O Sometimes O Usually O Always
13. I worry about failing the chemistry tests.
O Never O Rarely O Sometimes O Usually O Always
14. I am concerned that the other students are better in chemistry.
O Never O Rarely O Sometimes O Usually O Always
15. I think about how my chemistry grade will affect my overall grade point average.
O Never O Rarely O Sometimes O Usually O Always
16. The chemistry I learn is more important to me than the grade I receive.
O Never O Rarely O Sometimes O Usually O Always
17. I think about how learning the chemistry can help my career.
O Never O Rarely O Sometimes O Usually O Always
18. I hate taking the chemistry tests.
O Never O Rarely O Sometimes O Usually O Always
19. I think about how I will use the chemistry I learn.
O Never O Rarely O Sometimes O Usually O Always

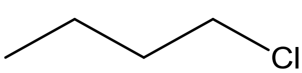
20. It is my fault, if I do not understand the chemistry.
O Never O Rarely O Sometimes O Usually O Always
21. I am confident I will do well on the chemistry labs and projects.
O Never O Rarely O Sometimes O Usually O Always
22. I find learning the chemistry interesting.
O Never O Rarely O Sometimes O Usually O Always
23. The chemistry I learn is relevant to my life.
O Never O Rarely O Sometimes O Usually O Always
24. I believe I can master the knowledge and skills in the chemistry course.
O Never O Rarely O Sometimes O Usually O Always
25. The chemistry I learn has practical value for me.
O Never O Rarely O Sometimes O Usually O Always
26. I prepare well for the chemistry tests and labs.
O Never O Rarely O Sometimes O Usually O Always
27. I like chemistry that challenges me.
O Never O Rarely O Sometimes O Usually O Always
28. I am confident I will do well on the chemistry tests.
O Never O Rarely O Sometimes O Usually O Always
29. I believe I can earn a grade of "A" in the chemistry course.
O Never O Rarely O Sometimes O Usually O Always
30. Understanding the chemistry gives me a sense of accomplishment.
O Never O Rarely O Sometimes O Usually O Always

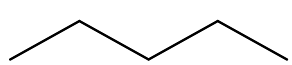
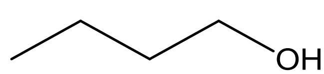
Appendix II

Example Question from Lecture exam (CHEM 624) in fall 2011

Directions: Answer the following questions. 3 points for correct answer and 0 points for incorrect answer.

1. **Question 1:** Arrange the following compounds in order of **increasing boiling point** (lowest to highest)

(I) 

(II) 
(III) 

A. II < III < I **B.** I < II < III **C.** III < I < II **D.** II < I < III

Appendix III

KU RESEARCH & GRADUATE STUDIES
The University of Kansas

7/13/2010
HSCL #18834

Deblina Pakhira
CHEM
2010 Malott Hall

The Human Subjects Committee Lawrence Campus (HSCL) has reviewed your research project application

18834 Pakhira/Heppert (CHEM) Affect of the Sequence of Laboratory and Lecture Instruction on Student Performance in Chemistry

and approved this project under the expedited procedure provided in 45 CFR 46.110 (f) (5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for non-research purposes. As described, the project complies with all the requirements and policies established by the University for protection of human subjects in research. Unless renewed, approval lapses one year after approval date.

Since your research presents no risk to participants and involves no procedures for which written consent is normally required outside of the research context HSCL has waived the requirement for a signed consent form (45 CFR 46.117 (c) (2). HSCL notes the study data set is de-identified.

1. At designated intervals until the project is completed, a Project Status Report must be returned to the HSCL office.
2. Any significant change in the experimental procedure as described should be reviewed by this Committee prior to altering the project.
3. Notify HSCL about any new investigators not named in original application. Note that new investigators must take the online tutorial at http://www.rcr.ku.edu/hscl/hsp_tutorial/000.shtml.
4. Any injury to a subject because of the research procedure must be reported to the Committee immediately.
5. When signed consent documents are required, the primary investigator must retain the signed consent documents for at least three years past completion of the research activity. If you use a signed consent form, provide a copy of the consent form to subjects at the time of consent.
6. If this is a funded project, keep a copy of this approval letter with your proposal/grant file.

Please inform HSCL when this project is terminated. You must also provide HSCL with an annual status report to maintain HSCL approval. Unless renewed, approval lapses one year after approval date. If your project receives funding which requests an annual update approval, you must request this from HSCL one month prior to the annual update. Thanks for your cooperation. If you have any questions, please contact me.

Sincerely,
Mary Denning
Mary Denning
Coordinator
Human Subjects Committee Lawrence

cc: Joseph Heppert

Human Subjects Committee Lawrence
Youngberg Hall | 2385 Irving Hill Road | Lawrence, KS 66045 | (785) 864-7429 | Fax (785) 864-5049 | www.rcr.ku.edu/hscl

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