Analysis of Student Performance in Peer Led Undergraduate Supplements

By

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Abstract

Foundations of Chemistry courses at the University of Kansas have traditionally accommodated nearly 1,000 individual students every year with a single course in a large lecture hall. To develop a more student-centered learning atmosphere, Peer Led Undergraduate Supplements (PLUS) were introduced to assist students, starting in the spring of 2010. PLUS was derived from the more well-known Peer-Led Team Learning with modifications to meet the specific needs of the university and the students.

The yearlong investigation of PLUS Chemistry began in the fall of 2012 to allow for adequate development of materials and training of peer leaders. We examined the impact of academic achievement for students who attended PLUS sessions while controlling for high school GPA, math ACT scores, credit hours earned in high school, completion of calculus, gender, and those aspiring to be pharmacists (i.e., pre-pharmacy students). In a least linear squares multiple regression, PLUS participants performed on average one percent higher on exam scores for Chemistry 184 and four tenths of a percent on Chemistry 188 for each PLUS session attended. Pre-pharmacy students moderated the effect of PLUS attendance on chemistry achievement, ultimately negating any relative gain associated by attending PLUS sessions. Evidence of gender difference was demonstrated in the Chemistry 188 model, indicating females experience a greater benefit from PLUS sessions.

Additionally, an item analysis studied the relationship between PLUS material to individual items on exams. The research discovered that students who attended PLUS session, answered the items correctly 10 to 20 percent more than their comparison group for PLUS interrelated items and no difference to 10 percent for non-PLUS related items. In summary, PLUS

has a positive effect on exam performance in introductory chemistry courses at the University of Kansas.

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Chapter 1 : Introduction to Study and Literature Review

Introduction

Cooperative learning has gained recognition within the last twenty years as introductory chemistry courses have been reformed from the traditional lectures into more active learning environments at colleges and universities across America (D. Gosser et al., 2001; Spencer, 1999). Scholars have developed various models of cooperative learning by integrating a social-constructivist platform to increase student engagement in order to meet the needs of students or course objectives at the approval of the instructor (Eberlein et al., 2008; Nurrenbern, 2001; Robinson & Samarapungavan, 2001; Donald R. Woods, 2014). Piaget's theory emphasized the fact that students create their own cognitive growth through individual experiences (Piaget, 1964). Such growth has been accomplished most effectively in classrooms when intertwined with existing problem-based learning, which prompts students with objectives through complex application and self-directed learning (Bodner, 1986). The combination of these methods has developed into a unique pedagogy that aims for an active learning process, greater conceptual understanding, an increase of critical thinking skills, and heightened interest in chemistry (D. K. Gosser & Roth, 1998; Varma-Nelson & Coppola, 2005).

Success in general chemistry is vital for any student seeking a degree in a natural science. Underperformance or failing the course could deter students from enrolling in the subsequent sciences courses, lower self-efficacy, and cause students to change their degree or career plans.

Based on previous research, numerous models show promising results for higher student achievement and higher passing rates in general chemistry courses.

Peer Led Undergraduate Supplements (PLUS) is a cooperative learning program where students voluntarily attend peer-led sessions. Students are not required to enroll in a separate course nor are they penalized for not participating. No assignments, homework, quizzes, or laboratory experiments were conducted during PLUS sessions. Rather, PLUS sessions used developed material to assist students in understanding the conceptual and analytical objectives presented in the lecture. This research project investigated if students who take advantage of PLUS chemistry performed significantly different than students who did not while controlling for background variables.

Literature Review

Lecture style learning has been at the heart of the American collegiate educational framework since the beginning of the country's existence (Lucas, 2006). In this type of framework, students' level of engagement depends upon the size of the lecture halls, type of course, and the method of delivery (Miller, McNear, & Metz, 2013). Within the last few decades, academic leaders have transitioned away from faculty-centered lecture settings in order to focus on smaller, more intimate learning environments (Spencer, 1999). In the early 1990s, the National Science Foundation (NSF) granted Systemic Changes in Undergraduate Curriculum awards to universities in order to develop and analyze new pedagogies in chemistry (Barrow, 1999; D. Gosser et al., 2001). Universities and colleges have attempted to adopt more student-centered and interactive courses through seminars (Jaarsma, de Grave, Muijtjens, Scherpbier, & Van Beukelen, 2008), online forums (Paré & Joordens, 2008), problem-based learning curricula (Ruiz-Gallardo, Castaño, Gómez-Alday, & Valdés, 2011), and peer-led learning workshops (Báez-Galib, Colón-Cruz, Wilfredo, & Rubin, 2005; Hockings, DeAnglis, & Frey, 2008; Woodward, Weiner, & Gosser, 1993). The objective of each was to move away from teaching methods that were less effective for students such as passive lecturing, instructor's use of algorithms, students solving problems at the board, and repetitious homework problems (Freeman et al., 2013; D.R. Woods, 1987, pp. 55 – 69).

Reform efforts in the early 1990s led to the implementation of these active learning core objectives in Workshop Chemistry, which soon developed into a more structured platform known as Peer-Led Team Learning (PLTL) (Woodward et al., 1993). Other forms of cooperative learning such as Process-Oriented Guided Inquiry Learning (POGIL) also emerged (Farrell, Moog, & Spencer, 1999). Several years later, a hybrid model known as Peer-Led Guided Inquiry (PLGI) came into existence (Lewis & Lewis, 2005). Each model was built on a social constructive framework with an emphasis on problem-solving (Eberlein et al., 2008; Farrell et al., 1999). Key differences in the models are outlined in Table 1 and further descriptions are provided below.

Peer-Led Team Learning

David Gosser developed the Workshop Chemistry program at City College of New York as a cooperative learning exercise that engaged students through peer mentors; this progressed into Peer-Led Team Learning (Woodward et al., 1993). Professors provided supplemental aid through these workshops for the large lecture courses and consequently replaced the recitation sections for introductory chemistry courses (D. K. Gosser & Roth, 1998). The sessions were comprised of six to eight undergraduate students that met weekly with a peer leader, who had already successfully completed the course. Students in the course generally enrolled into a no credit class for PLTL at the beginning of the semester. Attendance at PLTL sessions was vital to the success of the model (Lyle & Robinson, 2003; Wamser, 2006). As a result, students are often penalized for missing workshops. For example, in the PLTL program at Washington University in Saint Louis, students who miss two of the thirteen workshops are permanently removed from the program (Hockings et al., 2008).

Gosser documented the six critical components that must be executed for successful PLTL, which include:

(1) workshops are closely integrated with the course

(2) peer leaders are trained in leadership skills

(3) faculty are involved but not present at workshops

(4) materials are challenging to promote collaboration among students

(5) environments must be conducive to group learning (noise level, appropriate rooms)

(6) support by the department and the institution (D. Gosser et al., 2001).

There are numerous studies showing significant improvement in student academic performance and course retention in chemistry, as well as other science, technology, engineering, and mathematic courses (Liou-mark, Dreyfuss, & Younge, 2010; Lyle & Robinson, 2003; Utschig & Sweat, 2008).

Three studies specifically investigated potential gender differences within PLTL. No differences were noted for academic achievement gain between males and females (Hockings et al., 2008; Lyle & Robinson, 2003; Wamser, 2006).

Chan and Bauer conducted a randomized study after students opted-in to participate in the University of New Hampshire's PLTL program. Students were randomly assigned the PLTL treatment group or the active study control group while the students who did not opt-in were removed from the study. No documented differences were noted in achievement, attitude, or self-concept between the groups. These surprising results emphasized the lack of control in quasi-experimental designs with the potential for co-founding factors. The authors suggest current research of success of supplemental instruction may be inflated since individuals who are involved in these programs are more highly motivated (Chan & Bauer, 2015).

Process-Oriented Guided Inquiry Learning

POGIL incorporates the same objectives, but with a very different approach. Unlike PLTL, this model is constructed to replace lectures with students learning in self-assembled groups on carefully crafted problems designed by the professor (Moog et al., 2011). Each group has four to five students with defined roles that progress through a problem set intended to take the participants through the three phase learning cycle of exploration, concept invention, and application (Farrell et al., 1999). Smith shows the learning cycle reconstructs the scientific method so students are actively engaged in research-based learning (Smith, 2010). The instructor facilitates these sessions; however, he or she does not directly answer questions but rather guides the students to known conclusions. Groups share their new knowledge with the class and report any struggles that arise (Eberlein et al., 2008). In Professor Wood's book entitled, *Lecture-fee Teaching: A Learning Partnership between Science Educators and Their Students*, provides a detailed approach on developing the transition from traditional lecture to daily engagement with students (2009).

It is common, but not a requirement in POGIL environments, to incorporate laboratory experiments into the lecture settings. Research shows these results positively influence conceptual understanding and academic achievement (Burrowes & Nazario, 2008; Gonzalez, 2014).

Peer-Led Guided Inquiry

The youngest model, Peer-Led Guided Inquiry, amalgamates PLTL and POGIL for alternative approaches on collaborative learning. This pedagogy transformed POGIL by adding a peer leader to help facilitate the small group interactions during class. In addition, only one of the weekly lectures is replaced with a peer-guided session. Groups of five to eight students are formed at the beginning of the semester and remain intact to optimize interactions and trust among the peers. Lewis has shown student's performance in courses correlated with SAT scores (Lewis & Lewis, 2005). Only quantitative SAT scores were consistently significant predictors in all regression models with β's ranged from 0.253 to 0.460, while verbal SAT scores were fluctuated in significance. For every PLGI session attended, students increased their final exam scores by 1.8% ($\beta = 0.493$, $p = 0.006$) with a 44.5% of the model's variance explained by verbal and quantitative SAT scores, and session attendance.

Several years later, Lewis published another study which found a 15% increase in the pass rate in general chemistry, while maintaining similar scores on the comprehensive American Chemical Society final exam in General Chemistry. Largest pass rate improvements were demonstrated in the underrepresented minority groups (Lewis, 2011).

Table 1
Comparison of Current Cooperative Learning Models (Eberlein et al., 2008).

Program	Replace Lecture	Group Size	Facilitator	Participation	Consistent Group
Peer-Led Team Learning (PLTL)	No	6 – 8	1 PL	Voluntary*	Yes
Process-Oriented Guided Inquiry Learning (POGIL)	Yes	4 – 5	1 I	Required	No
Peer-Led Guided Inquiry (PLGI)	Partial	5 – 8	1 I , 1 PL	Required	Yes
Peer Led Undergraduate Supplements (PLUS)	No	8 - 20	2 PL	Voluntary	No

Note. PL = Peer Leader. I = Instructor. *PLTL initially is a voluntary but then required.

Additional Research

Scholars conducted ample research on these varying models showing their effectiveness in improving student academic performance (Hockings et al., 2008; Lewis & Lewis, 2005; Lyle & Robinson, 2003; Lyon & Lagowski, 2008) and increasing retention rates in introductory chemistry courses (Becvar, Dreyfuss, Flores, & Dickson, 2008; Hensen & Shelley II, 2003; Lewis, 2011). Most current models were integrated into the course framework by replacing lecture or by an opt-in program and then mandatory participation (Eberlein et al., 2008; Woods, 2014). These models have shown significant success; however, they may lack flexibility in maximizing success for all students.

Research conducted at San Francisco State University "found that [supplemental instruction] appears to be most effective in courses at the beginning of the chemistry sequence and least effective in those which students have already had to demonstrate effectiveness with material in order to succeed..." (Rath, Peterfreund, Bayliss, Runquist, & Simonis, 2012). Students involved in the treatment group improved course grades by six percent in General Chemistry I, while no increase was associated with General Chemistry II.

Purpose of the Study

Peer Led Undergraduate Supplements

Many institutions may still hesitate to implement these programs based on the additional resources required, or because faculty do not wish to reconstruct their classes in order to meet the requirements for PLTL, POGIL, or PLGI (Cooper, 1995; Prichard & Sawyer, 1994). The PLUS program incorporated principles from these models to create a new pedagogy. PLUS was most closely related to PLTL in that the lectures remain completely intact and the peer-led sessions are supplemental but not remedial. However, there were several key differences. Unlike PLTL, PLUS did not have mandatory attendance, therefore, would not have consistent student groups throughout the semester much like POGIL. Students were allowed to attend any number of sessions during the semester without being penalized or required to enroll in a separate course. Students were made aware of the week's PLUS topics during Monday's lecture; however, students were not required to prepare specific material for PLUS sessions.

This model could be optimized to meet the needs of a range of student abilities. Higher performing students who need help with a few specific concepts would be able to attend several sessions throughout the semester, while underperforming students could utilize most or all sessions for the semester. Students are reminded weekly of PLUS sessions and encouraged by the professor to attend. This program directly addressed the concern laid out by Chan and Bauer, since students were allowed to begin participating at any time throughout the semester. Participations was not limited to students who had the forethought to sign-up within the first week of classes.

Two specific hypotheses were developed to determine to what extent differences were observed: (1) in a multiple regression analysis that the number of PLUS sessions attended predicted exam achievement in Chemistry while controlling for academic and background variables; and (2) in an item analysis for comparison of both PLUS and non-PLUS related material.

Chapter 2 : Structure and Design

Introduction

Foundations of Chemistry I and II (Chemistry 184 and 188) are sequential introductory courses at the University of Kansas. The focus of these courses was to provide students with a working knowledge of core conceptual fundamentals in addition to quantitative chemical relationships that develop the building blocks for subsequent physical sciences classes. By the end of the year, students were exposed to a large array of topics including atomic theory and structure, chemical bonding and reactions, stoichiometric conversions, properties and behaviors of solids, liquids and gasses, chemical equilibria including acid-base chemistry, and nuclear chemistry. Students must have satisfactorily completed a pre-calculus or similar course approved by the chemistry department prior to the start of the semester to qualifying for enrollment in Chemistry 184. No other prerequisites, including high school chemistry, were required for course enrollment. In fall of 2013, the Foundations of Chemistry course numbers changed to CHEM 130 and CHEM 135.

Undergraduates have several options for an introductory chemistry course at the University of Kansas. The Foundations of Chemistry sequence was just one of these options. Others are offered to tailor the material to the needs of the students. A one semester College of Chemistry (CHEM 124/125) offers basic concepts of general chemistry and very brief introduction to organic chemistry. This course was designed for non-science majors and allied health students. No prerequisites are required for this course and it may be taken with (CHEM 125) or without the corresponding two-hour laboratory (CHEM 124).

Chemistry for Engineers (CHEM 150) was a one-semester course designed and required for students in the School of Engineering. The material emphasized the relation of chemistry concepts to the physical world. Prior to enrollment, students must have completed high school chemistry and be eligible for entrance to Calculus I.

Chemistry for the Chemical Sciences (CHEM 170 and 175) is a two-semester course for individuals interested in majoring in the chemical sciences such as chemistry, biochemistry, and chemical engineering. The course covers topics and concepts similar to Foundations of Chemistry with added emphasis on modern applications and an intergraded lecture and laboratory. The prerequisites are equivalent to those required for enrollment in CHEM 184.

The final introductory course was Foundation of Chemistry Honors (CHEM 185 and 189). The course parallels its non-honors counterpart course; but was more rigorous and thus has more demanding requirements. Students must have completed a calculus course and high school chemistry as well be part of the KU Honors program, receive at least a three on the AP Chemistry exam, or have a mathematics ACT score of 28 or higher.

At the time of data collection, Foundations of Chemistry courses were the largest introductory chemistry class offered at the university. The student population of this course may potentially not be comparable to those in a similar courses at outside universities due to the large number of student enrolled in the general chemistry courses geared towards more targeted populations (CHEM 150, 170/175, and 185/189). A population analysis should be conducted between courses to determine if generalization can be made.

Course Structure

Meetings

The Foundations of Chemistry courses (CHEM 184 and 188) meet for three one-hour lectures and one three-hour laboratory weekly for the duration of the semester. Course lectures were held in the largest lecture hall at KU with a student capacity for nearly 1,000 students. The labs consisted of only 20 students led by a graduate or undergraduate teaching assistant. Optional discussions sections are led twice a week by the lecture graduate teaching assistant.

Grades

Students were evaluated on weekly online homework worth twenty percent of the total grade, thirty percent from laboratory performance including lab reports and group exercises, and the remaining fifty percent on written examinations.

Four semester exams were given at approximately one-month intervals throughout the semester. Each exam was a twenty-five item multiple-choice format test worth 100 points. The lowest of the four semester exams was dropped from the final grade. If a student missed an exam due to an unexcused absence or illness, the student was allowed to drop this exam. The final exam was administered on the last class meeting, was cumulative in nature with fifty multiple choice items, and was worth 200 points or twenty percent of the total grade.

Testing Conditions

All exams for Chemistry 184 and 188 were very comparable though some minor changes were made for the final. The exams were administered by the professor with help by the course teaching assistants. Students were assigned a seating section by their laboratory instructor in one of three lecture halls. This allowed an empty seat between each student in an attempt to minimize possible cheating. Each teaching assistant proctored the exam for no more than 40 examinees. All desks have identical dimensions; however, the number of desks did vary per room due to the capacity of the lecture hall. At the beginning of the exam, teaching assistants distribute presorted exams with corresponding scantron answer sheet (i.e., machine-graded bubble sheet) that alternated between the two forms (*Green* and *Red*). The last page of the exam was intentionally left blank for the purpose of scratch paper. Students had exactly two hours to take a twenty-five item multiple-choice exam. Each student was allowed his or her own personal calculator without any restrictions on brand or model. Undergraduates with documented illness or learning disabilities took the exam in a smaller, separate room and accommodations were made to best support his or her needs. Students who had a conflict in scheduling may have opted to take the early exam arranged the night before the normal exam with permission from the instructor or lecture teaching assistant.

The final exam was given during regular school hours at a time determine by the administration, thus only the main lecture hall was available for use. As a result, the examinees sat directly next to their peers with few empty seats in the auditorium. A small room was still offered to students will special needs. Individuals were granted one “cheat sheet” with the dimensions of 8.5” x 11” on the final. Both sides on the paper maybe used to write notes, equations, or diagrams; however, students were not permitted to write previous exam questions verbatim. The allotted time for this exam was two and a half hours for 50 multiple-choice items.

Additional Recourses

Those courses offered a multitude of avenues for student assistance. The professor had office hours directly after each lecture for an hour. Students could meet directly with the professor for clarification of concepts, concerns about grades, or help with homework. The graduation lecture teaching assistant (GTA) offers two discussion sections throughout the week for students in a question-answer format. PLUS sessions were held five to eight times a week for structured facilitation among students. A help room was staffed over forty hours a week with graduate and undergraduate teaching assistances. Additional help could be requested by a student on an individual basis through appointments. These resources were available free of charge to all students enrolled in the course. Some students did seek help through group or private tutoring for an additional fee.

PLUS Structure

PLUS Sessions

The Peer Led Undergraduate Supplements (PLUS) program incorporates theories from a social constructivism platform to create a new pedagogy with peer guided learning. These supplemental sessions allow for students to discuss course material with classmates in a guided, non-threatening environment. PLUS was uniquely set apart from other programs--Peer Led Team Learning, Process-Oriented Guided Inquiry Learning (POGIL), and Peer-Led Guided Inquiry--by designing a program that fits the needs of the University of Kansas and not requiring mandatory attendance (Abrahamson, 2011). Students are allowed to attend any number of sessions during the semester without being penalized or required to enroll in a separate course. One advantage of this approach was that it does not increase a student's tuition bill, which occurred at certain universities that require enrollment in a separate course (Hockings et al., 2008). Also, students did not have to make a commitment to participate in a supplemental instruction program within the first week of the semester. The open attendance policy was developed to capture students who wanted and needed to utilize PLUS for its benefits at any time during the semester.

PLUS sessions were offered in six to eight 50-minute sessions throughout the week at various times. The actual number of PLUS sessions was dependent on the demand from the students as well as on the available resources for funding peer leaders. During this study, CHEM 184 had seven weekly sessions for a total class enrollment of 875 while the CHEM 188 had six sessions with a course of 665 students. Sessions were offered during school hours, Monday through Thursday. The PLUS schedule was established on the basis of well-attended sessions from previous years and the availability of peer leaders. Friday and evening sessions had such minimal attendance in the program's first two years that resources were reallocated to meet the needs of the students at other times.

Each week, students were provided with a new packet of material for discussion from the prior week's lecture. This was to prevent students from being exposed to new material during PLUS and provided an opportunity for the students to become familiar with concepts and equations through homework or laboratory aids. Students were encouraged to expand their knowledge beyond the material provided by asking fellow peers questions for clarification of a concept. Peer leaders did not answer questions relating to either the homework problems or the laboratory reports.

Peer leaders worked in pairs during sessions in order to optimize interaction among the undergraduates, while allowing for flexibility in attendance. The ideal student to peer leader ratio was ten to one or lower, thus PLUS sessions were designed to allow for twenty students. If the number of peers attending was greater than twenty, additional peer leaders or a graduate teaching assistant might be called upon to help facilitate that particular session. Students were required to sign-in at the beginning in order to receive the weekly packet.

PLUS Peer Leaders

Peer leaders were the facilitators of individual PLUS sessions and were hired by the university. Requirements for becoming a peer leader were as follows: (1) students have successfully completed a general chemistry course with a grade of “A” or “B,” (2) demonstrate strong leadership and interpersonal skills, (3) have participated in the PLUS program as a student (Foundations of Chemistry, Organic Chemistry, or General Biology) or have a good working knowledge of the program, and (4) able to dedicate eight hours a week including attending the course lecture. If undergraduates felt the requirements were met, they were encouraged to apply. Students who completed the Foundations of Chemistry course were given preferential treatment over applicants that took the honors class, received AP credit, or took the course at another institution. The applications were reviewed by the PLUS coordinator and three PLUS graduate teaching assistants. Interviews were offered to students who had completed the requirements and could commit to at least two semesters to the program. Interviews for all potential peer leaders spanned several days near Thanksgiving Break for the fall semester and middle to late April for the spring semester.

Each interview lasted approximately twenty minutes and was conducted by two PLUS graduate teaching assistants and two undergraduate peer leaders. The candidate was asked questions dealing with the course material, desire for becoming a peer leader, previous leadership roles, different circumstances that may arise during a PLUS sessions and how would he or she approach the situation. These PLUS scenarios could range from a peer leader who provides incorrect information, a disruptive or rude student, students who only want to know information that will be on the exam, and neither peer leader knowing a correct answer. If time allows, the student may be asked to explain a chemistry concept of their choice. The panel would answer any questions that the peer leader candidate might have.

PLUS Workshop

A training workshop played a vital role in providing new peer leaders with skills necessary to become an effective facilitator in the PLUS program. This session took place the day prior to the start of each semester. All new and returning peer leaders were required to participate in PLUS leader training sessions. Any peer leaders who missed this workshop would not be offered a contract for that particular semester with very few exceptions. Experienced leaders were able to recreate an environment comparable to PLUS sessions. This allowed new leaders to recognize potential issues and address matters effectively before one became elevated. The workshop agenda was collaboration between senior peer leaders, graduate teaching assistants, and the PLUS program coordinator. Content might vary from semester to semester, but the general outline was an introduction to history and statistics of PLUS, a learning activity, and a mock session working with students. The training session would conclude with administrative protocols.

The introduction established the structure and foundation of PLUS to current student leaders. This was to ensure peers were not misinformed about what precisely the PLUS program was and was not. One of the largest misconceptions candidates associated with PLUS was that it was only applicable to undergraduates who were performed poorly in the course or that it was simply another discussion section. Students are also reminded that this program was available to all students enrolled in the course, not a means of private tutoring, and preliminary results concluded that students who participated in the program received about a half of grade higher than their peers.

Prior to the training workshop, all peer leaders were encouraged to complete the Education Planner's quiz in order to determine his or her primary learning style of visual, auditory, and tactile (Agency, 2011). The results provided a cooperative activity demonstrating diverse ways to present material through media and learning styles. Students were asked to assemble by learning style into groups for the activity portion of training.

Graduate teaching assistants designed a list of words ranging from scientific terms, name of movies, and everyday nouns. One activity was playing popular games to show peer leaders how different information can be conveyed to students. Pictionary allowed for good visual cues, while Taboo stimulated creative thinking to express synonyms or analogies, and clay modeling to build structures or objects in a timely fashion. The group was split into thirds with a team beginning at each station. The object was for each team to correctly guess the most words within the game in a ten-minute round. The peer leaders built leadership skills by working as a group to accomplish tasks throughout day as well as certain words might be easier or more effective in one particular game. For example, the word "glitter" was used in Pictionary with only one team correctly identifying this word through a unique drawing of vampires exposed to sunlight. The peer leaders unanimously agreed that "glitter" would be easier to identify with synonyms in Taboo such as sparkle, shimmer, and twinkle.

Packet Development and Material

The PLUS packets contained the chemistry concepts in text, diagrams, equations, and problems. Material was not designed from previous exams or homework questions, rather solely on material presented during the course lecture. This prevented two major concerns with students being taught to an exam and the potential case for academic dishonesty by giving PLUS students exposure to prior exams. Packet material was designed throughout the semester by the graduate teaching assistant. Peer leaders reviewed the content to assure the packet was aligned to the lecture and for typographical and grammatical editing.

The Chemistry 184 and 188 courses had same the lecturer and course syllabus from the beginning of PLUS chemistry through the end of this research. Therefore, a lot of the material was developed in fall of 2011 and refined in fall of 2012 for this study.

Chapter 3 : Methods

Design

Participants introduced to PLUS

The undergraduates were introduced to Peer Led Undergraduate Supplements (PLUS) during the first lecture. The PLUS graduate teaching assistant explained that the program was offered to all students in the course free of charge and was a means of additional learning through small group interactions with peers. The class was informed that this program was voluntary and for their own benefit, neither resulting in extra credit nor loss of points for lack of participation.

During lectures and through the course Blackboard site, students were informed of the concepts and formulas being discussed at that week's PLUS session. All students were encouraged to attend. Materials from PLUS sessions were made available to all students through the course website after sessions have been completed for the week.

Quasi-Experimental Study

Participants self-selected into the comparison (non-PLUS) or treatment group (PLUS) by their choice to participate in PLUS sessions. No control group was established since random sampling was not done on the design level. The final study included $N = 566$ students who gave consent and completed the survey. The regression analysis had $n = 236$ for the treatment group and a few less with $n = 211$ in the comparison group. Two students who were previously enrolled in the course were omitted from this study. This analysis used a confidence level of 95 percent, which was consistent with the literature in chemical education. Students who did not complete the course were removed from the regression analysis. They remained participants when testing the course item analysis, so PLUS could be evaluated by all students who participated to give a more accurate reflection.

Due to the self-selecting nature of this study, it was necessary to begin with *t-test* between the comparison and treatment groups for all background information. Any significant differences found between the two groups was considered for use as control variables in the multiple regression.

Procedures

Student performance was evaluated on two separate levels: the overall course exams measured by average exam scores and conceptual understanding of individual items. Lecture and lab scores were integrated into a single letter grade for this course, thus performance analysis was conducted using each student's average exam score as opposed to student's final percentage in the course. The average exam scores variable was formulated by dropping the lowest semester exam consistent with the syllabus, then finding the mean of the remaining three exams and final. This was to reduce the amount of students who had missing data. Also some students did not adequately prepare for the last exam, since they were satisfied with their exam average.

The first analysis provided an overarching insight to determine if students who attended PLUS regularly performed significantly different than their peers in the class. A regression analysis was conducted in order to determine how the average exam scores would change by the number of PLUS sessions a student attended while controlling for demographic variables in a hierarchical model. An in depth analysis of assumptions for multiple regression was conducted as well as full diagnostics for outliers and influential points. Andrew Hayes' SPSS Process was utilized to maximize the regression model by an in-depth investigation of moderation, mediation, and complex modeling of independent variables.

Conceptual understanding was analyzed through the midterm exams by means of item analysis. Three versions of the exams were given; therefore, items needed to be compared from between forms. This was accomplished by removing the early exam from the study and classifying items as identical, algorithmic and different for the two forms of the general exam. Each exam item was corresponded to the PLUS session in which the topic was addressed. Students that attended only that particular session were placed in the treatment group, while all other students were in the comparison. An independent *t-test* was used to compare mastery of a chemistry topic by students in either group to determine if students who attended specific PLUS sessions performed differently than their peers who did not attend. Conditional testing was not performed on the item analysis.

Data Collection

The data for this study was obtained from several sources including the following: (1) consent and surveys, (2) the course grade book, (3) university records, and finally (4) PLUS attendance.

Consent and Survey

The Human Subjects Committee of Lawrence approved this survey for use in fall of 2012. Students were made aware that results for this course would be used in a dissertation study for the analysis of PLUS chemistry. All students were asked to fill out a survey and give consent to participate in this study regardless if the student planned on utilizing the PLUS program throughout the year or not (Appendix A).

For this study, peer leaders distributed 900 surveys to students in the course. Five hundred eighty forms were signed and returned; however, only 566 participants filled out the corresponding survey. Due to the size of the auditorium, many students were not able to hand in the surveys directly to a peer leader or graduate teaching assistant. This may have caused forms to not be turned in either by rushing off to the next class or perhaps handing down the row and getting lost among classmates' belongings.

The survey requested information which included: (1) Name and KU ID, (2) gender, age, race, and ethnicity, (3) intended major and profession, (4) advanced high school courses and GPA, (5) academic standing.

Course Grade-Book Records

Mid-term exam data was collected from the University of Kansas' Testing Scoring Service. The exams are transported by the professor to the Testing Center on the following day. The answer key form was scanned followed by the students' exams. On the majority of exams, an all response data was collected; however, with a few exams forms only item-correctness was amassed. The center's all responses data option provided a Microsoft Excel spreadsheet, which included the individual's raw answer for each item as well as the answer key. Items were scored one if correct and zero if incorrect. The compiled files were sent through the university's secure data transfer system known as Hawkdrive. Item responses could be not collected for final exams. Exam 3 for Chemistry 188 had incorrect data set. The corrupted file contained student responses that was not consistent the course grade-book. Consequently, an item analysis was not conducted on this exams for this study.

Undergraduates' official grades were obtained from the course Blackboard site for the mid-term and final exam scores. However, the final course grade was acquired through the University of Kansas' Chemistry Department.

Data from the University of Kansas Records

All demographic and background variables were obtained through Office of Institutional Research and Planning (OIRP) or provided by the student in the initial survey.

Data Cleaning

The original class roster for Chemistry 184 was obtained through the course Blackboard site on the day following the first midterm exam, on 7 September 2012. The total number of students listed was 913, which exceeded the course enrollment of 875. Official enrollment was collected on 10 September 2012. During that three-day period, thirty-eight students dropped the course. The final withdrawal date from the course was 14 November 2012; these students received a "W" on their transcript ("The University of Kansas: Office of the University Registrar," 2013). Student surveys and signed consent files were compiled into a database in IBM Statistical Package for the Social Sciences v20 (SPSS). Survey results were entered by hand into SPSS at a rate near 50 surveys to minimize data entry error.

Once the full database was complete, data files for these students, including PLUS attendance, grades for Foundations of Chemistry I & II, background data from OIRP, survey information, and consent was encrypted to KU's Hawkdrive. The resulting comprehensive file was trimmed back into a workable database. The first major modification to the database was to remove students who did not give consent to be part of the study, totaling 347 individuals. This removal of a third of population did not significantly change the academic variables including average exam scores of the sample. Values are not reported to honor students the privacy of student who chose not to participate in the study. Fourteen additional students were removed, as these students dropped the course before the withdrawal date. The revised data set was saved for the Exam- Item Analysis.

Testing the first hypothesis, prediction of exam performance in chemistry while controlling for academic background, was conducted through a multiple regression analysis. Because of the nature of this analysis, any missing independent or dependent variables prohibit these cases from entering to the regression and thus were removed prior to the regression in order to have a more accurate analysis of descriptive statistics, scatterplots and graphs, and additional testing.

The 39 students that officially withdrew the course and received a grade "W" on their transcript were deleted. Furthermore, 14 students missing the final exam grade or more than one semester exam grades were also removed from the database. A total of 26 students were dropped for missing a college admission exam score and lastly 20 records were missing information on high school grade point average (GPA).

Data Manipulation

Mathematical Conversion

Average exam scores. The average exam scores were formulated by dropping the lowest semester exam, consistent with the syllabus, then finding the mean of the remaining three exams (worth 100-points each) and final (worth 200-points). Exam scores were calculated separately for each semester.

Credit Hours. Specific high school courses can be offered for college credit in three ways giving students an opportunity to earn college credit hours for rigorous work. High schools may offer Advanced Placement (AP), International Baccalaureate (IB), and/or dual college credit courses. Dual college credit courses are course offered at high schools and student can obtain college credit hours from predetermined community colleges or four-year institutions, usually for an additional fee. A single variable of college credit hours earned while in high school (Credit Hours) was created by the aggregation of these independent variables.

High school grade-point average. The GPA variable was imported from OIRP but unfortunately, these GPAs were not standardized and do had a consistent form of measurement. Some schools offer larger than the traditional 4.0; however, these scales vary from institution to institution due to honors classes or other unique parameters making transferability problematic. The University of Kansas adjusted any incoming GPAs by utilizing a ceiling function that reduces any value greater than 4.0 to simply 4.0. This created a mild ceiling effect and will be addressed on page 43 under the heading *Normality*.

Math ACT Score. A majority of undergraduates take the ACT as an entrance requirement for the College of Liberal Arts and Sciences, while a few students take the SAT. In order to measure a single construct for a college preparatory exam, SAT scores were converted into ACT scores. The composite and the mathematical or quantitative scores are displayed in Table 39. This math conversion was transformed for 30 cases and all data were compiled into the single variable, math ACT or sometime simply noted as ACT.

Coding Transformation

Dichotomous Variables. Gender is the categorical variable of males and females, which cannot directly be entered into the multiple regression. Instead, dichotomous variables needed to be transformed into a numerical value often done by asking a yes-no question. Arbitrarily, the question was "Is this student male?" The answer "no" resulted in females being coded as zero, while "yes" for males was coded as one.

In a similar manner, the two variables of previously being enrolled in calculus and completed high school chemistry are answered either "Yes, this student did take calculus" or "No, this student did not complete high school chemistry." If the student failed to complete the course, then he or she received a zero. A student that completed the course was coded with a one.

Dummy Coding. When categorical variables have more than two options, dummy coding was used in multiple regression. As with dichotomous variables, a yes-no question was asked but occurs over the span of several variables instead of one. The number of created variables would be one less than the number of choices for the original predictor. For example, if a categorical variable has four outcomes, then three variables would be created. Each case may have only one option, so that a student may answer "yes" to one of the three. The fourth outcomes would come from "no" to all three variables.

Demographic background regarding to race and ethnicity was a complex categorical variable that required dummy coding. In addition to the four self-selected options for race such as Caucasian, African American/Black, Asian/Pacific Islander, and Native American or Native Alaskan, students may belong to the multiple races. Additionally, a separate variable notes whether student ethnicity was of Hispanic or Latino origin.

Outliers

Removal of outliers or data points that do not fit the general pattern of the study can improve accuracy and reduce Type I and II errors (Pedhazur, 1997). A methodical approach using statistical testing instead of the visualization method was used to remove true outliers in an informed manner (Garson, 2012, p. 29).

Univariate outliers. All continuous variables of in this study were checked for univariate outliers. This outlier analysis was completed by converting each case's continuous variable into a *Z-score* in SPSS. *Z-scores*, or standard scores, are effectively the number of standard deviation a data point falls from the mean. The general practice was observed for removing extreme data points when a case has a *Z-score* greater than the absolute value of three to 3.29, which fall in the 0.999 confidence internal (Garson, 2012, p. 30; Keith, 2006, p. 193).

Z-scores were calculated for the following variables: PLUS attendance for each CHEM 184 and 188 semesters, high school GPA, high school credit hours, math ACT scores, and high school graduation year. All *Z-scores* for PLUS session attendance and math ACT were within the acceptable range for 99.9% of the data at value of $|3.29|$ so no outliers were detected. High school GPA had one case that exceeded the maximum with a score of -5.206. The created variable Credit had four cases with *Z-scores* higher than the cut off.

Lastly, the variable of high school graduation year had 14 cases with *Z-scores* between -3.46 and -10.46. When these outliers were removed from the database, 13 new outliers emerged. The distribution curve was not only negatively skewed from recent graduations but was also leptokurtic. Ninety percent of students graduated from high school in 2011 or 2012. The remaining ten percent of students in the study ranged from graduation years of 1998 to 2010. By removing these outliers, the variable inadvertently became a dichotomous variable of first-time freshman and second year students. To avoid the loss of 14 or possible even 27 outliers, the continuous variable of graduation year was reduced to the categorical variable of first-time freshman. Literature review provided not additional insight, to determine if age related variables impacted supplemental learning programs.

Multivariate outliers. These outliers were evaluated for each regression by calculating Mahalanobis distance and high influential points measured by Cook's distance (Stevens, 1984). The χ^2 cut off value for 4 and 5 independent variables at a 0.001 level (*C.I.* = 0.999) was 16.27 and 18.47 respectively (Fisher, 1995). Multivariable outliers were evaluated and analyzed after each multiple regression step.

Chapter 4 : Hypothesis I: Regression

Regression Analysis

The author was originally interested in whether students who attended PLUS sessions regularly performed significantly differently on the course's average exam score than their peers who did not attend any PLUS sessions. A multiple regression analysis was conducted in order to determine how the average exam scores changed as a function of the number of PLUS sessions a student attended, while controlling for demographic and academic background variables in hierarchical model. The initial research plan controlled for the following variables: gender, first-time freshman, ethnicity, intended major, math ACT scores, high school GPA, and completion of high school chemistry and calculus. After the preliminary examination of descriptive statistics and assumptions, the regression model was modified to better explain the research.

Categorical Variables: Descriptive Statistics

Calculus Completed

Students who were previously enrolled in a calculus course regardless of successful outcome, level of institution during enrollment, or repeated the course were categorized as "calculus completed." Again, the prerequisite for CHEM 184/188 only stated that students were eligible for calculus, therefore, all students should have met this institution requirement. This variable identified students who had completed a calculus course in some capacity. Fifty-two and nine-tenths percent met the requirements for calculus complete for the Chemistry 184. The treatment group had just over half of the students with 50.4% resulting in the increase of the comparison group to 55.7%. This mean difference was not statistically different at the 0.95 level (p = 0.268).

Similar results were seen in Chemistry 188. The total percentage of students calculus completed prior to the fall semester increased to 58.5%. Students who attended PLUS sessions made up 53.3% while their peers in the comparison group completed calculus at a 61.4% rate. Once again, the difference was not significant in an independent *t-test*, where $t(246) = -0.368$ and $p = 0.713$.

Gender

The Foundations of Chemistry I course contained slightly more females in the sample than males by a ratio of 53 to 47. The females comprised of 57.6% of the treatment sub-sample and while the comparison to 48.1%.

The second semester course contained an even higher percentage of females for the total sample just over 58.1%. Students that attended PLUS sessions for Chemistry 188 had a 2:1 ratio of females to males. This substantially raised the female percentage by nearly eight percent to 66.7%.

The independent *t-test* confirmed that female students were more likely to attend PLUS sessions than males for both Chemistry 184 and 188.

Ethnicity

Seventy-six percent of students included in this sample identified themselves as non-Latino Caucasian or white. The next largest ethnic group was Asian/Pacific Islanders with 10.6%. African Americans or students of African descent comprised just under five percent of the sample (4.8%) while Native Americans or Alaskans Natives were one percent fewer at 3.8%. Students of Hispanic or Latino origins totaled 27 or just over six percent of the sample. Students could identify multiple ethnicities which resulted in the summation of percentages to be over one hundred. Only two groups had a ratio less than 90:10 and could be tested in the regression analysis, the Caucasian and Asian groups. Caucasian students had a significant positive correlation with Chemistry 184 exams with a Pearson's r value of 0.166. A correlation of $r = -0.038$ for Asian/Pacific Islanders with 184 exam scores was shown not to be significant, $p = 0.212$. Therefore, this variable was not entered to the regression since no relationship could be determined between average exam scores and the ethnic group of Asian/Pacific Islanders.

First-Time Freshmen

Chemistry 184 was a foundations class for many other science courses, so naturally freshmen comprised the majority of the class. Seventy-six percent of the sample was first-time freshmen. Students who attended PLUS sessions were statistically more likely to be incoming freshmen at 83.1% whereas those who chose not to participate in PLUS only 68.9% were freshmen. The *p*-value for this independent *t-test* was $p \approx 0.000$.

The percentage of continued first-time freshman who made up the sample for Chemistry 188 was 81.5%; however, no difference was noted between groups of students within the second semester.

High School Chemistry

Student experience with high school chemistry was determined by a self-reported response on the survey. Eighty-three percent of students reported taking chemistry prior to the CHEM 184 course, which increased to 88.3% for CHEM 188. The treatment group, which comprised the PLUS participants, were within one percent of the mean of the comparison group for each semester and were not statistically different.

Intended Major and Profession

In the initial survey, students were asked a two-part inquiry of "What is your intended major?" followed by "What is your intended profession?" The open-ended question delivered 32 unique responses for major and 26 for profession. In the sample, 9.2% declared a major in a natural science, 38.2% in biological or life science, 2.7% in social or behavioral sciences, 14.7% in the pre-pharmacy track, 8.0% in applied health sciences, and 14.3% in engineering. Twenty-one students were undecided and 22 students claimed to major in "pre-med" despite the lack of such a major. Both of these group represented just under five percent of the respondents for the study. A handful of other majors including business, education, and humanities comprised the remaining 3.3%.

Bivariate correlations were analyzed on average exam scores for CHEM 184 and 188 for each intended major classification represented at least one-tenth of the sample. The only significant correlation was between pre-pharmacy students and 184 exams scores, $r = 0.143$ ($p = 0.001$). This correlation was on the cusp of negligible or weak relationship with a low Pearson's r value.

Students that declared their intended degree to be chemistry (3.1%), biochemistry (2.9%), or engineering (14.3%); despite the existence of specialty freshman chemistry courses of CHEM 170/175 for those in chemical sciences and CHEM 150 for engineers specifically intended to serve students pursuing these respective degrees. Requirements for CHEM 170/175 were identical with CHEM 184/188, so students should not have been prohibited to enroll due to prerequisites for this class. The Chemistry for Chemical Sciences course was new to the course catalog in the fall 2012 semester so academic advisors may not have been familiar with the change in graduation requirements. Of the 27 students that declared chemistry or biochemistry, 24 were first time freshmen.

In engineering, 51 of the 64 students were incoming freshman at KU while 11 students were in their second year. Neither group of students met the requirement for being grandfathered into the Foundations of Chemistry course. While 16% of these student could not enroll into Chemistry for Engineers since they had not completed prerequisite high school chemistry, the remaining 84% had and may have been ill advised, enrolled too late, or simply changed their major without editing their course load.

Professional aspirations centered largely on the medical field that would require a graduate level degree. The most sought career path was medical doctor with 37.5% of initial students taking the survey followed by the pharmacist with 16% of the class. An additional fifteen percent of students were seeking further schooling for dental, veterinarian, optometry, physician's assistant, occupational or physical therapy. Twenty-one (4.7%) wanted to become medical researchers but did not indicate at which level. The last collection of students varied greatly from working in the government through military service, several personal trainers, and more. A summary of these data is presented in Table 40.

Once again, Pearson's correlations were conducted on average exam scores for CHEM 184 and 188 for each intended profession with at least one-tenth of the sample. The results coincided with the above data for the major selection. The eleven students who declared a major outside of the pre-pharmacy track brought the correlation from 0.143 with p = 0.002 to 0.118 and a *p*-value of 0.013. Since the pre-pharmacy track students had a slightly stronger correlation, data with pre-pharmacy students were analyzed as a predictor in the multiple regression. Either correlation was weak due to Pearson's values under 0.200.

Numerical Variables: Descriptive Statistics

High School GPA

The mean high school GPA for 448 students in the fall semester sample had a mean of 3.723 and a standard deviation of 0.336. The comparison group had a mean 3.681, while the PLUS mean was significantly higher at 3.761 and a *p*-value of 0.011.

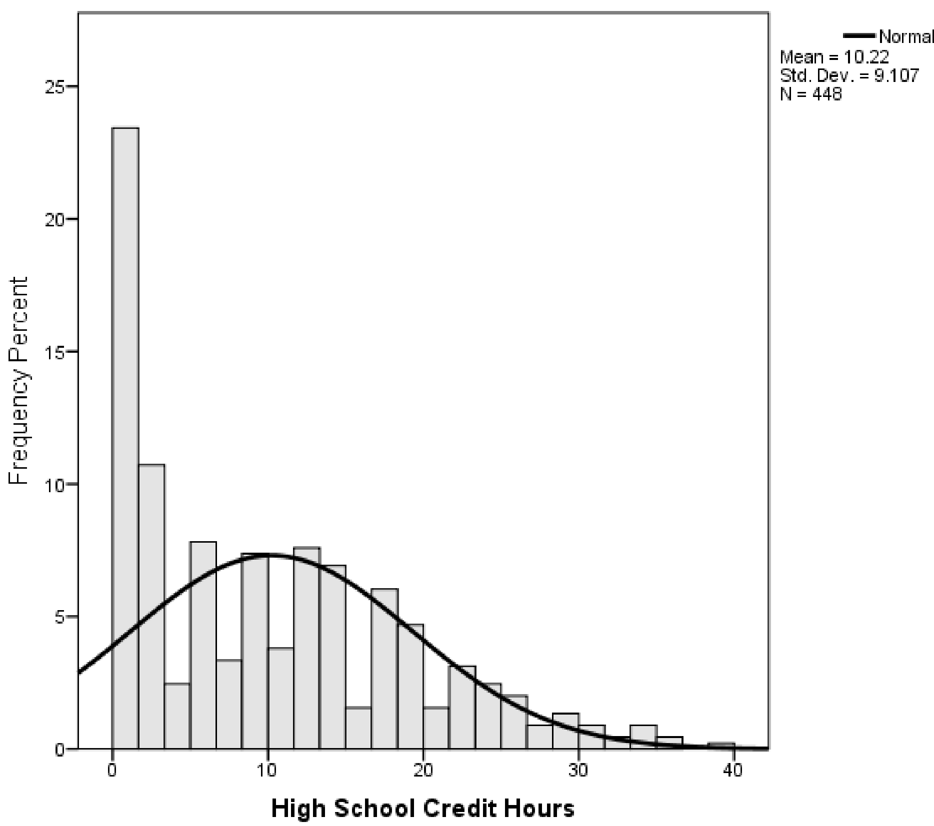
Foundations of Chemistry II's sample did have a minimal increase to 3.783 for the mean while the distribution curve tightened, reducing the standard deviation to 0.264. No differences were observed in grand mean statistics.

Incoming College Credit

The credit hours variable ranged from zero to 39 hours. The average for the full sample was just over ten hours (10.2). The standard deviation was 9.1. As seen in Figure 1, a floor effect. The left tail of the normal curve extended beyond zero or the lower limit of measure, which was seen here as over 20% of the sample did not earn or transfer-in any college credit while in high school. The PLUS treatment group has a significant difference with a mean of 11.09 hours while the comparison group was 9.25 hours. Both sub-samples also had large standard deviations.

The continuation of the course resulted in higher earned incoming hours, which averaged 11.25 for the 248 students. The respective means for the comparison verses treatment group was 10.81 to 12.01, which failed to show a different mean in an independent *t-test*. The *p*-value for the comparison was 0.304.

Figure 1
Histogram of Credit Hours earned in High School for Chemisry 184.



Math ACT Scores

The math ACT scores averaged just under 27 for the first semester and 27.5 for the students who completed the second half of the course. Neither semester showed a difference between the comparison and treatment groups.

PLUS Attendance

PLUS attendance variables were created by totaling the number of sessions a student attended for the semester. Separate variables were generated for Chemistry 184 and 188 with variable names of PLUS 184 and PLUS 188, respectively. If a student happened to attend two sessions within a week, only one session was added to the overall semester's attendance. The maximum number of sessions for PLUS 184 was 13 while PLUS 188 only had ten sessions. The percent breakdown of session attendance can be found in Table 2.

Table 2
Frequency Table for PLUS Attendance Variable.

	Percent of Student Participation	
Total Attended	PLUS 184 (N = 448)	PLUS 188 (N = 249)
0 Sessions	47.3	63.5
1 Sessions	15.6	10.4
2 Sessions	6.9	4.8
3 Sessions	4.0	5.2
4 Sessions	4.0	2.4
5 Sessions	3.3	1.2
6 Sessions	3.1	3.2
7 Sessions	3.8	3.2
8 Sessions	2.9	2.8
9 Sessions	3.6	1.2
10 Sessions	1.3	2.0
11 Sessions, (184 only)	2.0	~
12 Sessions, (184 only)	1.1	~
13 Sessions, (184 only)	0.9	~

Descriptive Statistics

The mean and standard deviations of the continuous variables along with bivariate correlation can be found in Table 3. The Pearson's *r* for Average Exam Scores for CHEM 184 with 448 students has the strongest positive relationship for math ACT scores with $r = 0.529$ and secondly followed high school grade point average with $r = 0.460$. Credit hours and 184 PLUS sessions have moderate positive relationship with Pearson's *r* values of 0.302 and 0.298 respectively. All correlations have *p*-values less than 0.05.

Pearson's correlations with Chemistry 188 had the highest value with GPA (*r* = 0.467) followed by math ACT scores with *r* = 0.453. The variable, credit hours, increased to *r* = 0.319 from *r* = 0.302 in the first semester. The most notable change occurred with the PLUS 188 and average scores correlation, which dropped to *r* = 0.192.

All independent-dependent variable correlations were significant. Significant intercorrelations exist between GPA, math ACT, and credit hours for both semesters. The highest Pearson's *r* was well below the problematic value of 0.8, which would indicate multicollinearity (Garson, 2012, p. 9). Additional tolerance testing was conducted to ensure the continuous variables were not too closely related.

Table 3

Descriptive Statistics and Intercorrelation for Chemistry 184 and 188.

Variable	1	2	3	4	5
	Chemistry 184 (N = 448)				
1. GPA	—				
2. Math ACT	0.439**	—			
3. Credit Hour	0.394**	0.265**	—		
4. PLUS 184	0.180**	0.075	0.082	—	
5. Exam 184	0.460**	0.529**	0.302**	0.298**	—
6. Mean	3.72	26.96	10.31	2.36	71.96
7. *SD*	0.334	3.812	9.052	3.371	15.396
	Chemistry 188 (N = 449)				
1. GPA	—				
2. Math ACT	0.369**	—			
3. Credit Hour	0.399**	0.258**	—		
4. PLUS188	0.188**	0.05	0.316**	—	
5. Exam 188	0.467**	0.453**	0.319**	0.192**	—
6. Mean	3.77	27.42	11.14	1.47	71.90
7. *SD*	0.292	3.68	8.85	2.62	14.270

Note. **p < 0.01 and *p < 0.05.

Assumptions of Multiple Regression

The statistical framework for a multiple regression rests on mathematical assumptions which if not met, it may lead to over or underestimation of Type I and Type II error. Multiple regression has four major assumptions: (1) linearity, (2) normality, (3) independence of observation, and (4) homoscedasticity (Keith, 2006, pp. 186 – 187).

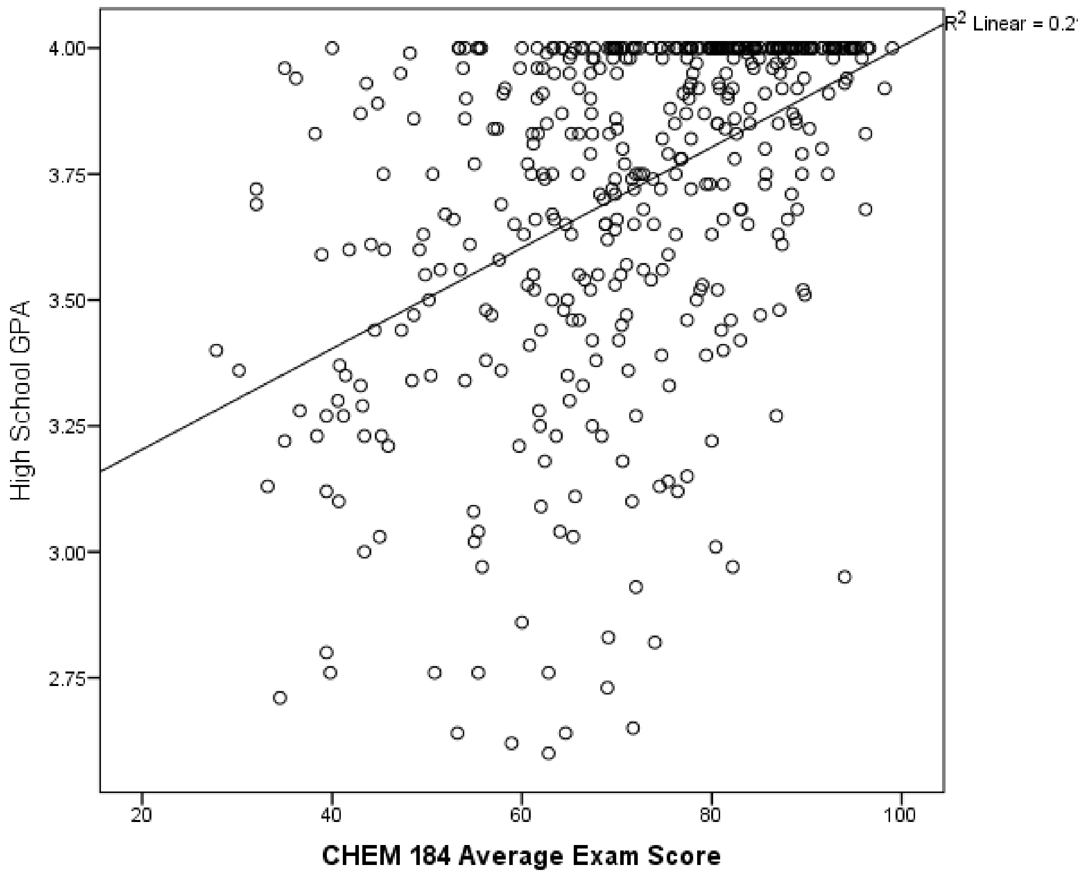
Linear Regression

A linear least squares multiple regression assumes the independent variables must be related to the dependent variable in a linear fashion. Meeting the assumption of linearity was the most critical aspect to reduce the amount of error and provide meaningful results. Each continuous variable was tested for this linear relationship by means of graphical analysis. Several trend lines (exponential, linear, logarithmic, quadratic, cubic, and inverse) were added to the bivariate scatter to determine the best fit through the highest R^2 value. If several trendlines had equal values of R^2 and one of them linear, then the untransformed variable was used in the multiple regression. However, if best fit trendline was not linear, then the appropriate variable transformation was conducted.

High school GPA had three trendlines with $R^2 = 0.21$, which were linear, quadratic, and cubic. Since the linear was one of the best-fit trendlines, no manipulation was done for the variable. The linear trendline is provided in the bivariate scatterplot, Figure 2. This was verified by plotting the unstandardized residuals from the multiple regression and the independent variable, GPA. The loess line did have the appearance of a straight line drawn by a child as seen in Figure 3. High School GPA was determined to be a linear variable in the multiple regression for Chemistry 184.

The R^2 values was higher for math ACT scores and Chemistry 184 exam average. Linear, quadratic, cubic, and exponential trendlines resulted in a model fit with $R^2 = 0.29$, as displayed in Figure 23. Once again the variable was not transformed and math ACT scores met the assumptions for linearity. The variable credit hours with Chemistry 184 provided a different outcome. The linear trendline can be viewed in upper portion of Figure 25, while the better fit cubic function is directly below. The linear trendline has an $R^2 = 0.08$, while the cubic line improved to $R^2 = 0.10$ but the leading coefficients were 1.0×10^{-4} for the x^3 and -1.8×10^{-2} for x^2 in the trendline equation. The improvement in the model fit was minimal, so the square and cubic roots were added to the regression. No significant change was documented by an increase in R^2 or less error in the model. The loess line in Figure 26 resolved credit hours was related to the model in a linear fashion despite the better fit cubic trendline. The treatment variable, PLUS 184 attendance had the best fit for a linear trendline with $R^2 = 0.08$. The loess line indicated that PLUS attendance effected the model in a linear capacity. Bivariate scatterplots for PLUS 184 are displayed Figure 27 and Figure 28. All continuous variables met the assumptions for linearity in the Chemistry 184 regression.

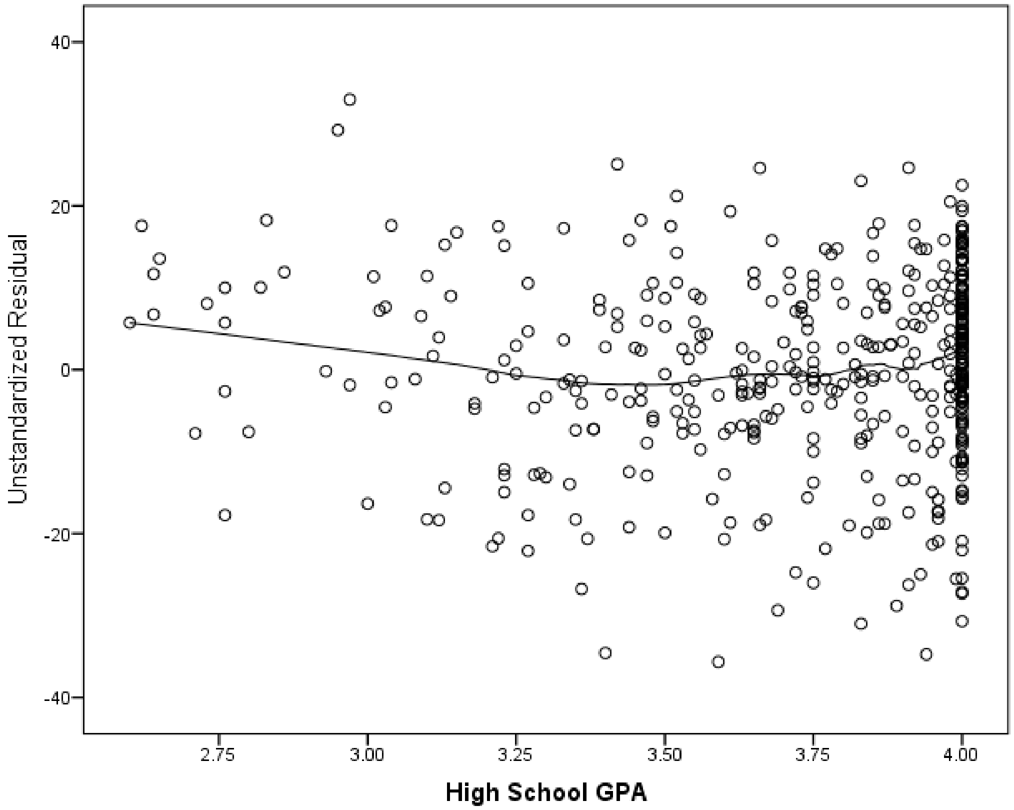
Figure 2
Bivariate Scatterplot of High School GPA and Chemistry 184 Exam Scores.



Note. N = 448.

Figure 3

Bivariate Scatterplot of High School GPA and Residuals from CHEM 184 Multiple Regression.



Note. N = 448.

The process was repeated for the same variables with the Chemistry 188 average exams scores and the corresponding PLUS sessions. Bivariate scatterplots can be found in Appendix B. Math ACT scores and GPA had increase of R^2 with the cubic trendline over the linear trendline by 0.01 and 0.02, respectively. Manipulate variables, cubic and quadratic, were conducted to investigate these two variable and neither provided larger R^2 values. PLUS 188 sessions and credit hours had best fit linear trendlines. The assumptions of linearity was met for all variables in the Chemistry 188 semester.

Normality

The assumption of normality had conflicting interpretations depending on the researcher. Several authors claim only the residuals or error from the regression need to be normally distributed (Keith, 2006, pp. 186, 192), while others claim independent variables that vary sharply from the normal curve either by kurtosis or skew can alter magnitude and significance of a variable thus these predictors need to be normal as well (Osborne & Waters, 2001; Tabachnick & Fidell, 2001, p. 139). To minimize any possibility of error, all continuous variables including the dependent variables have been checked for normality as well as the residuals for the regression. Multiple regression may be robust to the assumption of normality but a thorough examination was conducted for each variable (Cohen, Cohen, West, & Aiken, 2003, p. 424).

General Practice. The general rule of thumb to test for normal distribution is by dividing each variable's skewness and kurtosis by their respective standard error. Skewness should be within an absolute range of 2 while kurtosis has a tighter range of -1 to 1 (Garson, 2012, pp. 17 – 19).

Shapiro-Wilk Test. This statistical measure calculates deviations from normality by using the Equation 1, which essentially states covariance divided by variance for a given sample. In this test, a normal curve equals one and when $p > 0.05$ (Shaprio & Wilk, 1965). Calculations for this test were performed in SPSS.

Equation 1
Shapiro-Wilk Formula

$$W = \frac{\left(\Sigma_{i=1}^{n} a_i x_i\right)^2}{\left(\Sigma_{i=1}^{n} (x_i - \bar{x}\right)^2}$$

High school credit hours deviated from the normal curve as seen in Figure 1. The credit hour variable has a skewness of 6.2 and a kurtosis approximately -1. The skew was three times higher than generally allowed for normal distribution curve. The skew was observed by a floor effect because the lowest value of credit hours a student can enter college with was zero. Secondly, the Shapiro-Wilk test was calculated and W = 0.812 with a $p \approx 0.000$, which concluded credit hours was not normally distributed. Similar calculations can be found for all the continuous variables in Table 4. Math ACT barely exceeded the limits for both skew and kurtosis with a W = 0.974. GPA, PLUS 184 and PLUS 188 all varied drastically from normality. Histograms of math ACT and high school GPA are seen in Figure 4 and Figure 5, respectively. The average exam scores for Chemistry 184 were not normally distributed but the Shapiro-Wilk did approach one with a value of 0.982. However, the 188 exams were normally distributed confirmed by W = 0.992 and p = 0.168.

Figure 4
Histogram of math ACT Scores for Chemistry 184.

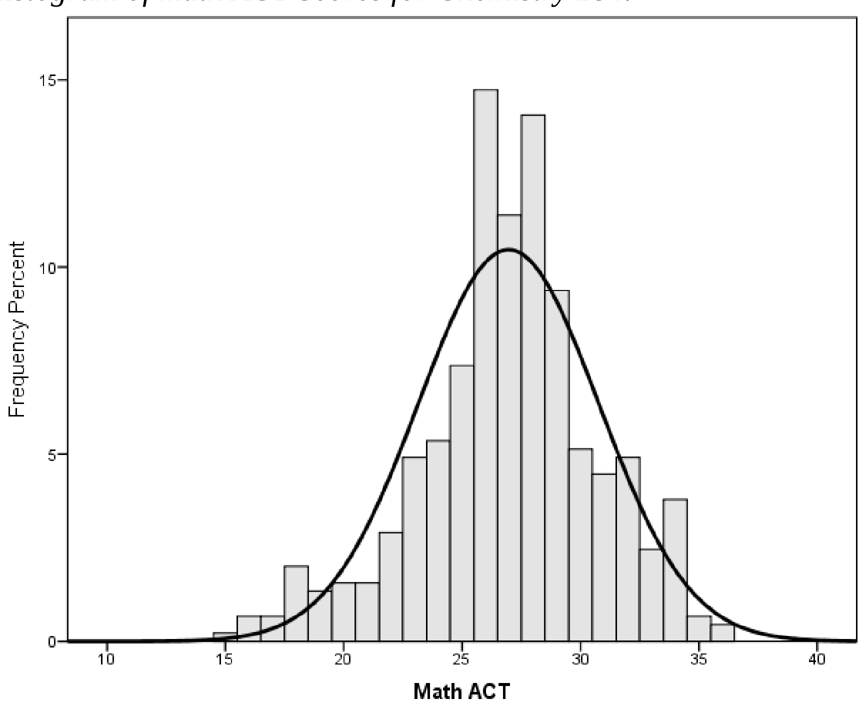
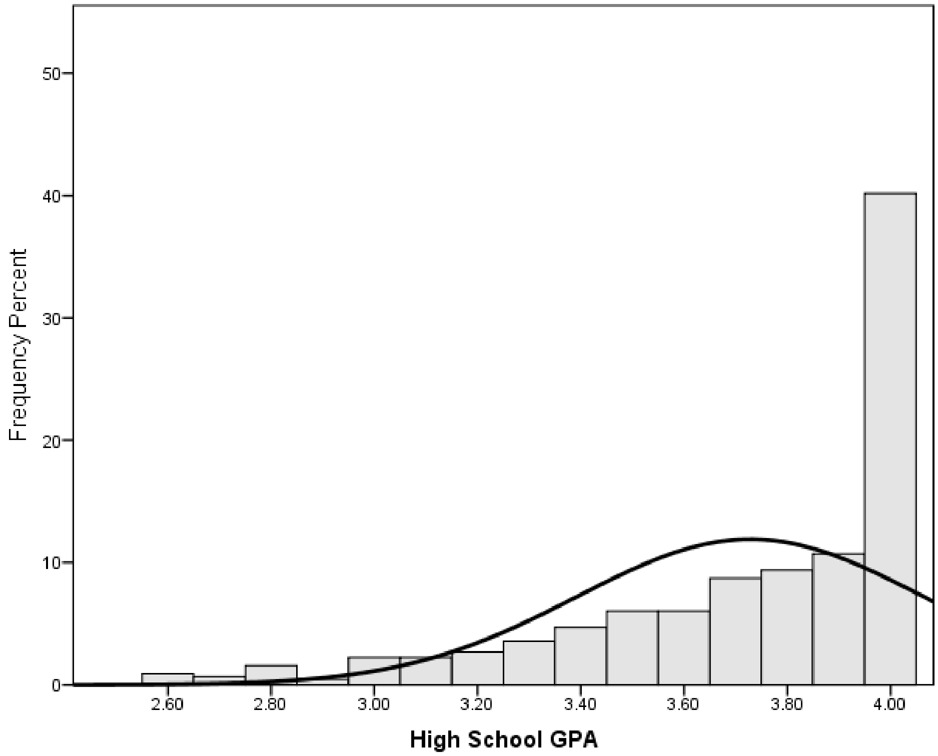


Figure 5
Histogram of High School GPA for Chemistry 184.



Box-Cox Transformations. Variable transformations have been conducted to correct for lack of normality in nearly all variables and improve homogeneity of variance. The Box-Cox transformation (BCT) had optimized variables that were highly skewed through a family of continuous power transformation with a single analysis. This effectively minimized the traditional approach of guess and check while maximizing transformation to normalize data. Jason Osborne at North Carolina State University wrote a Box-Cox transformation macro for SPSS which was successfully used for all continuous variables (2010).

Box-Cox transformations were conducted for the independent variables of high school GPA, credit hours, math ACT scores, and PLUS sessions. These mathematical conversions have been optimized for reduction of skew but often resulted in kurtosis increasing in magnitude.

Lambda was the power the variable was raised to minimize skew. Theses transformations are found in Table 4.

Table 4

Box-Cox Transformations and Normality Test.

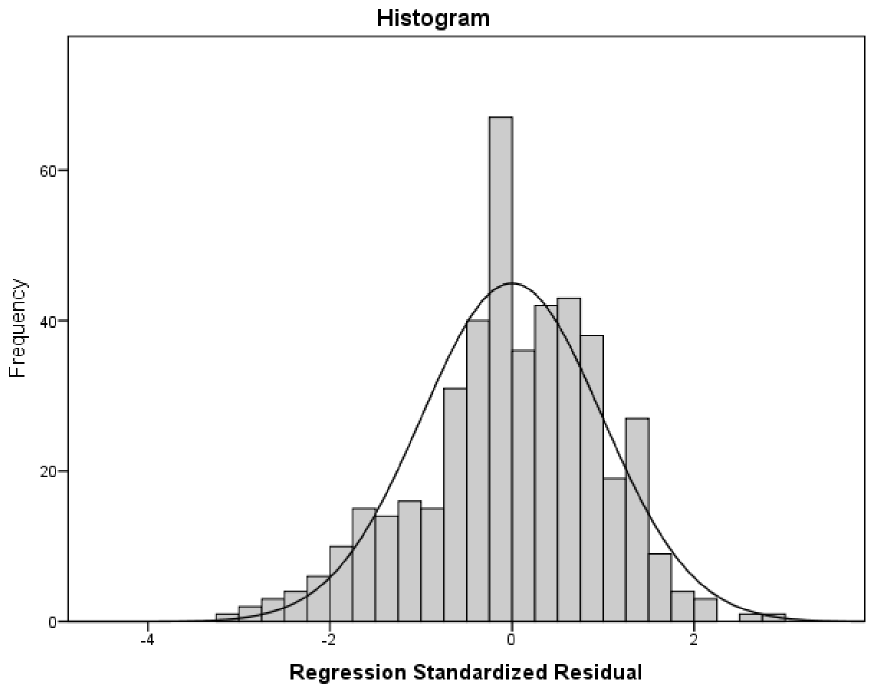
				Shapiro-Wilk (Normality)		
Variable	Lambda	Skew	Kurtosis	*W*	*df*	*p*
Math ACT		-3.551	2.319	0.974	446	0.000
BCT Math ACT	1.3	-0.064	0.448	0.983	446	0.000
Credit Hours		6.186	-0.996	0.812	446	0.000
BCT Credit Hour	0.5	0.238	-5.041	0.823	446	0.000
HS GPA		-11.651	5.150	0.915	446	0.000
BCT GPA_{HS}	11.0	-0.003	-7.438	0.940	446	0.000
184 PLUS		12.572	4.306	0.733	446	0.000
BCT PLUS 184	-1.7	0.0540	-8.220	0.730	446	0.000
PLUS 188		12.093	7.710	0.625	254	0.000
BCT PLUS 188	-3.1	-3.724	-5.423	0.631	254	0.000
Exam Avg 184		-4.200	0.939	0.982	446	0.000
BCT Exam Avg 184	1.75	-0.466	-0.823	0.997	446	0.493
Exam Avg 188		-1.430	-1.25	0.992	254	0.168

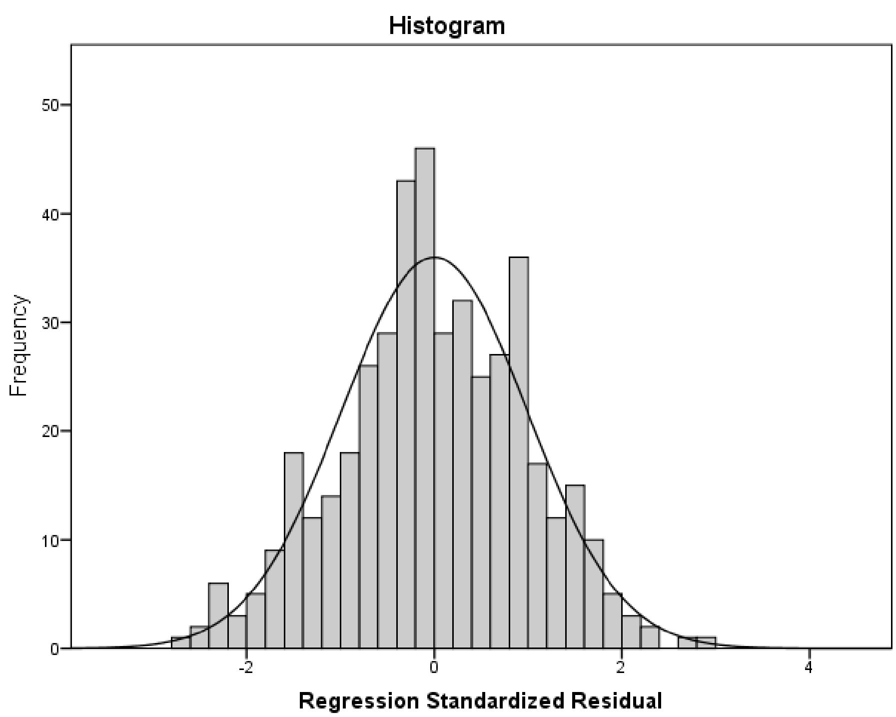
Note. The skew and kurtosis values have been divided by the respective SE of 0.115 and 0.230 when N = 448.

Residual Testing. A multiple regression was initially conducted to determine the normality of residuals for each semester. In CHEM 184, the dependent variable was the average exam score while the predictors were entered in a hierarchical regression. High school GPA, credit hours, math ACT, calculus completed were entered into the first step followed by the number of PLUS sessions. All predictors were significant to a $\alpha = 0.05$ level as well the *F-test* for both regression models. The residuals were saved so a separate normality analysis could be conducted. The Shapiro-Wilk test for normality showed the residuals varied significantly from the normal curve and the skew was twice as large as the desired absolute upper range and W = 0.984. The CHEM 184 exam average scores were transformed through Box-Cox transformation with a lambda value of 1.75. The residuals from the corrected regression revealed normality was achieved. The

Shapiro-Wilk Test was not significant but W=0.996. The R^2 value increase from 0.408 to 0.413. This assumption has been met for CHEM 184 once the transformation took place for the dependent variable.

Figure 6
Histogram of Standardized Residuals for CHEM 184 Regression.

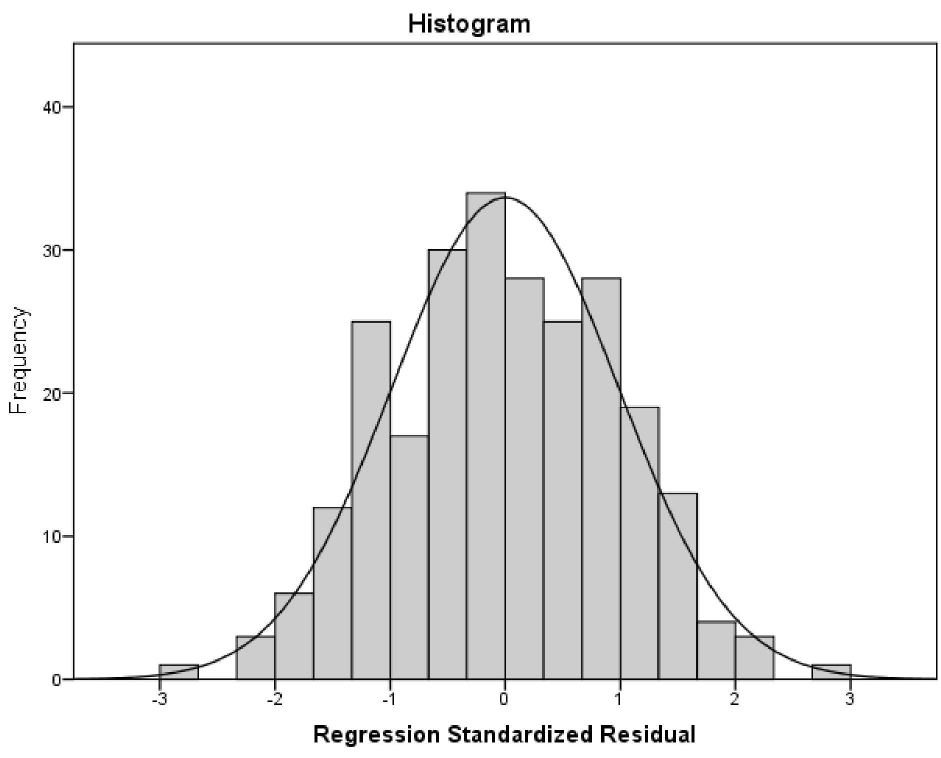




Note. Upper figure: Dependent vairable = CHEM 184 Exams.
Lower figure: Dependent variable = BCT CHEM 184 Exams.

Residual analysis continued with a new regression for the CHEM 188 semester. The sample was reduced so significant predictors from the previous regression may no longer be significant. Also, the CHEM 184 specific variables, PLUS sessions and average exam scores, were replaced with the corresponding CHEM 188 variables. Once again the remaining predictors and the *F-test* for hierarchical regression were significant at a 95% confidence level. The residuals did have a normal distribution as evident by failing to reject the null hypothesis (p = 0.108) for Shapiro-Wilk test with a value of 0.991. A transformation was not required to meet the normality of residuals assumption for Foundations of Chemistry II.

Table 5
Histogram of Standardized Residuals for CHEM 188 Regression.



Independent Variable Testing. The independent variables were analyzed to determine their effect on the regression. The variable, Credit Hours, was raised to the 0.5 power (square root) as a test transformation. The skew was reduced from 6.186 to 0.238 however kurtosis increases in magnitude from -0.996 to -5.041 after the manipulation. The Shapiro-Wilk value did increase by 0.011, indicating the overall transformation was favorable but still significantly varied from a normal curve.

High school GPA followed a similar pattern when raised to the eleventh power. This caused normality to increase from 0.915 to 0.940. The math ACT variable was raised to the 1.3 power and there was a reduction of skew and kurtosis while increasing the normality by 0.009 units. The 184 PLUS Sessions had an optimal skew when λ= -1.7. The kurtosis not only increased in magnitude, but also switched from leptokurtic to platykurtic due to the inverse function. This transformation also caused a decline in W by 0.003. All transformed variables were still significantly different than a normal curve.

Further evaluation was necessary to determine if the new variables resulted in a significant difference in the analysis. When the transformed variables were replaced one at time into the multiple regression analysis, neither a change in R^2 nor a change in significance of predictors was observed for BCT Credit Hours and BCT Math ACT. The BCT PLUS 184 was not analyzed since the Schapiro-Wilk value decreased after the transformation took place. The BCT for HS GPA did result in $\Delta R^2 = 0.016$ for the multiple regression for the CHEM 184 semester. Despite the increase in the explained variance of average exam scores, the transformation required the variable to be raised to the eleventh power. This may have optimized the data for the regression; however, it complicated the meaning and validity of results for little additional gain.

Normality of residuals was achieved by transposing the CHEM 184 scores by the Box-Cox method and no manipulation to the CHEM 188 scores. The pursuit to achieve normality to each continuous independent variable did not improve the R^2 results of the regression enough to justify the additional complexity.

Homoscedasticity

The third major assumption analyzed was homoscedasticity, or the magnitude of the residuals dispersed evenly across the all levels of the dependent variable. This variance of error was checked for patterns or functions of the independent variables. Violations of this assumption affect the statistical significance of the predictors rather than regression coefficients (Keith, 2006, pp. 190 – 191). Tabacknick and Fidell noted severe homoscedasticity must be present before there is a need for concern or manipulation (2001).

The analysis of homoscedasticity was not as straight forward as determining the linear relationship between the predictor and the dependent variable. Often times, visual examination of the standard residuals plotted against the predicted y-value were the only means for analyzing this assumption. In perfect homoscedastic data, the residuals are random but evenly distributed around zero. In extreme heteroscedastic cases, the residuals in the scatterplot would appear in a fan or butterfly shape (Keith, 2006, p. 191). When a fan shape occurs the error is statistically smaller at one end but increases while moving across the entire x-axis. However with a butterfly shape, the predicted y-values have little error in the middle but greater amounts both extremes (Garson, 2012, p. 38).

As seen in Figure 7 through

Figure 9, the scatterplots for the CHEM 184 and 188 semesters the graphical representation for homoscedasticity. The first figure has a Loess best fit line; which negatively sloped off beginning at one standardized residual unit. The scatterplot of the Box-Cox transformation for the 184 course resulted in a Loess line centered closer to zero in Figure 8. Cohens remarked that Loess lines should look like a young child's freehand drawing of a straight line centered near zero for homoscedastic data (Cohen et al., 2003, p. 111). None of the scatterplots provided evidence of residuals taking on a butterfly or fan appearance; however, there is a greater number of residuals with predicted y-values lower than 2 standard deviations.

Figure 7
Residual Scatterplot for Predicted Values of Average Exam Score for CHEM 184.

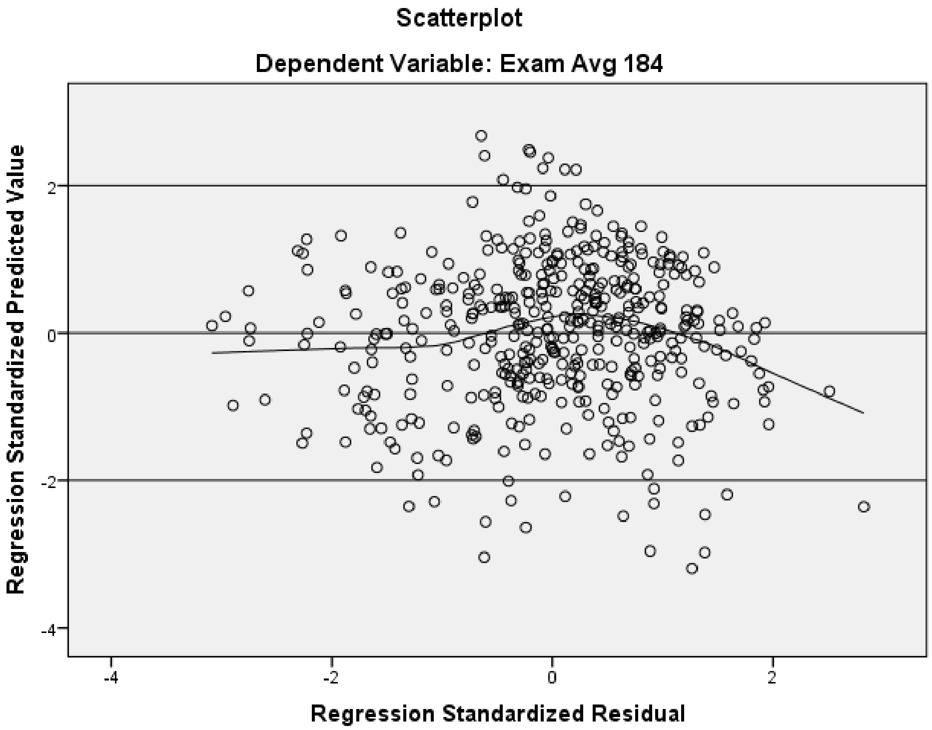

Scatterplot
Dependent Variable: Exam Avg 184
Regression Standardized Predicted Value
2
0
-2
-4
-4
-2
0
2
Regression Standardized Residual

Figure 8

Residual Scatterplot for Predicted Values of BCT Exam Score for CHEM 184.

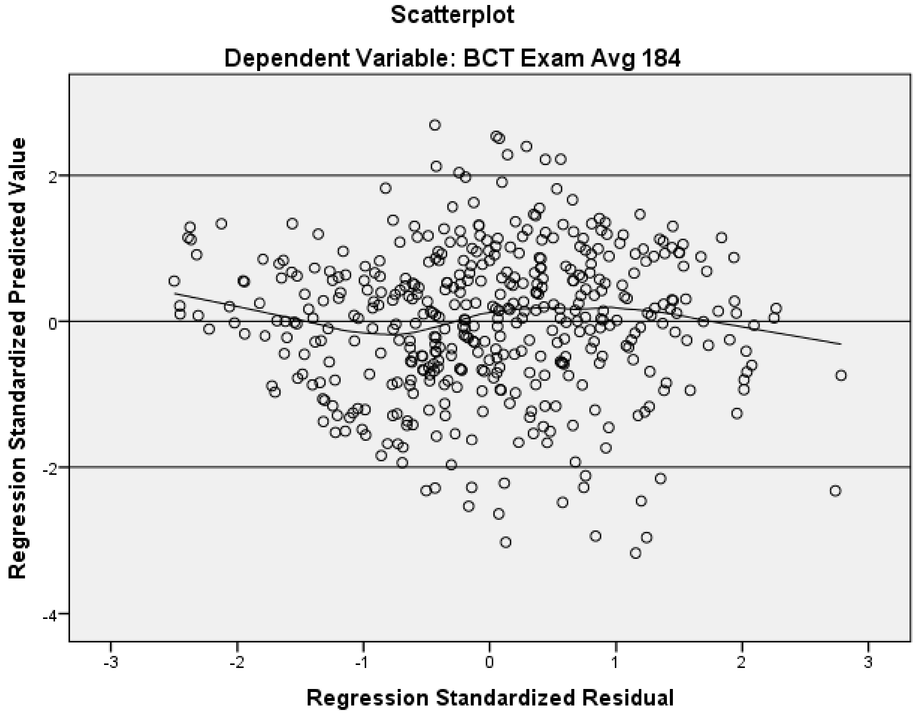
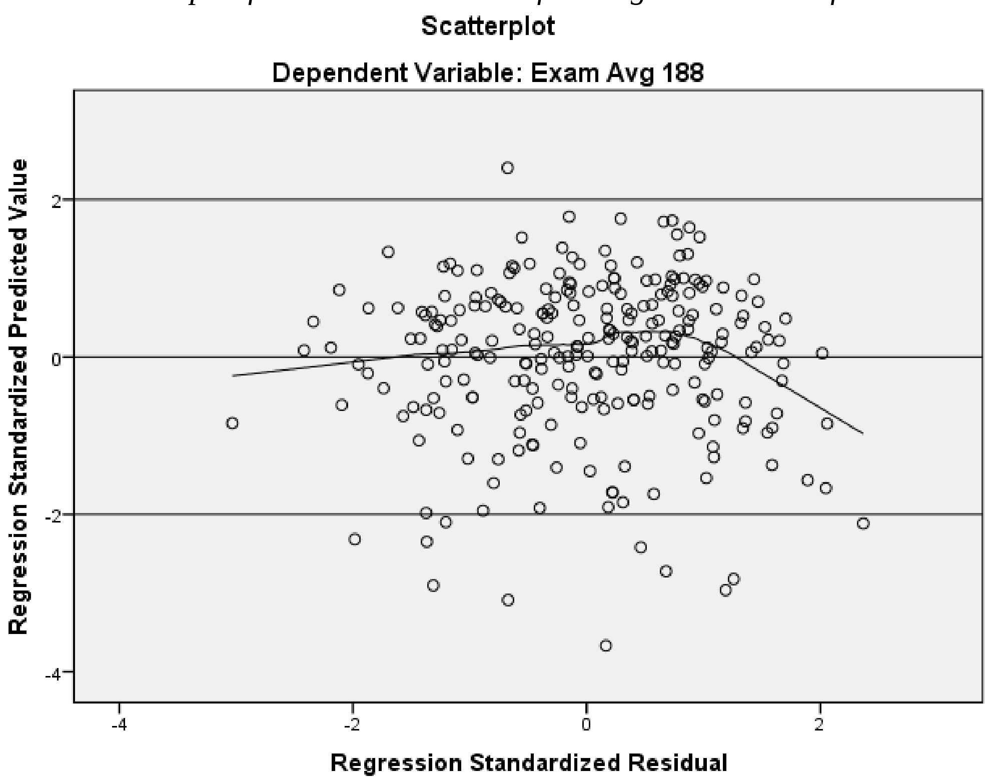


Figure 9

Residual Scatterplot for Predicted Values of Average Exam Score for CHEM 188.



Breusch-Pagan Test. Homoscedasticity was statistically measured by the Breusch-Pagan test by the macro developed by Marta Garcia-Granero (Garcia-Granero, 2002). The analysis for CHEM 184 and the corrected CHEM 184 regression rejected the equal variance among the residuals with a Breusch-Pegan value of 23.699 with $p = 0.000$ and 12.659 with a p-value of 0.027 respectively. The Box-Cox regression had less heteroscedasticity than the uncorrected Exam 184 scores, which was expected by the nature of this transformation to not only improve normality but homoscedasticity as well. The Breusch-Pegan test was also conducted on the CHEM 188 regression and was found to fail to reject the null hypothesis of homogeneity of variance. The assumption of homoscedasticity was met for CHEM 188 with a test value of 6.443 with $p = 0.168$. Since this assumption was not met for either CHEM 184 regression, the standard errors had to be adjusted. Hayes and Cai's macro estimated the consistent standard error was performed and results can be found in

Table 6 (Hayes & Cai, 2007). As seen, the standard error did increase which resulted in an increase in the *p*-value by a few thousandths but the standardize coefficients remained unaffected. The adjusted error was minor enough not to cause the independent variables to oscillate from significant predictors to non-significant. Mild heteroscedasticity did not violate the integrity of the multiple regression thus the robust assumption was met.

Table 6

Consistent Standard Error for Heteroscedastic Data.

Variable		Standard		Adjusted	
Dependent	Independent	β	*p*	β	*p*
Exam Avg 184					
	HS GPA	0.197	0.000	0.197	0.000
	Credit Hour	0.098	0.014	0.098	0.017
	Math ACT	0.369	0.000	0.369	0.000
	Calculus	0.093	0.017	0.093	0.022
	PLUS 184	0.222	0.000	0.222	0.000
BCT Exam Avg 184					
	HS GPA	0.201	0.000	0.201	0.000
	Credit Hour	0.104	0.010	0.104	0.015
	Math ACT	0.365	0.000	0.365	0.000
	Calculus	0.099	0.012	0.099	0.014
	PLUS 184	0.221	0.000	0.221	0.000

Note: N = 448.
** Correlation significant at $\alpha = 0.01$ level for two-tailed.

Independence of observation

In a theoretical study all cases should be random and independently sampled from the population. Since there is not a calculation for this independence of observation, the experimental design was thoroughly reviewed to meeting this assumption. The population for this study was all students enrolled in Chemistry 184. The research design was established to study the population not a random sample of the population. Equal opportunity for all students to participate in the study by providing surveys and consent on the first day of class as oppose to only researching certain laboratory sections. This first day of class was chosen since it is the highest attended lecture for the entire semester. Even with these efforts, all students did not have an equal probability of participate in the research. Given that the auditorium contained more students than enrolled in the class, not enough surveys were available. Consequently some students who wanted to participate could not, while others signed consent and were not even enrolled in the course.

The supermajority of the students were able read the purpose of study and consent before he or she choose whether to participate or not. It was possible an individual student's decision whether to participate in the study might have been influenced by (1) his or her surrounding peers, (2) absent from class due to late course enrollment, or (3) consent surveys will filled out but not collected. Still, the strategy for informed consent collection attempted to minimize omission of participation to meet this assumption.

Minor assumptions

The remaining assumptions were met through experimental design by making the treatment available to all student rather than a pre-selected group. These assumptions were the effects of the predictors on the dependent variable. This implied the independent variables were the "causes" while the dependent variable was the "effect" and the analysis included all pertinent independent variables to properly describe the dependent variable in the regression (Keith, 2006, p. 187).

The average exam scores did not influence any of the independent variable. In fact, all prospective predictors of student achievement were drawn from data in existence prior to the semester beginning. The independent variables were collected from OIRP during the spring of 2013 to allow adequate time for KU to receive information from feeder high schools.

Chapter 5 : Regression Results and Discussion

Multiple Regression Study for Chemistry 184

Block Regression

A single-block multiple regression was conducted in order to determine which of the predictors were significant in this study. The first regression analyzed all predictor regardless of a significant Pearson's correlation with Chemistry 184 exam scores. This model did violate the assumption of linearity to the dependent variable; however, this was necessary to determine if a particular independent variable was not correlated due to a mediated or moderated effect. Not only were the *p*-values checked, but the study also examined the part and partial correlations.

The following predictors were entered into this regression in a single step: first-time freshman, credit hours, high school GPA, math ACT score, PLUS sessions, completion of high school chemistry, calculus completed, gender, intended profession (engineer, medical doctor, and pharmacist), and ethnicity (non-Latino, white and Asian/Pacific Islander). Temporally, sets of student data were removed as multivariate outliers. Their Mahalanobis distance was greater than 34.5 for the thirteen degrees of freedom that this analysis allowed when *chi*-squared was 0.001.

The regression was overall significant with $R^2 = 0.441$ but reported values must be taken with reservations since assumptions were not met. Though the variables of medical doctor, engineer, and Asian ethnicity behaved as predicted; they did not have significant correlations to the dependent variable. These variables had $p > 0.050$ and their corresponding partial and part correlations were smaller than the *zero*-order. This finding indicated that these three independent variables showed no effect on mediation or moderation, and thus, they were removed from the regression. More information on moderation and mediation is provided in their sections beginning on page 62 and 71, respectively. The complete Regression I coefficients can be found in Table 7.

The simple correlation between gender and 184 exam scores was $r = 0.007$, while the 188 scores showed a similar correlation with value of $r = 0.022$. Neither Pearson's coefficient was significant. Further evidence established during the block multiple regression that the partial was larger than the *zero*-ordered correlation for gender. Consequently, separate regressions were conducted on males and females to determine if gender needed to be further investigated as a potential moderator or simply this variable had minute effect on exam scores. This was achieved by removing gender as a predictor from the regression and splitting the database by gender. Independent regressions analyses were conducted for males and females. The model fit increased from $R^2 = 0.399$ for males to $R^2 = 0.453$ for modeling female students for predicting achievement on exams in Chemistry 184. An explained variance difference of 5.4% pointed that gender did play a substantial role despite the zero correlation between gender and average exam scores for Chemistry 184. A future moderation investigation was conducted to determine exactly how gender and exam scores were related.

Table 7

Regression I: All predictors CHEM 184.

Variable	*B*	*SE B*	β	Zero-order	Partial	Part
Asian	-1.719	2.400	-0.033	-0.041	-0.033	-0.025
Calculus	3.622	1.254	0.114**	0.288**	0.133	0.101
Caucasian	2.099	1.779	0.039	0.166**	0.039	0.029
Credit Hour	0.107	0.070	0.077	0.305**	0.090	0.068
Engineer	-0.750	1.914	-0.007	-0.013	-0.008	-0.006
Freshman	1.763	1.532	0.074	0.263**	0.082	0.062
Gender	1.467	1.311	0.054	0.007	0.061	0.046
GPA	9.732	2.205	0.207**	0.463**	0.210	0.162
HS CHEM.	1.854	1.534	0.047	0.165**	0.061	0.046
Math ACT	1.392	0.192	0.327**	0.533**	0.316	0.252
Med Doc	1.258	1.433	0.045	0.049	0.048	0.036
PLUS 184	0.932	0.172	0.208**	0.295**	0.256	0.200
Pharmacy	3.687	1.796	0.098*	0.146**	0.112	0.085

Note. N = 440. R^2 = 0.441**.
Dependent Variable: Average Exam Score for CHEM 184.
**p < 0.01 and *p < 0.05 for 2-tailed.

The second block was regressed on CHEM 184 exam scores to determine if the remaining predictors with significant *zero*-order correlations were also significant in the multiple regression. The independent variables removed from the previous regression were the three with little to no impact on the model as well as the gender variable. The multivariate outlying cases in the first block regression were re-instated. No Mahalanobis distance exceeded the maximum threshold of 27.9 for nine degrees of freedom.

Of the nine independent variables, two had *p*-values greater than 0.1, two between 0.05 and 0.1, and five predictors fell below the 0.05 cut-off for significance. Full results can be seen in Table 8. The ethnicity variable for Caucasian and completion of high school chemistry, were removed from the regression analysis since their p > 0.1. High school credit hours and first time freshman had a non-significance value of 0.079 and 0.090, respectively. Although these values exceeded the 95% confidence interval, the predictors were not removed at this time in order to verify influence from potential mediation or moderation.

Table 8

Regression II: Significant predictors only for CHEM 184.

Variable	*B*	*SE B*	β	Zero-order	Partial	Part
Calculus	3.552	1.231	0.113**	0.290**	0.132	0.101
Caucasian	2.727	1.346	0.059	0.168**	0.075	0.057
Credit Hour	0.125	0.067	0.072	0.303**	0.084	0.064
Freshman	2.047	1.457	0.079	0.281**	0.088	0.066
GPA	8.197	2.003	0.190**	0.464**	0.202	0.157
HS CHEM	1.887	1.505	0.049	0.162**	0.064	0.049
Math ACT	1.416	0.178	0.337**	0.530**	0.340	0.274
PLUS 184	0.961	0.169	0.210*	0.143**	0.102	0.078
Pharmacy	2.913	1.554	0.080**	0.297**	0.257	0.202

Note. N = 448. R^2 = 0.432**
Dependent Variable: Average Exam Score for CHEM 184.
**p < 0.01 and *p < 0.05 for 2-tailed.

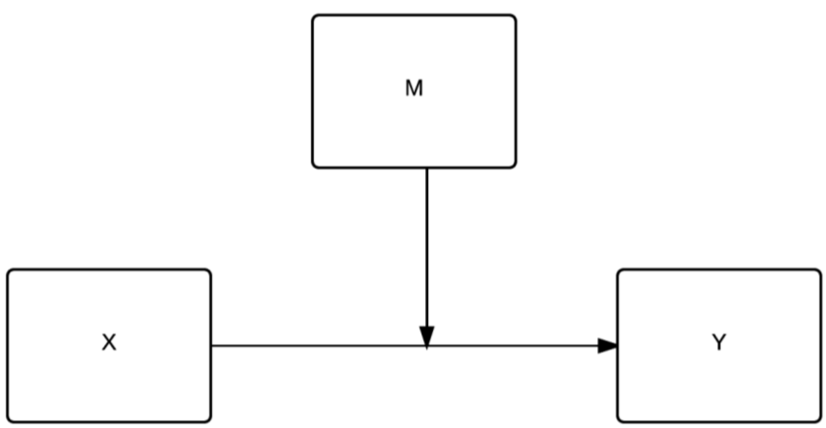
Moderation

Moderation in the education or behavioral sciences happens when a predictor alters the magnitude, direction, or strength of the relationship between another independent variable and the dependent variable in a regression. The casual slogan for moderation is “it depends,” meaning the slope of the regression will vary depending upon the sub-group within the moderator (Hayes, 2013a, p. 8; Keith, 2006, p. 168). Whereas Frazier et al. use the language of moderates as “for whom” or “when” while describing the relationship between the independent and dependent variables (2004).

A moderator (M) can include either a dichotomous or a continuous variable which is multiplied by the independent variable (X). This new variable (XM), known as the interaction term, is entered into the regression in the subsequent step. For a moderation effect to be seen, the interaction term as well as the ΔR^2 must both be significant. Often times the moderator and independent variable are grand mean centered prior to multiplication to curtail multicollinearity (Cohen et al., 2003).

Model 1. The variable gender showed a telltale sign of moderation by its *zero*-correlation coefficient lower than its part and partial correlations. A moderation analysis was conducted with the assistance of Andrew F. Hayes' PROCESS macro in SPSS. Regression III was a simple moderation regression, which was investigated with gender as the moderator (M), CHEM 184 scores as the dependent variable (Y), and cycling through the predictors as the independent variable (X) being moderated. PROCESS *Model 1* was used for this analysis; the conceptual diagram is provided below in Figure 10. The remaining variables were not controlled during the regression to minimize complexity. Results for Regression III can be found in Table 9.

Figure 10
Conceptual Diagram of Simple Moderation, PROCESS Model 1.



Note. Full template models including statistical diagrams for PROCESS are available through Professor Hayes' website (2013).

There was strong evidence ($p \approx 0.000$) to support that high school GPA was moderated by gender for Chemistry 184, meaning the strength of relationship between GPA and exam scores depended whether the student was male or female. The corresponding PLUS sessions were also moderated by gender in the simple regression of 184 exam scores. This statistically significant moderation interaction was found to increase the validity of this elementary model by an $R^2 = 0.014$.

Since basic moderation was found in the regression between gender and two variables, all variables subsequently were analyzed against the dependent variable regardless to test for evidence of moderation. Further testing was conducted to describe the data with the best possible representation. A total of 28 regressions were conducted with the simply moderation *Model 1* analysis and only four interactions were found to impact the model in a significant way. Two of those interactions involved gender and the results were mentioned in the previous paragraph.

The first additional interaction included high school GPA which was possibly moderated by math ACT. The p-value for the interaction teetered on the brink of significance with $p = 0.049$. The last notable interaction occurred between attendance for the PLUS 184 sessions and pre-track pharmacy students. The level of significance was found to be $p = 0.002$ with increased the R-squared by 0.018. The complete results can be found in the supplements section in Table 41 however, an abridged version showing only the significant interactions can be found in Table 9.

Table 9

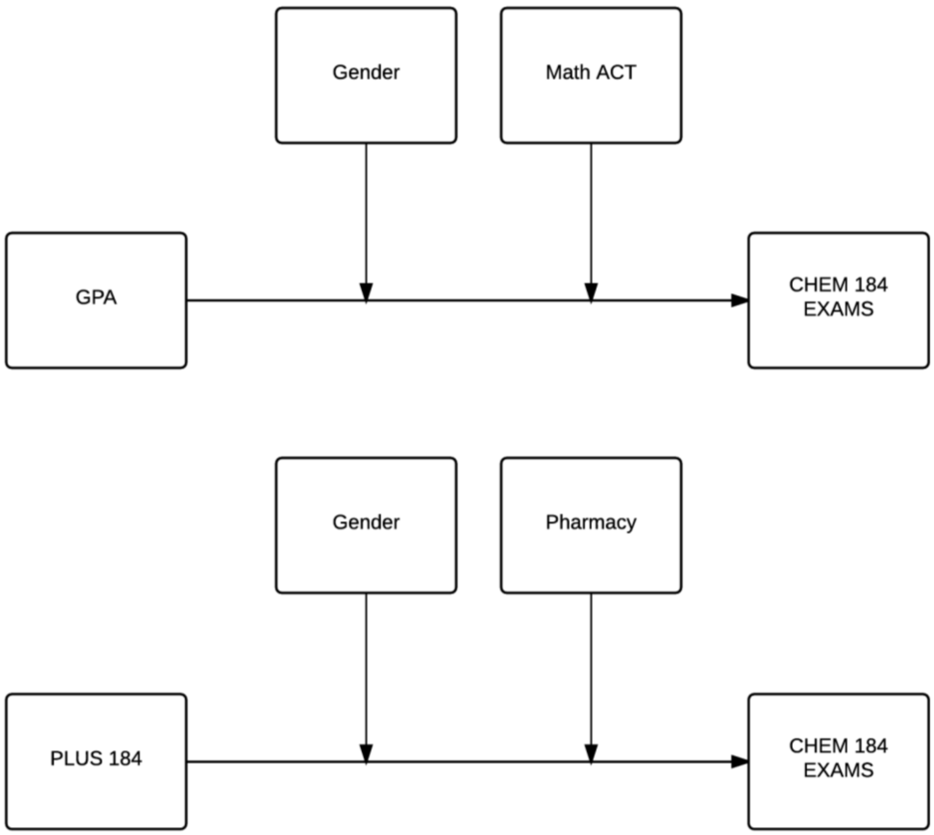
Regression Coefficients for Regression III, PROCESS Model 1.

Moderator	Variable	*B*	*SE B*	R^2	ΔR^2
Gender	HS GPA	-14.105**	4.047	0.250**	0.021**
Gender	PLUS 184	-1.104*	0.424	0.103**	0.014**
Math ACT	HS GPA	0.784*	0.426	0.350**	0.006*
Pharmacy	PLUS 184	-1.600**	0.503	0.121**	0.018**

Note: N = 448. Dependent Variable = Average Exam Scores for Chemistry 184.
**p < 0.01 and *p < 0.05 for 2-tailed.

Model 2. Two more complex moderation models were also analyzed. The two moderators model was introduced to determine if high school GPA was doubly moderated by gender and math ACT score. This regression was conducted by the PROCESS *Model 2*, which has two interaction terms as seen in Table 10 however the conceptual diagram in Figure 11. For this Regression IV model, the independent variable was high school GPA with the dependent variable CHEM 184 exam scores and the two moderators. Both interactions were found to be significant at $\alpha = 0.05$ level and together increased the explained variance by 0.017. Without the controlling for the four other predictors, this model appeared to be an improved fit.

Figure 11
Conceptual Diagrams of Regressions IV and V with Double Moderation, PROCESS 2.



The second *Model 2* regression looked at gender and pre-pharmacy students interacting with the number of PLUS sessions attended. Both individual interaction were significant, PLUS with gender $p = 0.002$ while PLUS and pre-pharmacy values was slightly larger at $p = 0.004$. Overall, the enhanced fit of the regression was just slightly less than twice of when GPA was the independent variable ($\Delta R^2 = 0.036$).

Table 10

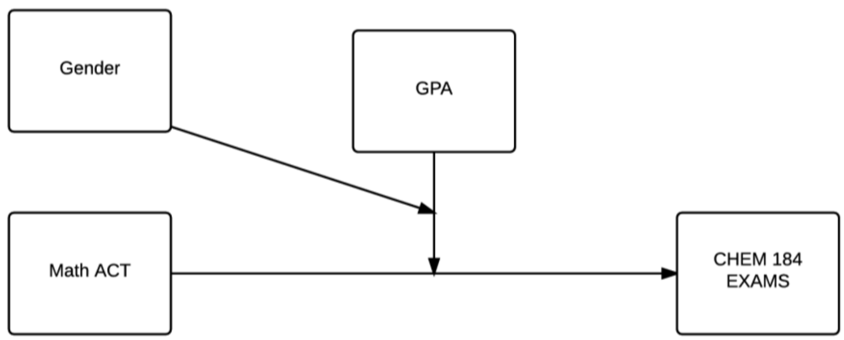
Regression Coefficients for Regression IV and V, PROCESS Model 2.

Regression	Interactions	*B*	*SE B*	R^2	ΔR^2
Regression IV					
	GPA x Gender	-10.471**	3.826		
	GPA x Math ACT	0.922*	0.429		
	Both			0.362**	0.017**
Regression V					
	PLUS x Gender	-1.667**	0.501		
	PLUS x Pharm	-1.212**	0.210		
	Both			0.140**	0.036**

Note: N = 448.
Dependent Variable = Average Exam Scores for Chemistry 184
Predictors: Gender, GPA_{HS}, Math ACT, Pharmacy, PLUS 184
**$p < 0.01$ and *$p < 0.05$ for 2-tailed.

Model 3. The last strictly moderation model involved a moderated moderator for the two regressions, where 1) gender moderated GPA, which subsequently moderated math ACT scores seen in Figure 12 and 2) PLUS was moderated by gender and pre-pharmacy students, and possibly an interaction between all three variables. These two separate regressions were analyzed by *Model 3* from PROCESS. The independent variable for the first case involved which GPA in *Model 2* was replaced by math ACT scores since high school GPA linked the two other variables. This model totaled four interactions including the two from the previous two moderators' model. Math ACT score was multiplied by gender for the third interaction. Finally, a three way interaction of GPA, math ACT, and gender were added to the regression.

Figure 12
Conceptual Representation of Regression IV, Model 3.



All independent variables in the interaction were mean centered. With the new regression, the only significant interaction was between GPA and gender. Even the GPA and math ACT interaction which was significant in *Model 2* had a *p*-value of 0.276. The three way interaction provided no notable increase to the model. As seen in Table 11, the explained variance in the moderated-moderator model did have a larger *R*-squared value at 0.374 compared to 0.362 with the two moderators. Despite this difference, the three way interaction was not significant so this model was not superior.

Regression VII with the *Model 3* had a comparable outcome. The additional interactions this model provided were not significant. These two interactions were gender multiplied with pre-pharmacy students and the three-way interaction between PLUS, gender, and pharmacy with respective *p*-values of 0.726 and 0.426. The number of PLUS sessions was not mean centered for this model unlike the previous one for interval and ratio level variables. Zero on this scale represented the comparison group and thus mean centering would provide less meaningful results. The model did not provide a better explanation of chemistry exam scores so it was not used.

Table 11
Regression Coefficients for Regression VI and VII, PROCESS Model 3.

Regression	Interactions	*B*	*SE B*	R^2	ΔR^2
Regression VI					
	GPA x Gender	-18.143**	5.156		
	GPA x Math ACT	0.610	0.471		
	Math ACT x Gender	0.170	0.374		
	Math ACT x Gender x GPA	-0.711	0.925	0.374**	0.001
Regression VII					
	PLUS x Gender	-1.423**	0.427		
	PLUS x Pharm	-2.007**	0.517		
	Gender x Pharm	1.791	3.966		
	PLUS x Gender x Pharm	0.868	0.482	0.114**	0.001

Note: N = 448.
Dependent Variable = Average Exam Scores for Chemistry 184
Centered Predictors: Gender, GPA_{HS}, Math ACT, Pharmacy
Non-Centered Predictor: PLUS 184
**p < 0.01 and *p < 0.05 for 2-tailed.

Hieratical Moderation Model. Gender exhibited moderation effects in *Models 1* and *2* on high school GPA and PLUS sessions with the absence of several predictors. Students who declared as pre-pharmacy also scored differently on exams than other students categories who attended a comparable number of PLUS sessions. Thus the complete regression was required to determine if gender and pre-pharmacy were the only moderators or math ACT scores also moderated high school GPA. Limitations for the PROCESS function ensued as it became essential to control for variables in a hierarchical fashion. The two moderation interactions were calculated by multiplying mean centered GPA with each mean centered gender and math ACT scores. Both of these interaction terms were placed in the second block of the multiple regression in order to verify the number of moderators. In the third block, PLUS sessions were entered in the regression, followed by the interaction terms which were the products of PLUS sessions with each gender and pre-pharmacy students.

The new hypothesis examined if the relationship between number of PLUS sessions and performance on chemistry exams was moderated by gender and math ACT scores for high school GPA while controlling for college hours earned in high school, completed calculus, and pre-pharmacy track student. The second set of moderation pertained to the number of PLUS sessions attended being moderated by gender and pre-pharmacy students.

As seen in Table 12, two of the four interaction terms were significant in the whole regression model. Only gender moderated high school GPA and pre-pharmacy moderated the number of PLUS sessions, and thus these interactions remained in the analysis. Math ACT score did not produce statistically significant results for moderation of GPA and neither was the PLUS-gender interaction. The non-significant interactions were removed from the regression.

Table 12

Hierarchical Regression VIII Analysis Determining Moderators for Chemistry 184.

	Consequent					
	Chem 184 *Exams*		*Chem* 184 *Exams*		*Chem* 184 *Exams*	
Antecedent	*B*	*SE B*	*B*	*SE B*	*B*	*SE B*
Calculus	3.266**	1.252	3.074*	1.211	3.021*	1.209
Gender	1.465	1.276	1.657	1.234	2.208	1.478
HS Credit	0.116	0.071	0.119	0.069	0.130	0.069
HS GPA	1.467**	0.187	1.491**	0.181	1.464**	0.182
mACT	14.625**	2.543	12.432**	2.489	12.022**	2.503
Pharmacy	4.082*	1.591	3.434*	1.542	5.946**	1.945
GPA x Gender	-9.272	3.824	-5.518	3.756	-5.378*	3.799
GPA x mACT	0.673	0.444	0.667	0.429	0.584	0.433
PLUS	–	–	0.961**	0.171	0.999**	0.174
PLUS x Gender	–	–	–	–	-0.145	0.355
PLUS x Pharm	–	–	–	–	-0.853*	0.409
	R^2 = 0.389**		R^2 = 0.433**		R^2 = 0.439**	
	F (8,439) =35.166		F(9,437) = 36.961		F(11,435) = 30.817	
	ΔR^2 = 0.010*		ΔR^2 = 0.041**		ΔR^2 = 0.006**	

Note: N = 448.
Dependent Variable = Average Exam Scores for Chemistry 184
Centered Predictors: Gender, GPA, Math ACT, Pharmacy, Credit Hour
Non-Centered Predictor: Calculus, PLUS 184
**p < 0.01 and *p < 0.05 for 2-tailed.

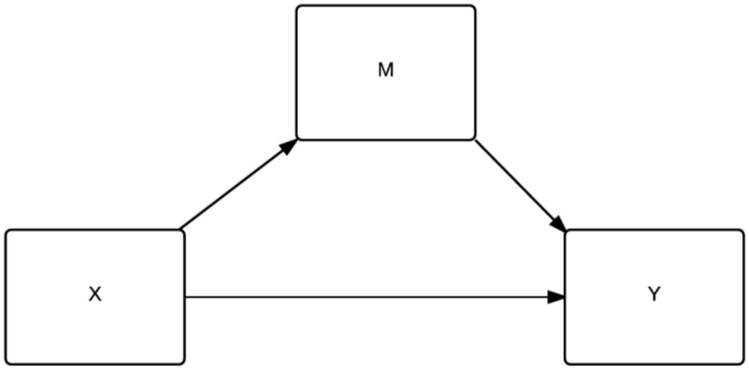
Mediation

With the establishment of moderation in the overall model, mediation was also considered for a better explanation of the current model. Mediation follows a more theoretical understanding of the variables as one independent variable causes a second independent, which in turn effects the dependent variable. The second independent variable is defined as a mediator and often answers “how” or “why” the independent and dependent variables are related (Frazier et al., 2004). By its nature, mediation will involve continuous variables and not dichotomous ones. This fundamentally reduced the variables of interest to high school GPA, high school credit hours, and math ACT scores. As seen in the previous moderation analysis, GPA and math ACT scores interacted with each other; however, no moderation relationship could be established once all the predictors were added. Due to the continuous nature of both variables, it was possible that mediation was taking place rather than moderation. Lastly, although the number of PLUS sessions was a continuous variable, it was not investigated since it's the experimental variable of this research and theoretically independent in nature from the remaining variables.

As stated above, mediation is often thought to be a cause-effect relationship or a directional relationship; therefore, it is imperative the variables follow in a chronological order (Baron, 1986). The variables of interest were not exclusively time sensitive, thought, it became necessary to evaluate which variable was the independent variable and which was the mediator. For example, the high school GPA value was a compilation of grades over the four-year period of high school. Typically high school students would earn the majority of their college credits during their senior year and perhaps a few during their junior year. Math ACT scores were even more diverse since it was common for students to take this exam once or even multiple times between mid-sophomore year through senior year.

Unlike moderation where the interaction term is simply added in the next step of the regression analysis, mediation involves two separate regressions. The first regression has the independent variable (X) with the mediator (M) as the outcome variable, then the second regression has both variables X and M regressed upon the dependent variable (Y). See Figure 13 for a flow diagram. For a significant mediation effect to be seen, X must be significant in the first regression and M must be significant in the second regression. In addition both models must have *p*-values less than 0.05. In a fully mediated model, X will not be significant when Y is the consequent and partially mediated when X is a significant predictor in the second regression (Frazier et al., 2004; Keith, 2006, pp. 168– 169).

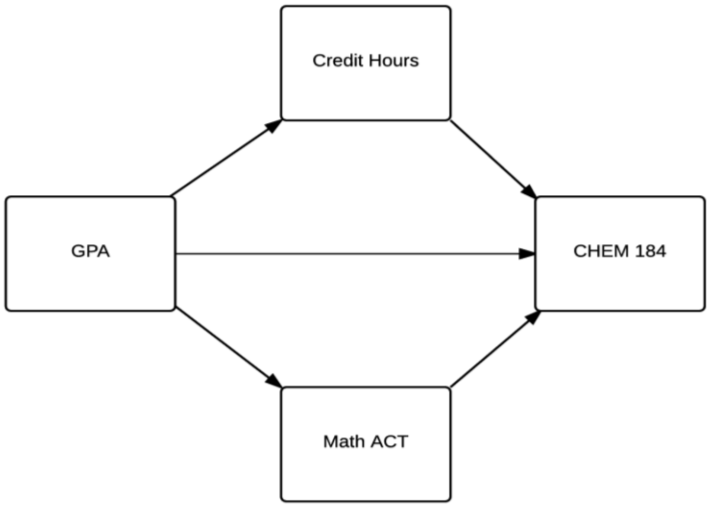
Figure 13
Conceptual Diagram of Simple Mediation, PROCESS Model 4.



The credit hours earned in high school could be a mediator for GPA with a Pearson's $r = 0.394$.** Even with the same correlation, the inverse relationship where GPA would mediate credit hours does not make theoretical sense for the reason that GPA preceded the ability to earn college credit in high school. A similar situation occurred with high school GPA and the highest math ACT score. Fundamentally, math ACT score should mediate high school GPA and not the reverse. The simple correlation for these two variables equaled 0.439^{**}. The interaction between math ACT scores and high school earned college-credit was ambiguous. The correlation between the two variables was smaller at $r = 0.265^{**}$ but significant nonetheless.

Model 4. To simplify the analysis, a regression which involved mediators was credit hours and math ACT scores each mediated grade-point average. PROCESS *Model 4* was used to investigate the continuous variables so both potential mediators were entered into M block of the regression with GPA entered as the independent variable and exam 184 scores as the dependent as seen in Figure 14.

Figure 14
Conceptual Diagram of Regression IX with Two Mediators, PROCESS 4.



In a mediator analysis, several regressions must be conducted. First, the regression has the independent variable in this case high school GPA regressed upon the mediator. If the independent variable was found to be significant with the potential mediator as the consequent, the model does have mediation. PROCESS analyzes each moderator separately, resulting in two preliminary regressions for this study. As seen in Table 13, high school GPA significantly predicted credit hours with an unstandardized coefficient of 10.508 at a 95% confidence interval. Similarly, math ACT scores predicted mediation of GPA with $B = 4.910$ with an approximate p-value of zero.

To complete the mediation analysis, the subsequent regression contained all mediators as independent variables and the dependent variable was restored to the studies original variable. Therefore, the consequent becomes Chemistry 184 exam scores. All three independent variable have $p < 0.05$ in a significant model where $F(3{,}444) = 83.784$, which concluded that math ACT and high school credit hours were independent or parallel mediators in this model.

Table 13
Regression Coefficients for Regression IX, PROCESS Model 4.

	Consequent								
	Credit Hours			Math ACT			CHEM 184 Exams		
Antecedent	*B*	*SE B*	β	*B*	*SE*	β	*B*	*SE B*	β
HS GPA	10.50**	1.201	0.408	4.910**	0.95	0.447	11.569**	2.128	0.262
Credit Hours	-	-	-	-	-	-	0.162*	0.072	0.081
Math ACT	-	-	-	-	-	-	1.636**	0.174	0.401
	$R^2 = 0.166$**			$R^2 = 0.185$**			$R^2 = 0.361$**		
	$F(1,446) = 11.94$			$F(1,446) = 100.99$			$F(3,444) = 83.78$		

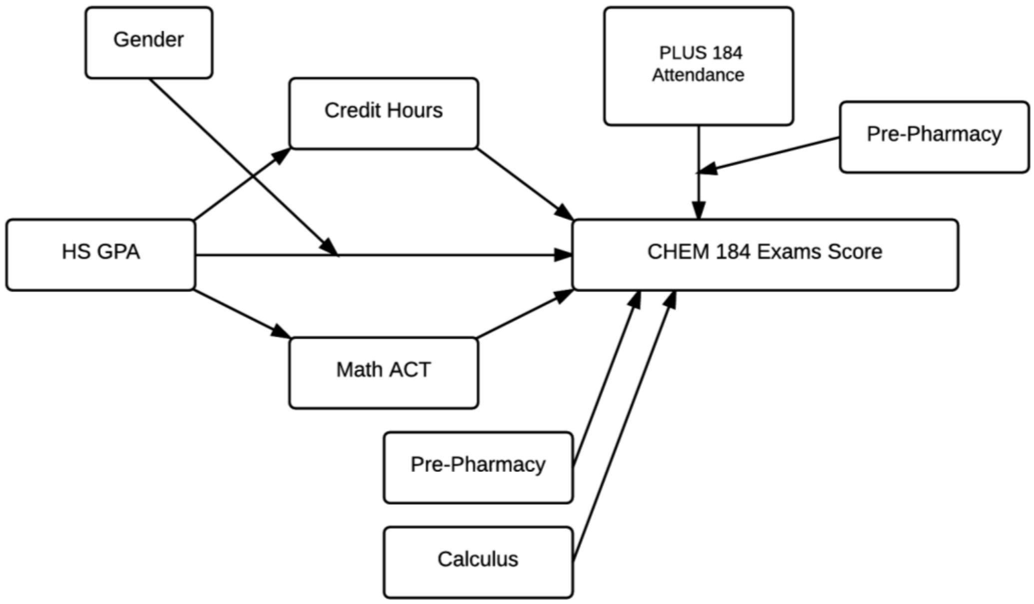
Note. N = 448. **$p < 0.01$ and *$p < 0.05$ for 2-tailed.

Moderated-Mediator Model

The hierarchical multiple regression was conducted in order to test the revised research hypothesis once moderation and mediation were established. The first regression laid the foundation for mediation by placing credit hours as the dependent variable. The variable GPA was entered into the first block while the remaining variables including calculus completed, gender, and pre-pharmacy students were analyzed in block two. No interaction term was entered for this step. The second regression was conducted by only replacing the first mediator with the second, credit hours with math ACT scores.

The first step on the third regression consisted of math ACT scores, high school credit hours, completion of calculus, gender, high school GPA, pre-pharmacy student and the GPA-gender interaction with average exam scores for Chemistry 184. Math ACT scores was a mediator in this model so a moderating interaction was not added. The second block or treatment block in the multiple regression was the addition of the number of PLUS sessions attended. Finally, the last step of the analysis was the product term of number of PLUS sessions attended with the pre-pharmacy students. Figure 15 is the pictorial representation.

Figure 15
Conceptual Diagram of Regression X with Moderation and Two Mediators.



All assumptions of this multiple regressions have been met. Exam score achievement for Foundations of Chemistry I was a linear function of the independent variables in the model and has equal variance across all the independent variables. Six multivariate outliers were identified as having excessively high Malahonabis distances and were removed. The analysis was repeated with the smaller data set. Outliers were once again evaluated using Malahonabis distance; however, no further cases appeared to be outlying.

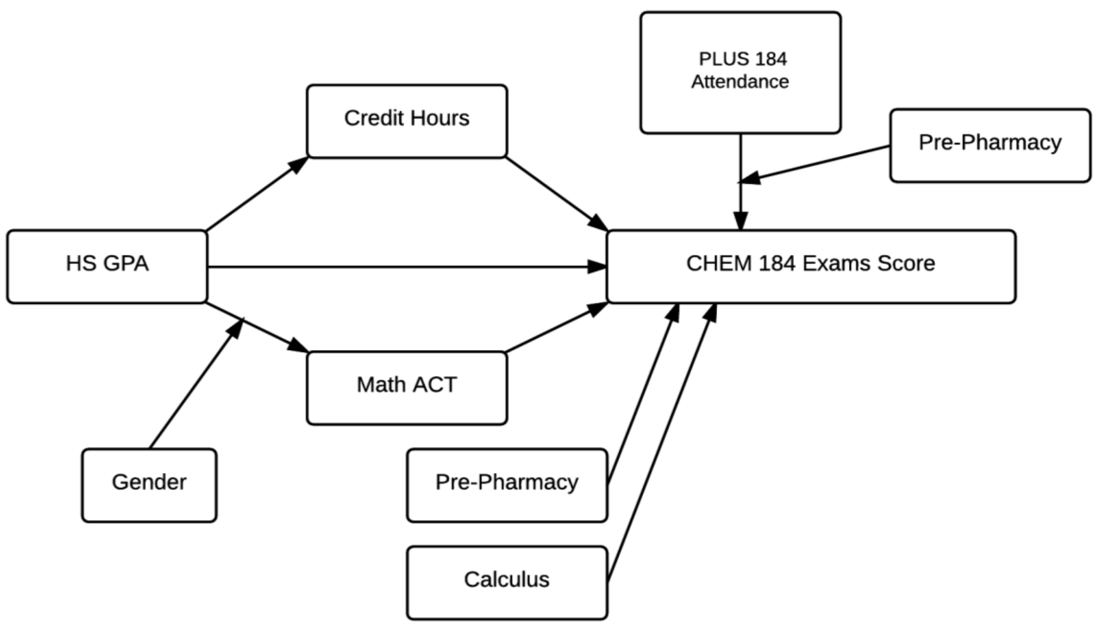
The initial regression failed to show the moderation interaction of the GPA-gender product was significant when regressed upon the average exam score in the two mediator model. To be sure gender was not interacting with the GPA in the mediation regression, gender was set to moderate high school GPA when the mediators where the dependent variable as opposed to exam scores. This was investigated by adding both the gender variable and the GPA-gender interaction as independent variables when mediators were the consequent in the regression. Gender and the high school GPA-gender interaction were significant at moderating the relationship between GPA and math ACT scores. The analysis once again was modified in light of the new findings.

Comprehensive 184 Model

The adjustment from the previous model to the current, Regression XI, transformed the moderation of GPA by gender from when the variable, average exams scores, was the dependent variable to the meditation regression with high school credit as the consequent. This slight alteration now includes gender and its interaction term in the mediation regression along with the variables of high school GPA, pre-pharmacy, and calculus. The new conceptual diagram,

Figure 16, reflected the gender moderator adjustment.

Figure 16
Conceptual Diagram for the Chemistry 184 Comprehensive Model.



The linear regression model fit was statistically significant for each regression conducted. The model fit for the mediators variables was ($F(5,436) = 37.956$, $p \approx 0.000$) with an $R^2 = 0.303$ when the consequent was math ACT scores and a $R^2 = 0.183$ with $F = 19.553$ reflecting the same degrees of freedom and *p*-value. High school GPA had a *p*-value of approximately zero for both regressions which was absolutely essential for the model to include mediation. Similar betas were recorded for high school GPA and pre-pharmacy students in each regression, but the additional predictors of gender, its moderation interaction, and calculus completed variables made the explained variance for the math ACT model more inclusive.

As seen in Table 14, gender did moderate the high school GPA and math ACT score relationship which was manifested by the significant *p*-value of 0.004 for the interaction term in the Regression XI. The negative coefficient of GPA-gender interaction, $B = -3.232$, provides a correction factor to increase the predicted math ACT scores for females with higher than average GPA scores. This also corrected the over inflation of predicted exam scores for males with high GPAs. This same effect was not seen when high school credit was the dependent variable and gender likewise was not a significant contributor.

Table 14

Regression Coefficients for Regression IX.

	Consequent					
	Credit Hours			Math ACT		
Antecedent	*B*	*SE B*	β	*B*	*SE B*	β
GPA	11.726**	1.394	0.423	5.506**	0.542	0.473
Gender	-0.329	0.812	0.018	2.299**	0.315	0.305
GPA x Gender	-4.82	2.633	-0.085	-3.232**	1.022	-0.136
Pharmacy	0.846	1.088	0.034	0.310	0.423	0.03
Calculus	0.908	0.808	0.051	1.711**	0.314	0.227
	$R^2 = 0.183$**			$R^2 = 0.303$**		
	F(5,2436) = 19.553			F(5,436) = 37.960		
	(Exam 184 Scores)			(Exam 184 Scores)		
Antecedent	*B*	*SE B*	β	*B*	*SE B*	β
GPA	10.982**	2.111	0.232	8.876**	2.054	0.187
Credit Hours	0.163*	0.071	0.096	0.172*	0.069	0.101
Math ACT	1.518**	0.173	0.373	1.528**	0.166	0.376
Pharmacy	4.759**	1.617	0.112	6.947**	1.987	0.169
Calculus	3.063**	1.237	0.100	2.819*	1.188	0.092
PLUS	-	-	-	1.024**	0.168	0.227
PLUS x Pharm	-	-	-	-1.039*	0.41	-0.120
	$R^2 = 0.382$**			$R^2 = 0.434$**		
	$\Delta R^2 = 0.382$**			$\Delta R^2 = 0.052$ **		
	F(5,436) = 53.929			F(7,434) = 47.543		

Note. N = 442. **p < 0.01 and *p < 0.05 for 2-tailed.

Calculus was furthermore a significant predictor in the math ACT mediation. Several interactions with the calculus were inspected for moderation between GPA in math ACT as well as Chemistry 184 exam scores regression. The interaction terms were not significant indicating the null hypothesis that the calculus variable fails to show an establish moderation relationship with math ACT scores. Mediation, or more specifically serial mediation was not investigated as a potential route since the calculus variable was dichotomous.

The analysis of Regression XI continued when Chemistry 184 exams scores became the dependent variable. The five independent variables included were high school GPA, credit hours earned in high school, math ACT scores, pre-pharmacy students, and calculus completed. Since gender was moderating GPA as it effected math ACT scores, this variable and the corresponding interaction were not included in this part of the analysis. All five predictors were significant with math ACT having the largest beta weight followed by GPA with respective values of 0.373 and 0.232. The three remaining predictors had similar beta-values hovering close to 0.1. Exact values pertaining to this regression can be found in Table 14.

The addition of the treatment variable, number of PLUS sessions attended, the model had a significant change in the variance, $\Delta R^2 = 0.052$, p ≈ 0.000. The comprehensive model had a significant model fit (F(7,434) = 47.543, $p \approx 0.000$). Just over forty-three percent ($R^2 = 0.434$) of the variance could be accounted for in Chemistry 184 exam scores when controlling for high school credits, calculus completed, math ACT scores, pre-pharmacy students, and number of PLUS sessions attended and its relationship moderated by self-identified pre-pharmacy students. The pharmacy variable and its interaction with PLUS was not grand mean centered in this regression since this did not change the significance of any predictors. This was solely done for ease of interruption.

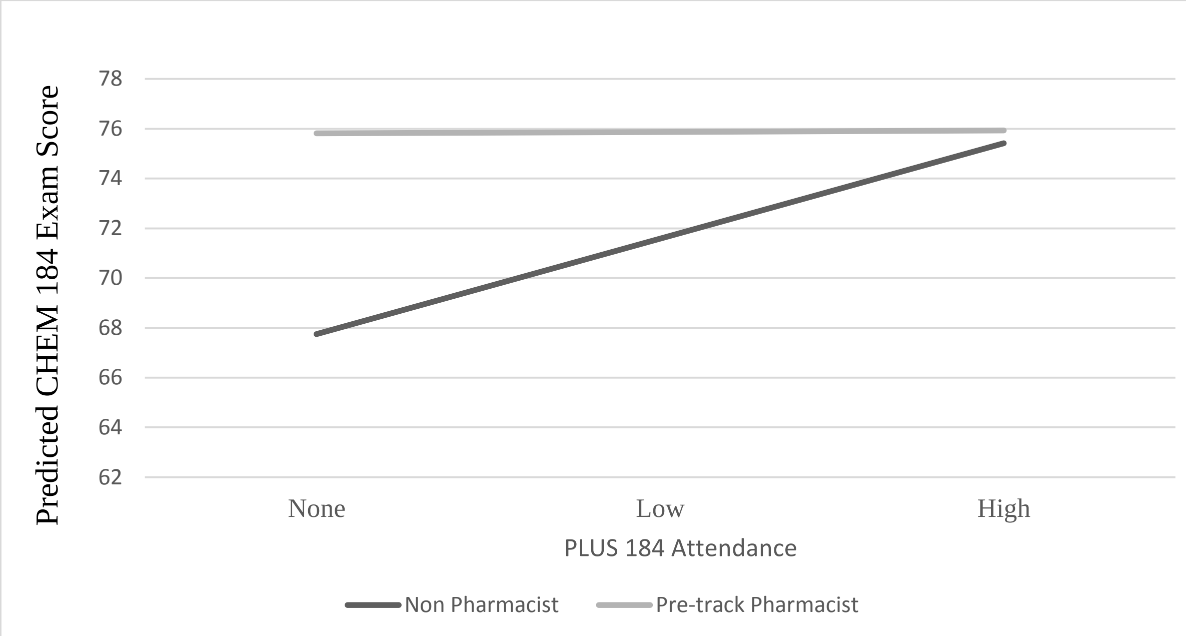
All predictors were found to be significant at an α-level of 0.05 in the concluding analysis. The most significant predictor for this model was math ACT score with a beta weight of 0.376 and an approximate *p*-value of 0.000. High school GPA was a medium sized predictor with the impact on the model of $\beta = 0.187$ and $p \approx 0.000$ as trailed by pre-pharmacy students with $\beta = 0.169$, p = 0.001. Calculus completed and high school credits have similar beta weights in the model with coefficients of 0.092 and 0.101 respectively.

The experimental interest of this research was the number of PLUS sessions attended had a significant positive beta value of 0.227. The total PLUS sessions that were offered during the fall semester was thirteen. In theory if a student attended all PLUS sessions, that student could have increased his or her average exam scores by 13.3% above expected success from incoming academic readiness and background variables.

Lastly, PLUS attendance was moderated by the student's declaration for pre-pharmacy. This negative effect was about half the beta weight but nearly identical magnitudes of *B*-values with 1.039 instead of 1.024, just the opposite sign. The conditional effect of moderation was not significant for pre-pharmacy, which essentially stated that PLUS sessions have negligible impact on these students. The moderation term corrected the regression by subtracting out the PLUS sessions for the pre-track pharmacy students. Figure 17 depicted the direct relationship in predicted exam scores of Chemistry 184 by non-pharmacy track individuals for the PLUS sessions attended. There was virtually zero slope by the students aspiring to be pharmacist, which indicated pre-pharmacy students did not see appear to benefit in the same manner of increased exam scores.

Figure 17

Moderation Effect for Pre-pharmacy on PLUS sessions for Chemistry 184 exam scores.



The comprehensive model was inspected for multicollinearity by calculating the tolerance of each independent variable. The general rule of thumb theorizes that tolerance levels less than 0.1 indicate severe multicollinearity and should be modified. The uncorrected variables could increase standard error and change magnitude along with direction of their corresponding beta weights. Tolerance values that range from 0.1 to 0.25 designate slight multicollinearity and should be further inspected however no manipulation was necessarily required (Pedhazur, 1997).

All tolerance levels were within the range of 0.5 to one for this regression. The controlled interaction between gender and GPA not was grand mean centered and did pose any concerns. Since pre-pharmacy was a dichotomous variable, tolerance levels were high enough not to be a concern despite the interaction was not mean centered. There was a theoretical understanding these two variable would have lower tolerance levels from the moderation in the regression and were not problematic.

The final check was performed to verify all the assumptions had been met. The comprehensive regression was conducted again; however, Chemistry 184 exam variable was replaced by its Box-Cox transformation. No predictors became insignificant and beta values did not fluctuate. As result, the mild lack of normality fail to impact the model; thus all assumptions were met with the untransformed dependent variable.

Chemistry 184 Predicted Equation. The comprehensive model was represented below in Equation 2. The mean of 3.72 was subtracted off the GPA variable, to be consistent with grand mean centering. This model accounts for nearly 44% of the explained variance for chemistry 184 exam scores.

Equation 2

$$\hat{y} = 24.246 + 8.876(\text{GPA}-3.72) + 0.172(\text{Credit Hour}) + 1.528(\text{Math ACT}) + 6.947(\text{Pre-Pharmacy}) + 2.819(\text{Calculus Completed}) + 1.024(\text{PLUS 184}) - 1.039(\text{PLUS 184})(\text{Pre-Pharmacy})$$

Direct and Indirect Effects

Background. The direct and indirect effects provide a capstone in a mediation model. The direct effect is the estimation between two cases that span exactly one unit on the scale for the independent variable (X) variable and consequently how dependent variable or the consequent (Y) is effected independently of the mediator (M). The direct effect is the coefficient of X when regressed on Y in simple mediation. If the direct effect is significant ($p < 0.05$) in the final regression when Y is the consequent, then the model is partially mediated. However, if the coefficient for X is not significant, then the model is full mediated (Keith, 2006, p. 169).

The indirect effect involves the path between the independent variable to the mediator and then from the mediator to the dependent variable. The most common practice in social science is to calculate the indirect effect by the Normal Theory or product of coefficient approach for simple mediation (Hayes, 2013a, pp. 349 – 350). Essentially, the regression coefficient of X while regressed on M is multiplied by the coefficient of M when regression on Y. Coefficient product may either both be standardized or unstandardized. The calculation of standard error for indirect effect is vital to determine if the indirect effect is significant, confirming that mediation is occurring. The standard error can be estimated several ways including the traditional Sobel test and through bootstrapping.

In this study, the PROCESS macro in SPSS was used to determine indirect effects with bias corrected bootstrapping confidence intervals, which were 95% and sampling 1,000 times. All effects were measured on the final regression which included the PLUS attendance variable and any possible interactions. Therefore, when the independent and potential moderator variables were regressed on the mediator, the coefficient for this analysis were slightly different due to controlling for the treatment variable.

When moderation occurs within a mediation model, conditions are applied to either direct or indirect effect depending where the moderation is occurring. If the relationship between X and Y is moderated, then the direct effect becomes conditional. However, if either the X and M or the M and Y relationships are moderated then indirect conditional effects is calculated.

Direct Effect. The direct relationship between GPA and the average exams was not moderated by either variable; therefore, the direct effect was simply the coefficient of 10.982 for high school GPA when regressed on average exam scores. The model was only partially mediated since the direct effect is significant.

Conditional Indirect effect. In this moderated mediation analysis, the high school GPA indirectly influences both the amount of credit hours earned in high school and math ACT scores while predicting average exam scores for Chemistry 184. The addition of gender moderating the relationship of GPA, the indirect effect cannot be measured strictly by the coefficient of products. Rather, the magnitude of indirect effect depended on a condition, which in this case was gender. The statistical diagram for PROCESS *Model 7* was referenced to determine the how the indirect effects changed (Hayes, 2013b). The moderation coefficient was multiplied by the gender variable then added to GPA coefficient when regressed on each mediator. Two separate effects are seen in Table 15 for each mediator due the moderation by gender, totaling four conditional indirect effects.

Table 15
Conditional Indirect Effects for Chemistry 184 Regression.

Mediator	Gender	Effect	SE	LLCI	ULCI
Credit Hour	Female	2.448	1.054	0.705	4.870
Credit Hour	Male	1.609	0.669	0.463	3.08
Math ACT	Female	10.873	1.900	7.651	15.183
Math ACT	Male	5.756	1.193	3.665	8.350

Note. N = 442. **p < 0.01 and *p < 0.05 for 2-tailed.

All four conditional effects are significant since their corresponding confidence interval does not contain zero. High school GPA had a larger impact on female students predicting exam scores which is represented by the indirect effect nearly twice as higher than males. GPA has a greater influence on exams scores through the math ACT path than the high school credit hours. Significant conditional effects are detailed in Table 15 for females and males with high school credit as the mediator despite the fact that gender did not actually moderate this relationship. The female effect of 2.448 and male with a value of 1.609 are not statistically different from each other so a basic product of coefficient indirect effect of 2.06 is more meaningful.

Discussion

The revised hypothesis was supported as seen by the empirical evidence provided from the multiple regression. All predictors from the hypothesis in this model were significant including the direct effect providing a partially mediated model. High school GPA was mediated by math ACT scores and the computed credit hours variable. The model became even more complex when gender was identified as moderating GPA scores in a buffering capacity through math ACT scores. The male students began with a higher intercept coefficient when predicting math ACT scores; however, in general females performed statistically higher with comparable increase in grade-point average. The most influential predictor was math ACT score with higher achievement on average exam scores in Chemistry 184.

The variable of interest, PLUS attendance for Chemistry 184, was significant and the second highest predictor in this model when predicting average exam scores. Each PLUS session attended increased 184 exam scores on average by one percent. The model fit increased from 0.382 to 0.434, which provided an increase in explained variance by just over five percent for the PLUS variable and its corresponding interaction while controlling for high school GPA, math ACT scores, credit hours earned in high school, and calculus completed prior to starting the Foundations of Chemistry course.

The pre-pharmacy track students did moderate the PLUS-exam score relationship, which negated the gain from attending those PLUS sessions. There are several conceivable explanations why this group of students did not appear to benefit of PLUS: (1) Pre-pharmacy students predicted average exam score was eight units higher than non-pharmacy so their ability to gain from PLUS sessions is sustainably lower, (2) cofounding factors such as motivation through a sense of urgency, since these students would be applying for pharmacy school in a year, and (3) the limitation of the exam causing a ceiling effect for a number students, thus dropping the potential predicted scores for chemistry achievement. In the multiple regression, pre-pharmacy students had a y-intercept of 75.8 while students who choose a different major had an intercept of 67.7 when GPA, math ACT scores, and credit hours were controlled through variable centering. The maximum amount of gain possible from PLUS sessions for pre-pharmacy students was 25%; while those who were not pre-pharmacy students was just under 33%. Therefore, the amount a student could increase average exam scores from attending PLUS sessions was lower for pre-pharmacy students.

Although participation in PLUS sessions did not mathematically predict higher exam score for pre-pharmacy track individuals, there could be other benefits not measured in this study such as higher level thinking, application of classroom learning, and peer discussions. Secondly, this group of students may have impacted fellow students through their discussion, insights, and contribution to the peer led model that assist in the success of the PLUS program.

Although gender was not a predictor in the final model when the dependent variable was CHEM 184 exams, females with low GPAs scored consistent and significantly lower than males with similar GPAs or math ACT scores. Females with a higher high school GPA increased more quickly in math ACT scores. Large differences are seen between males and females with low high school GPA’s when predicting math ACT scores. However, those differences in predicting math ACT scores diminish when evaluating students that are one standard deviation above the mean in high school GPA.

The variables that failed to impact the model were completion of high school chemistry, ethnicity, first-time freshman, and students interested in becoming a medical doctor or an engineer.

Multiple Regression for Chemistry 188

The Foundations of Chemistry II may be a continuation of its first semester course; however, the 188 sample demonstrated greater high school academic achievement and other keynote differences. Class averages for high school GPA, credit hours earned in high school, and percentage of student who completed calculus substantially increased. Pre-pharmacy students increased from 15% to 23% of the sample. Furthermore the percentage of females in course rose by five percent. The makeup of the sample evolved and so did the regression analysis.

The Pearson's *r* correlations were re-evaluated after partitioning off the students who did not complete the CHEM 188 final exam. Six cases were deleted from the 188 analysis as being univariate outliers, five of them for high school GPAs that were too low and one additional case with a math ACT score 3.72 standard deviations below the mean of 27.5. This reduced the sample to 248 students. The Pearson's correlations followed a similar trend between the predictors and 188 exam scores. Students who were enrolled in calculus prior to fall 2012, high school credit hours, GPA, math ACT scores, and PLUS 188 sessions had significant *zero*-order correlations with a value higher than 0.150. The comprehensive correlation values can be found in Table 16 under the "Zero-Order" heading. Gender, ethnicity (Asian or Caucasian), and students who aspired to be medical doctors did not have a significant correlation consistent with CHEM 184 results. Pearson's coefficient was significant for first-time freshman, pre-pharmacy track students, and completion of high school chemistry; however, the relationship was weak with $|r| < 0.150$.

Block Regression

Once again, a single block regression was analyzed with all predictors regardless of strength or significance of relationship to exam achievement for Chemistry 188 as Regression I.

The part and partial values were of greater interest to predict any possible moderators or mediators. Gender and pre-pharmacy variables parallel with the Chemistry 184 as potential moderators with partial correlations larger than Pearson's coefficient.

Table 16
Block Regression I: All predictors Chemistry 188.

Predictor	*B*	*SE*	β	Zero-order	Partial	Part
Asian	-0.881	3.121	-0.030	-0.059	-0.026	-0.021
Calculus	1.871	1.697	0.047	0.207**	0.052	0.042
Freshman	-0.307	2.370	0.034	0.144*	0.037	0.030
Caucasian	0.281	2.574	0.005	0.113	0.005	0.004
Gender	2.294	1.719	0.102	0.016	0.113	0.092
HS CHEM.	2.047	2.352	0.045	0.097*	0.054	0.044
Credit Hour	0.219**	0.096	0.129	0.315**	0.141	0.115
HS GPA	16.542**	3.402	0.362	0.488**	0.339	0.291
Math ACT	0.905	0.268	0.231	0.425**	0.225	0.186
Med Doc	-0.098	1.886	0.013	0.037	0.014	0.011
Pharmacy	-1.851	2.199	-0.044	-0.040*	-0.046	-0.037
PLUS 188	0.671*	0.307	0.119	0.182**	0.143	0.117

Note. N = 248. R^2 = 0.362. **p < 0.01 and *p < 0.05 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry 188

The second block regression (II) was analyzed only with the variables that had a significant linear relationship with the CHEM 188 average exam scores. Regression II coefficients are found in Table 17. PLUS 188 attendance and first-time freshman have weak Pearson's value, which might increase the standard errors making the statistically test unreliable. An all-inclusive investigation of potential moderations or mediation would provide justification of including or omitting these variables.

Table 17
Block Regression II: Significant predictors only for Chemistry 188.

Predictor	B	SE	β	Zero-order	Partial	Part
Calculus	1.944	1.650	0.044	0.207**	0.051	0.041
Freshman	0.139	2.204	0.005	0.144*	0.059	0.048
HS Credit	0.205**	0.093	0.114	0.315**	0.126	0.104
HS GPA	15.393**	3.136	0.328	0.488**	0.328	0.283
Math ACT	1.007**	0.248	0.285	0.425**	0.285	0.242
PLUS 188	0.664*	0.303	0.113	0.182**	0.136	0.111

Note: N = 248. . $R^2 = 0.351$. **p < 0.01 and *p < 0.05 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry 188
**p<.01 and *p<.05 for 2-tailed.

Moderation

Model 1. The full moderation evaluation was conducted by the use of PROCESS *Model 1*. The dependent variable was average exam scores for chemistry 188 while the moderators and independent variables cycled through the significant Pearson's r values as well as gender. No variables were controlled for during this initial procedure. Of the twenty-eight simple moderation models, four were found to notably increase the *R*-squared value. The significant moderation interactions can be found in Table 18 and values for the complete analysis can be found in the Table 42. As expected from the previous semester's results, gender had a significant interaction with high school credit but not GPA. PLUS 188 attendance appeared to be moderated by both gender and pre-pharmacy students, which increased the respective models' explained variance by 0.036 and 0.018 with the addition of the interaction terms. The new potential moderation interaction occurred between grand mean centered GPA and calculus completed; this improved the uncontrolled model from $R^2 = 0.245$ to 0.281 with a p-value of 0.001.

Table 18
Regression Coefficients for Regression III, PROCESS Model 1.

Moderator	Independent Variable	B	*p*	R^2	ΔR^2
Calculus	HS GPA	21.825	0.001	0.281**	0.036**
Gender	HS Credit	0.407	0.043	0.117**	0.015*
Gender	PLUS 188	-2.080	0.002	0.070**	0.036**
Pharmacy	PLUS 188	-1.724	0.035	0.052**	0.018*

Note: N = 248. Dependent Variable = Average Exam Scores for Chemistry 188.
**p<.01 and *p<.05 for 2-tailed.

Mediation

Model 4. College credit hours completed while in high school was evaluated again as a mediator to high school GPA along with math ACT scores. A simple mediator model was established using PROCESS *Model 4*. The independent variable was set to high school GPA with CHEM 188 exams as the dependent variable. No other variables were controlled for during this analysis. First, college credit was tested as the mediator. Both the mediator outcome regression and the dependent regression were significant models respectively with $R^2 = 0.148,\ F(1,247) = 42.602,\ p \approx 0.000$ and $R^2 = 0.231,\ F(2,246) = 36.748,\ p \approx 0.000$. High school GPA was significant in each regression with *p*-values approaching zero. The direct effect of GPA on exam scores was significant with $B = 21.653$ and $p \approx 0.000$ indicating this model was only partially mediated by credit hours. This reflected the mediation as seen in the previous section with Chemistry 184 exam scores.

Table 19

Regression Coefficients for Regression IV and V, PROCESS Model 4.

Regression IV	Consequent					
	Credit Hours			CHEM 188		
Antecedent	*B*	*SE B*	β	*B*	*SE B*	β
HS GPA	12.962*	1.986	0.408	21.653**	3.299	0.433
Credit Hours	-	-	-	0.251*	0.098	0.158
	R^2 = 0.148**			R^2 = 0.231**		
	F(1,246) = 42.602			F(2,245) = 36.748		
Regression V	Consequent					
	Math ACT			CHEM 188		
Antecedent	*B*	*SE B*	β	*B*	*SE B*	β
HS GPA	3.958**	0.824	0.495	19.976**	3.043	0.37
Math ACT	-	-		1.246**	0.225	0.3
	R^2 = 0.086**			R^2 = 0.299**		
	F(1,246) = 23.062			F(2,245) = 51.937		

Note. N = 248. **p < 0.01 and *p < 0.05 for 2-tailed.

A second basic mediator analysis was conducted by replacing credit hours with math ACT scores. For a second time PROCESS *Model 4* was used in SPSS while not controlling for any additional predictors. The two models were statistically significant, which indicated math ACT scores may indeed be a second mediator. The mediator model had a lower R-squared value of 0.086 but a larger value on the model with 188 scores as the dependent variable with $R^2 = 0.299$. Complete model information can be found in Table 19.

With two potential mediators, a multiple mediator regression was conducted. Consequently theses mediators were added in a parallel fashion with *Model 4* and both mediators in the M_i box. The first two regressions had the mediators as the consequent and were identical to their corresponding regression from their elementary model. The parallel model outcome was a significant with 31.0% of the variance explained and $F(3,245) = 36.438$. Similar to the analysis of Chemistry 184, the comprehensive model partially mediated with the two mediators.

Moderated-Mediator Model

Model 22. All significant predictors, interactions, and mediators were aggregated into a single model. Hayes' online PROCESS template was reviewed to find a model that accurately reflected the moderator of the direct effect as well as the moderator between the mediator and the dependent variable (Hayes, 2013b). PROCESS lacked the specific model but the closest model was number *22* as seen in Table 20. There was an additional moderation interaction between the independent variable and the first mediator that was not seen in the basic moderation models. The second limitation to this model was the moderators would create interactions for each mediator not just credit hours causing extraneous interactions much like the high school credit-gender interaction seen in the 184 conditional indirect effects.

In *Model 22*, the independent variable (X) was high school GPA, mediators were credit hours (M_1) and math ACT scores (M_2), the dependent variable (Y) was CHEM 188 Exam scores, Calculus as a moderator was (W), and finally the second moderator (V) was gender. The additional interaction this model uses but does not reflect the prior analysis was represented by the straight line from W pointing to the line between X and M_1 and straight line between V and M_2. Pre-pharmacy students were entered into the regression as controlled a variable. Due to the limitations of PROCESS, hierarchical regression cannot be analyzed with this method so moderation interactions for PLUS 188 attendance with each gender and pre-pharmacy were calculated first then entered as controlled variables. PLUS 188 attendance was not mean centered since it was a ratio level, treatment variable.

In the first regression, credit hours was the dependent variable since it was the mediator and the only significant predictor was high school GPA. This confirmed credits hours earned in high school as the mediator and no other predictors were likely to be parallel mediators. The calculus and GPA interaction was not significant as expected and was only added due the limitations of PROCESS. The four variables below the dashed line in Table 20, which includes the three variables containing PLUS were disregarded since they were control variables.

The outcome regression was significant with F(6,435) = 13.954 and a *p*-value of approximately zero. The overall R^2 value including PLUS interactions accounted for 0.422 of the explained variance. Five of the seven single variable predictors were found to be significant in the regression analysis. Calculus had a *B*-value of -0.001 with a *p*-value of 0.999 so it was trivial but its corresponding interaction with GPA was significant with $b = 19.493$ and $p = 0.001$. Gender was significant with males scoring 5.605% higher on exam 188 scores. High school GPA, math ACT scores, and the mediator credit hours were all significant at a 95% confidence level. PLUS 188 attendance increased the average exam scores by 1.487% for each week attended totaling just under 15% increase in scores. The PLUS participation was moderated by gender with a negative coefficient of 2.033 and $p = 0.000$, suggesting males who attend PLUS sessions (N=30) negated their gain and potentially did worse. This interaction was examined in greater depth during the final regression.

Pre-pharmacy students had essentially no impact of the 188 exam scores, neither exclusively nor as the moderator for the number of PLUS sessions. This group of pre-pharmacists students had a completion rate for Foundations of Chemistry II of 82.4%, while the remaining sample of students' rate was much smaller at 51.2%. This discrepancy points to differences with in the student populations from CHEM 184 to CHEM 188, not merely smaller but equivalent sample in for Chemistry 188. Further investigation of these differences can be seen beginning on page 106 with the analysis of Chemistry 184 by only students who have completed Chemistry 188.

The last two predictors in this analysis are interaction terms with gender as the moderator. Gender was mean centered so males have a value of 0.58 calculated by the code for male (1) minus the mean (0.42). Females were coded at zero, so their corresponding mean centered number was -0.42. High school GPA was not moderated by gender (*p*-value of 0.886); however, credit hours earned in high school was significant. The *B*-value for this interaction was 0.400, which indicates males' preform 0.232% better for each additional credit hour earned in high school while females preformed 0.168% lower for each hour. The conditional direct and indirect effects of the moderation were analyzed for the final regression to determine if males and females have significant results or just one sexes.

Table 20

Regression Coefficients for Regression VI, PROCESS Model 22.

	Consequent								
	Credit Hour			Math ACT			CHEM 188 Exams		
Antecedent	*B*	*SE*	β	*B*	*SE*	β	*B*	*SE*	β
GPA	13.521**	2.125	0.400	3.872**	0.853	0.382	19.398**	3.314	0.367
Credit Hour	-	-	-	-	-	-	0.218*	0.088	0.155
Math ACT	-	-	-	-	-	-	1.015**	0.228	0.203
Calculus	0.57	1.106	0.002	1.593**	0.444	0.203	0.775	1.542	0.025
Gender	-	-	-	-	-	-	5.516**	1.743	0.195
GPA x Calc	3.685	4.132	0.053	-0.218	1.659	-0.03	18.681**	5.694	0.127
ACT x Gend	-	-	-	-	-	-	0.119	0.436	0.012
Credit x Gend	-	-	-	-	-	-	0.366*	0.170	0.129
PLUS 188	-0.303	0.260	-0.048	-0.129	0.105	-0.014	1.534**	0.371	0.083
Pharmacy	0.28	1.463	0.039	0.156	0.587	0.018	0.275	1.990	0.008
PLUS x Gend	0.185	0.362	0.007	0.344	0.145	0.074	-1.830**	0.552	-0.169
PLUS x Pharm	0.413	0.485	0.127	-0.158	0.195	-0.081	-1.118	0.662	-0.091
	R^2 = 0.158**			R^2 = 0.223**			R^2 = 0.419**		
	F(7,240) = 6.439			F(7,240) = 9.649			F(12,235) = 113.953		

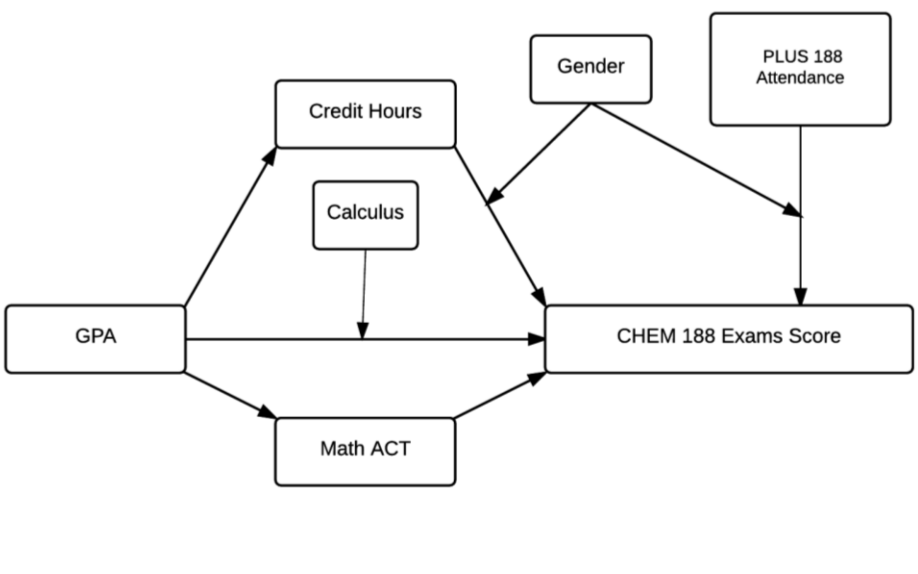
Note. N = 248. **p < 0.01 and *p < 0.05 for 2-tailed.

Comprehensive 188 Model

The final hierarchical regression was trimmed back to only significant predictors and interactions; therefore, the analysis was conducted with manual entries to maximize customization by removing non-significant interactions from the regression. Neither the pre-pharmacy predictor nor its interaction with PLUS 188 attendance significantly contributed to a better explanation of chemistry achievement so both were removed from the regression. As expected the GPA-Calculus interactions were not significant with either mediator as the dependent variable indicating calculus does not moderate the mediators but only the direct relationship from GPA to average 188 exams scores. Figure 18 illustrates the completed model diagram for Chemistry 188. All independent variables and interactions were centered with the exception of PLUS attendance and its interaction with gender. Three cases had excessively high Mahalanobis distances indicating multivariate outliers and were removed the study, reducing the sample to 245 students.

Figure 18

Conceptual Diagram for the Chemistry 188 Comprehensive Model.



In the mediator outcome models, two regressions were analyzed one with each mediator set as the dependent variable while GPA was treated as an independent variable. The author failed to reject the null hypothesis with calculus completed as a moderator seen by the non-significant interaction; therefore, both the Calculus-GPA interaction term and the Calculus variable were entered into these regressions. The first mediation model was significant $F((1,244) = 40.028)$ and $p \approx 0.000$ with credit hours as the dependent variable. The second model with respect to math ACT scores as the mediator was also significant with $F((1,244) = 31.384)$ and a similar *p*-value.

With the coefficients established from the mediators, the consequent was set to the Chemistry 188 average exam scores. The following independent variables were added in the first step of the regression: (1) high school GPA, (2) credit hours, (3) math ACT, (4) Calculus Completed, (5) Gender, (6) the product of Credit Hours and Gender, and (7) the product of GPA and calculus completed. The model fit was statistically significant with the seven degrees of freedom and 38.8 percent of the variance accounted for in the model. The first three listed predictors were significant and centered GPA had a *B*-value of 23.132. The two predictors that had *p*-values greater than the cut-off for significance were gender with p = 0.075 and calculus completed at 0.178. These variables did remain as an integral part of the study, since each variable had a significant interaction.

Table 21

Results of Hierarchical Regression Analysis Predicting Chemistry 188 Exam Scores.

	Consequent					
	Credit Hours			Math ACT		
Antecedent	*B*	*SE*	β	*B*	*SE*	β
GPA	12.774**	2.019	0.375	4.688	0.837	0.338
	R^2 = 0.141**			R^2 = 0.114**		
	F(1,242) = 40.028			F(1,242) = 31.384		

	Consequent								
z	CHEM 188 Exams			CHEM 188 Exams			CHEM 188 Exams		
Antecedent	*B*	*SE*	β	*B*	*SE*	β	*B*	*SE*	β
GPA	23.132**	3.454	0.412	22.078**	3.460	0.395	21.717**	3.398	0.388
Credit Hour	0.205*	0.091	0.124	0.213*	0.091	0.127	0.222*	0.089	0.135
Math ACT	0.923**	0.237	0.224	0.941**	0.235	0.225	0.928**	0.231	0.228
Calculus	2.063	1.537	0.071	1.893	1.517	0.066	1.305	1.500	0.045
Gender	2.856	1.593	0.097	3.000	1.883	0.100	5.412**	1.730	0.189
GPA x Calc	24.06**	5.824	0.212	23.357**	5.788	0.206	22.447**	5.688	0.199
CreditxGend	0.369*	0.170	0.108	0.368*	0.169	0.106	0.375*	0.166	0.111
PLUS 188	-	-	-	0.603*	0.278	0.101	0.509	0.275	0.093
PLUSxGend	-	-	-	-	-	-	-1.799**	0.568	-0.192
	R^2 = 0.388**			R^2 = 0.400**			R^2 = 0.424**		
	ΔR^2 = 0.388**			ΔR^2 = 0.012*			ΔR^2 = 0.012**		
	F(7,237) = 21.462			F(8,236) = 19.659			F(9,235) = 19.259		

Note. N = 245. **p<.01 and *p<.05 for 2-tailed.

In step two of the hieratical regression, the only added variable was total PLUS attendance for Chemistry 188. This improved the explained variance to 0.400, while the F-value was reduced by nearly two with the addition of one degree of freedom. The PLUS attendance variable was significant with a *p*-value of 0.031. The unstandardized coefficients have a value of 0.603 with a maximum number of sessions that a student could attend was ten. While controlling for all variables, a student could increase average exam scores by six percent through full participation in the PLUS chemistry program. Unfortunately this increase in percentage was averaged between males and females, thus the last moderation term needed to be evaluated before a generalized conclusion could be reached.

The last block of the regression only added the moderation interaction between gender and the 188 PLUS sessions. The model fit significantly improved by 0.025 to the increase the overall R^2 to 0.425, with $F(9,235) = 19.259$. PLUS attendance was moderated by gender with B = -1.799 and p = 0.002. Through the addition of this interaction to the model, the PLUS 188 variable switched from significant in the previous regression to non-significant in this regression with p = 0.065. This transformation in significance proposed that PLUS was most likely only significant with either males or females, not necessarily both.

Since gender was mean centered, the values were replaced in Equation 3 to combine the PLUS variable and its interaction into a single coefficient for each gender. This was done, to provide a straight forward comparison of the impact associated with PLUS attendance. For females, the treatment unstandardized coefficient was 1.265 for each PLUS session attended while males had a negative *B*-value of 0.534.

Equation 3

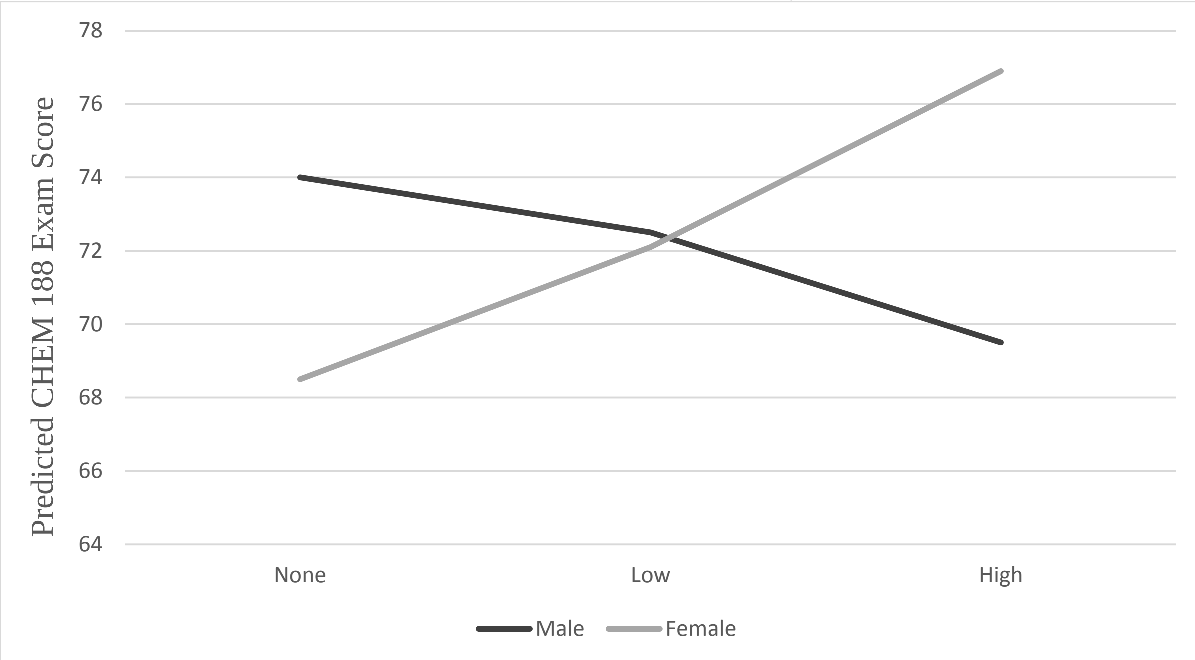
$$\text{Treatment Coefficient} = (0.509 \times \text{PLUS 188}) + (-1.799 \times \text{PLUS 188} \times \text{Gender}^{\text{C}})$$

$$\text{Note: Gender code for males} = 0.58 \text{ \& females} = -0.42$$

These results demonstrated, that on average, females' exam scores increased by 1.2 percent for each PLUS session attended. These finding are consistent results with the 184 semester. However at first glance, it appeared the males students performed half a percent lower with each additional PLUS session as seen in Figure 19. To determine if this decrease was different than zero, the *p*-value associated with just the regression coefficient needed to be found individually for each gender.

Figure 19

Moderation Effect for Gender on PLUS sessions for Chemistry 188 exam scores.



Unfortunately, the *p*-values cannot be calculated using a simple equation like Equation 3, as was done for their corresponding *B*-values. Estimated *p*-values were found by splitting the database by gender then constructing the preceding hierarchical regression but eliminating all gender variables (Gender, Credit x Gender, and PLUS x Gender). In the split regression, females had a PLUS 188 coefficient of 1.271 compared to 1.265 and a *p*-value of 0.001 when calculated by hand from Equation 3. The males' coefficient had a *B*-value of -0.590 with the split database and a non-significant *p*-value of 0.130. The difference in the *B*-value was greater at 0.056 for the males but still well within the standard error range of 0.386. Although it is often ill advised to compare numerical values of one regression to another, the *B*-values are mathematical equivalently for the PLUS 188 variable for both genders. Thus it was reasonable to project these approximated *p*-values onto the comprehensive model. In doing so, the treatment variable failed to reject the null hypothesis, which stated that PLUS sessions did not impact average exam scores for male students. Therefore, the *male line* in Figure 19 should be extend straight across from the original number, 74, without decreasing. The null hypothesis was rejected for female students, which indicates they performed the 1.2 percent higher on average exam scores for each additional PLUS session attended.

Chemistry 188 Predicted Equation. The comprehensive model was represented below in Equation 4. High school GPA, gender, credit hours, and calculus were grand mean centered therefore, revised coding must be considered. This model accounts for nearly 42.4% of the explained variance for chemistry 188 exam scores.

Equation 4

$$\hat{y} = 70.902 + 21.717GPA - 3.78) + 0.222(Credit\ Hr - 11.25) + 0.928(mACT) + 1.305(Calculus) + 5.412(Gender) + 22.447(GPA)(Calculus) + 0.375(Credit\ Hr - 11.25)(Gender) + 0.509(PLUS\ 188) - 1.799(PLUS\ 188)(Gender)$$

Note: Gender code for males $= 0.58$ & females $= -0.42$.
Calculus completed code for No $= -0.585$ & Yes $= 0.415$

Direct and Indirect Effects

Conditional Direct Effects. In this comprehensive model, the direct relationship between GPA and the Chemistry 188 exam scores was moderated by the variable, calculus completed. As a result, the direct effect became a conditional one meaning the relationship depended on whether a student completed calculus or not. Since the moderator was dichotomous, two conditional effects are reported between high school GPA and exam scores. The first effect was 8.771 ($p = 0.043$) for student who did not complete calculus ($n = 104$), while a much large effect, 31.247 ($p \approx 0.000$), was seen for student who did complete calculus prior to fall 2012. Standard errors and confidence intervals are reported in Table 22. Both conditional effects are significant so the model was only partially mediated by math ACT scores and credit hours.

Table 22
Conditional Direct Effects for Chemistry 188 Regression.

Calculus Completed	Effect	*SE*	LLCI	ULCI
No	8.771*	4.338	0.264	17.358
Yes	31.247**	4.505	22.200	39.953

Note. N = 245. **p < 0.01 and *p < 0.05 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry 188.

Conditional Indirect effect. Two parallels mediators, credit hours and math ACT scores, influences the relationship of how much high school GPA impacted Chemistry 188 exams above and beyond the direct effect. Math ACT has a significant indirect effect of 4.701 with a *SE* = 1.409, concluding that mediation did occur within this variable. Gender was moderating credit hours when regressed upon average exam scores for Chemistry 188. This moderation allowed for two conditional indirect effects. Males had a significant effect of 5.247, while females did not. Thus for females, high school GPA did not influence average exams scores through credit hours mediator and thus mediation would not take place in a female only model.

Table 23
Conditional Indirect Effects of High School GPA on 188 Exam Scores.

Mediators	Gender	Effect	Boot *SE*	*LLCI*	*ULCI*
Credit Hours	Female	0.787	1.427	-1.751	3.667
Credit Hours	Male	5.247*	1.390	2.736	9.065
Math ACT	Both	4.701*	1.409	2.324	8.081

Note. N = 245. *p < 0.05 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry 188

Once more with the presence a moderator, normal theory could not be exclusively used for calculations. The indirect effect equations were designed based on PROCESS *Models 4* and *14*.

When credit hours was the mediator, Equation 5 was used. However no conditional effects were seen with Math ACT so product of coefficient, which is Equation 6, was used.

Equation 5

$$M_{Credit\ Hour} = a_{GPA}\left(b_{Credit\ hours} + b_{gender} \times Gender\right)$$

Equation 6

$$M_{math\ ACT} = a_{GPA} b_{math\ ACT}$$

The "a"s represent the coefficients when the mediators were the dependent variables; while "b" are the corresponding coefficients when 188 exam scores were the dependent variable. Gender was mean centered so males have a value of 0.581 and females -0.419. The standard error and confidence intervals were determined through PROCESS despite the lack of a specific model. They were piecemealed together through various models but the regression outcome results were always the same, just the direct and indirect results varied.

Discussion

The mediation framework remained constant with credit hours and math ACT still mediated the GPA and exam score relationship but resemblance ended there. Pre-pharmacy students were no longer a predictor in this regression, which included the pharmacy and PLUS interaction. This may have occurred since there was a higher percentage of pre-pharmacy students in Chemistry 188. An independent t-test revealed no significant mean differences between the pre-pharmacy students and the remainder of the sample on any academic variables or the number of PLUS sessions attended. The PLUS attendance was now significantly moderated by gender in the 188 comprehensive model, which this interaction was occurred in the development but not comprehensive 184 regression. Change occurred with gender moderating the credit hours to exam score relationship and not GPA to math ACT. The final manipulation included calculus completed as a moderator of the direct effect.

Gender played a more substantial role in this regression as perceived through conditional effects. High school credit hours did not mediate the relationship between GPA and Chemistry 188 exam scores for females, which is seen by the non-significant indirect effect. A more tailored model for the female sub-sample would include math ACT as the only mediator and PLUS attendance without its corresponding gender interaction.

For every PLUS session attended, a female had an average increase of 1.2%, which was consistent with last semester's results. Forty-two percent females participated in at least one PLUS session while their male counterparts were only at 30%. Males fail to reject the null hypothesis, which stated no differences were observed by their participation in PLUS. Several potential reasons why no relationship was established (1) the lack of long-term participation from men poses an increase chance of Type II Error or a false negative. (2) the peer leaders had voiced concerns during weekly peer leader meetings. They noted some men were more likely to disengage from the discussions, while (3) others came to sessions out of a sense of obligation to their girlfriend and expressed little interest in group activities. Over time some of these males did fully participate in discussion; however, for a number of individuals PLUS attendance may have been inflated. This effect may not have been observed in the first semester, since a larger number of males participate in PLUS sessions, especially more than five. The girlfriend effect may have initially been present in the first semester; however, the higher percentage in participation may have limited this inflationary effect. PLUS sessions are not passive learning environments, therefore, treating one as such would have reduced the perceived benefit. Other cofounding variables that may contribute to negligible results would include motivation and higher performing students, which is discussed below.

The loss of the pre-pharmacy predictor represented a shift in the overall dynamics of the course population. These students stood out as a group due to higher academic performance in first semester. These same students did not underperform in 188, rather the natural reduction of students from 184 to 188 resulted in a pre-pharmacy students becoming indiscriminate with the remainder of class. Pre-pharmacy students did not benefit with increased exam scores in Chemistry 184 for their participation in PLUS. As the 188 sample possesses more characteristics of the pre-pharmacy students, it was reasonable to conclude that the overall impact of the PLUS benefits declined for this reason. The rejection of the null hypothesis for males may be partially attributed as well. Given that the regression coefficients, males start with an expected 5.4% higher on Chemistry 188 exams than females. The associated gain with PLUS was lower for males and therefore a greater chance for non-significance.

With the conditional direct effects, partial moderation of the high GPA and Chemistry 188 exams was seen regardless if a student took calculus. For those students who completed calculus, the direct effect was substantially larger with a value of 32. By previously taking calculus and having the average GPA, a student was predicted to score on average 20% higher than a peer who had not yet taken the course.

Similar size indirect effects for GPA on 188 exam scores were reported for math ACT and credit hours for males with effect size close to five. GPA was the largest predictor; but with the addition of the GPA-calculus interaction and conditional indirect effects, GPA has a much greater weight than its corresponding β-value of 0.388.

Multiple Regression for Chemistry 184 with 188 Sample

This final regression analysis amalgamates the results from the two previous sections by analyzing only the students who completed Foundations of Chemistry II in their performance of the first semester course. This analysis was denoted as CHEM 184[†]. Several prominent differences between the two analyses were as follows: (1) PLUS sessions were moderated by pre-pharmacy students in Chemistry 184 and then gender in Chemistry 188, (2) pre-pharmacy students were not a predictor in the Chemistry 188, (3) gender moderated high school GPA in 184 but credit hours in 188, and (4) calculus completed moderated GPA in Chemistry 188. Since the student population of the course evolved from the completion of the second semester, it reasonable to assume this regression would most closely align with the results from the Foundations of Chemistry II.

Block Regression

Regression I was conducted in a similar manner by single-step block regression. The participants Chemistry 188 exam regression study, N = 245, was projected upon Chemistry 184 exam scores with corresponding 184 PLUS sessions. The list of predictors for the initial block regression was equivalent to the Chemistry 188: Regression I. The full correlation values including *zero*-order, partial, and part along with coefficients can be found in Table 24.

Potential predictors followed a general fashion for very weak or non-linear correlations in which $r < 0.150$ were the variables of Asian ethnicity, gender, completion of high school chemistry, and those interested in either the medical or pharmaceutical field. Gender and pre-pharmacy students had part and partial correlations larger than the Pearson value, while the variable for aspiring medical students had inverse signs. Both scenarios indicate moderation.

Gender and pre-pharmacy students were moderators in the previous analysis; however, the pre-medical variable had yet to be a significant predictor in a comprehensive model.

Also, first-time freshman and high school chemistry variables experienced sign a change when comparing the zero-order to part and partial but not an increase in magnitude. High school chemistry was further investigated as a potential moderator, but was removed from Regression II since it failed to have a significant linear correlation with Chemistry 184† exam scores. On the other hand, first-time freshman was continued in the block regression analysis since Pearson's r = 0.194 and p < 0.05.

Since students of Asian or Pacific Island origins did have a significant correlation (p = 0.047) with Chemistry 184 but the associated *r*-value was less than 0.150, this variable was removed so as to not violate the assumption of linearity in the multiple regression analysis.

Table 24

Block Regression I: All predictors for CHEM 184†.

Predictor	*B*	*SE B*	β	Zero-order	Partial	Part
Asian	-2.694	2.484	-0.076	-0.144*	-0.071	-0.054
Calculus	0.896	1.326	0.034	0.211**	0.043	0.033
Freshman	-0.281	1.672	-0.021	0.194**	-0.010	-0.008
Caucasian	1.614	2.031	0.053	0.205**	0.052	0.040
Gender	1.623	1.367	0.067	0.004	0.078	0.059
HS CHEM	-0.068	1.933	-0.005	0.074	-0.002	-0.002
Credit Hour	0.158*	0.078	0.117	0.320**	0.131	0.100
HS GPA	15.513**	2.930	0.318	0.495**	0.328	0.264
Math ACT	1.181**	0.206	0.341	0.494**	0.340	0.275
Med Doc	-.390	1.456	-0.025	0.006	-0.017	-0.013
Pharmacy	-1.081	1.691	-0.041	-0.008	-0.041	-0.031
PLUS 184	0.525*	0.167	0.158	0.189**	0.201	0.156

Note: N = 245. Dependent Variable: Average Exam Score for CHEM 184.
**p < 0.01 and *p < 0.05 for 2-tailed

The second block regression contained only the predictors with significant linear relationship with the Chemistry 184† exams as seen by Pearson's correlation with values greater a 0.150. This new regression contained one additional self-reported ethnicity Caucasian variable beyond the 188 analysis.

The predominant predictors from pervious analysis held consist with this block regression as seen in Table 25. The high school variables of GPA and math ACT scores were significant along with PLUS 184 attendance. Credit hours just missed the level of significant with a *p*-value of 0.054, but the past would indicate this variable was a mediator and have the potential for several interactions that impact the overall regression. Calculus completed did not significantly predict in this model with a *p*-value just above five-tenths. Its corresponding Pearson's *r* was 0.211 and the partial and part systematically reducing as expected. Thus there was no indication that moderation would occur but these results are very similar to the 188 analysis where calculus completed moderated GPA.

Table 25
Block Regression II: Significant CHEM 184† Predictors.

Predictor	*B*	*SE B*	β	Zero-order	Partial	Part
Calculus	0.778	1.277	0.028	0.211**	0.043	0.033
Freshman	-0.197	1.589	-0.015	0.194**	-0.010	-0.008
Caucasian	3.284	1.427	0.116	0.205**	0.052	0.040
Credit Hour	0.148	0.077	0.107	0.320**	0.131	0.100
HS GPA	14.373**	2.715	0.354	0.495**	0.328	0.264
Math ACT	1.219**	0.187	0.300	0.494**	0.340	0.275
PLUS 184	0.510**	0.165	0.157	0.189**	0.201	0.156

Note: N = 245. **$p < 0.01$ and *$p < 0.05$ for 2-tailed.
Dependent Variable: Average Exam Score for CHEM 184.

New to this regression was the ethnicity variable for Caucasian students. Despite the established relationship with the 184† exam scores; nothing came to fruition of successfully predicting an outcome for course success through average exam scores. Consequently, this variable was removed from this regression.

Moderation

Model 1. The simple moderation model was set up using PROCESS *Model 1* to determine if any new interactions were established beyond the prior findings. Again this model did not control for predictors but rather provided an oversimplification where moderation might exist in the comprehensive mode. The potential moderators paralleled with the pervious semesters. For example, in the Chemistry 184 analysis: *Model 1*, gender and pre-pharmacy students appear to moderate PLUS sessions. Pre-pharmacy ultimately moderated PLUS session in 184 while gender moderated in 188. Calculus completed was also shown to moderate GPA consistent with the 188 discoveries, while gender did in the 184 results.

As seen in Table 26, the single additional interaction between first-time freshman and high school GPA was discovered and full results are reported in Table 43. No interactions were discovered with students completing high school chemistry. A significant interaction was also noted between GPA and the math ACT scores, which would be accounted for in mediation.

Table 26
Regression Coefficients for Regression III, PROCESS Model 1.

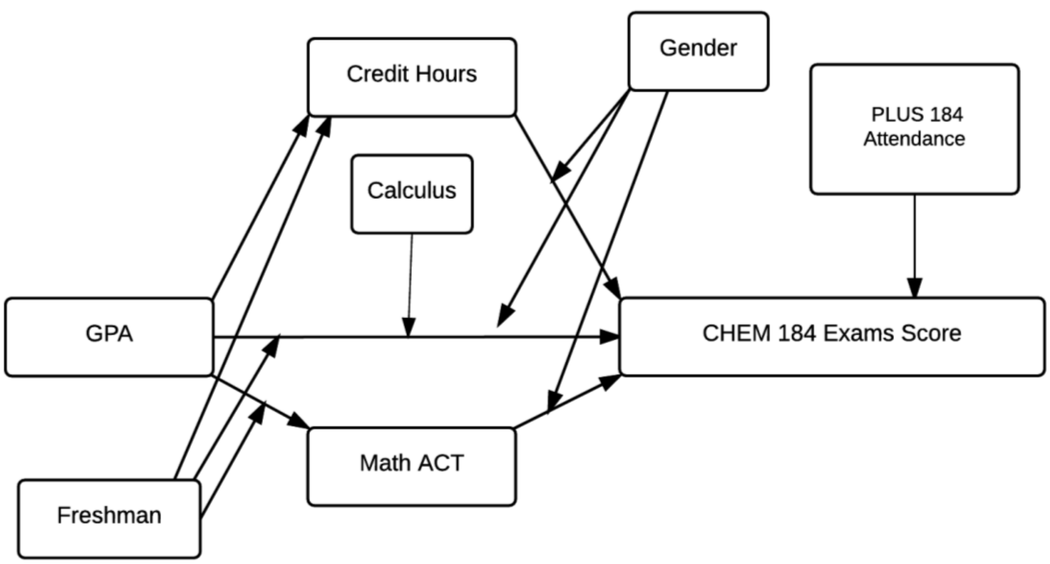
Moderator	Independent Variable	B	*p*	R^2	ΔR^2
Calculus	HS GPA	16.100	0.003	0.285**	0.027**
Freshman	HS GPA	-12.872	0.030	0.272**	0.014**
Gender	HS GPA	-19.900	0.000	0.305**	0.038**
Gender	PLUS 184	-1.150	0.009	0.063**	0.027**
HS GPA	Math ACT	-1.322	0.043	0.377**	0.011*
Pharmacy	PLUS 184	-1.005	0.040	0.053*	0.017*

Note: N = 245. Dependent Variable: Average Exam Score for CHEM 184
**p < 0.01 and *p < 0.05 for 2-tailed.

Complex Models

Model 31. The PROCESS *Model 31* provided the structural framework essential to meet the minimum requirements with the two mediators and five interaction which include two with the PLUS attendance. Figure 20 provides a pictorial representation of Andrew Hayes' *Model 31*. Unfortunately, this model contained too many moderation interactions; however, a baseline was established to shed light on this complex analysis in Regression IV.

Figure 20
Conceptual Diagram for the Chemistry 184†, Model 31.



The first consequent regression with credit hours earned in high school contained only two predictors, grade-point average and incoming freshman, as significant. Both interaction with GPA multiple to each previously enrolled in calculus and first time freshman did not contribute to the fuller explanation of the model with $R^2 = 0.173$ and $F(9{,}235) = 5.444$. When math ACT scores was the second consequent by becoming the dependent variable the regression had several significant interactions. The predictor high school GPA was significant confirming its mediation effect. Several other predictors including the calculus and freshman variables did have *p*-value approximately zero and the GPA-freshman interaction with $p = 0.009$. This model did improve the explained variance to an $R^2 = 0.303$ and the F-test value to 11.364 with the same degrees of freedom. The PLUS coefficients and standard errors were not analyzed in the first two regressions.

The concluding analysis for *Model 31* came with the Chemistry 184[†] exams scores as the dependent variable. High school GPA, the mediators, and number of PLUS sessions all had positive impact on the general model. The three moderation variables were not individually significant but interactions with GPA and gender along with credit hours and gender were. The incoming freshman variable failed to show a relationship with GPA on the final model. The moderation effect of calculus on GPA had a *p*-value of 0.051. Although this was not within the desired level of confidence, modifications to the regression could affect the significance of this interaction.

Table 27

Regression Coefficients for Regression IV, PROCESS Model 31.

	Consequent					
	Credit Hours		Math ACT		CHEM 184 Exams	
Antecedent	*B*	*SE*	*B*	*SE*	*B*	*SE*
GPA	12.528**	2.304	2.244**	0.854	12.528**	2.157
Credit Hours	-	-	-	-	0.161*	0.07
Math ACT	-	-	-	-	1.128**	0.234
Calculus	0.520	1.100	1.736**	0.408	0.685	1.422
Freshman	3.433*	1.414	2.918**	0.524	-1.897	1.987
Gender	-	-	-	-	2.066	1.453
GPA x Calculus	2.576	4.356	-1.821	1.614	12.401	6.325
GPA×Freshman	2.286	4.789	-4.641	1.775	-2.131	6.464
GPA×Gender					-15.743*	7.356
ACT x Gender	-	-	-	-	0.354	0.448
Credit x Gender	-	-	-	-	0.305*	0.142
PLUS 184	-0.160	0.142	-0.090	0.053	0.429**	0.165
Pharmacy	0.646	1.269	-0.059	0.470	-0.791	1.446
PLUS x Gender	-0.023	0.300	-0.283*	0.111	-0.103	0.355
PLUS x Pharm	0.349	0.330	-0.083	0.122	-0.64	0.399
	R^2 = 0.173**		R^2 = 0.303**		R2 = 0.455**	
	F (9,235) = 5.444		F(9,235) = 11.364		F(15,229) = 12.758	

Note. N = 245. **p < 0.01 and *p < 0.05 for 2-tailed.

The four controlled variables of pre-pharmacy, PLUS 184 attendance, and PLUS' interactions with each gender and pre-pharmacy were only investigated for significance when average exams scores were the dependent variable. The treatment variable of PLUS attendance was indeed significant; however, the remaining three control variables were not. Pre-pharmacy students and their moderation of PLUS sessions did impact the CHEM 184 with the sample of students; however, failure to do so with the reduce sample size in either Chemistry 184 or 188 course. Additionally, gender did not appear to moderate the PLUS attendance.

Regression V. Based upon regression results for *Model 31*, the following controlled variables have been removed: Pre-pharmacy, PLUS x Gender, and PLUS × Pre-Pharmacy. Additionally, several superfluous moderation interactions needed to be excluded to ensure their submission did not influence the interactions that appeared to be significant. The first-time freshman variable only significantly moderated GPA when math ACT scores were the dependent variable. The regression was analyzed once again but removing the extraneous calculus-GPA interactions to determine if previously calculus completed inflated the significance. By this elimination, the GPA and calculus product did not have a p-value less than 0.05 in any of the three regressions as seen in Table 28. The removal of the calculus variable did affect significance, therefore, a separate study was conducted to determine if calculus was moderating first-freshman. The separate regression did not find that the freshman-calculus interaction or a three-way interaction involving high school GPA, where significant; therefore, a systemic breakdown of the regression coefficients was not given. The failure to show an establish moderation relations resulted in the first-time freshman variable to be excluded from the analysis.

Table 28
Regression Coefficients for Regression V.

	Consequent					
	Credit Hours		Math ACT		CHEM 184 Exams	
Antecedent	*B*	*SE*	*B*	*SE*	*B*	*SE*
GPA	12.29**	2.102	3.659**	1.763	20.465**	3.339
Credit Hours	-	-	-	-	0.150	0.076
Math ACT	-	-	-	-	1.160**	0.210
Calculus	-	-	-	-	0.941	1.313
Freshman	3.582**	1.372	2.661**	0.537	-2.058	1.754
Gender	-	-	-	-	1.939	1.322
GPA x Calculus	-	-	-	-	12.401*	6.325
GPA × Fresh	1.973	4.502	-2.878	1.763	-2.182	5.740
GPA × Gender	-	-	-	-	-15.403*	6.018
Credit x Gender	-	-	-	-	0.308*	0.153
ACT x Gender	-	-	-	-	0.286	0.402
PLUS 184	-0.147	0.139	-0.065	0.055	0.422**	0.170
	R^2 = 0.166**		R^2 = 0.216**		R^2 = 0.448**	
	F (4,240) = 11.940		F(4,240) = 16.204		F(12,232) = 15.678	

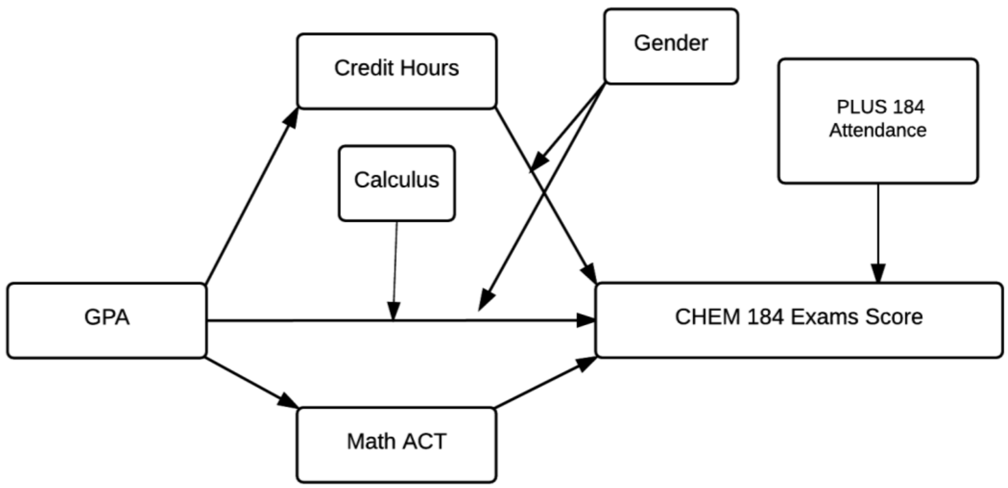
Note. N = 245. **p < 0.01 and *p < 0.05 for 2-tailed.

Comprehensive Model

The pinnacle regression for this chapter was summarized in Regression VI. The extraneous predictors and interactions have been removed to provide a clear and concise regression that reflected how the students whom completed an entire year of chemistry preformed in Chemistry 184[†]. All assumptions of least square linear regression have been met, no multivariate outliers were found, and tolerance levels were within their accepted range.

Figure 21

Conceptual Diagram for the Chemistry 184† *Comprehensive Model.*



The coefficients for Regression VI are noted in Table 29. The variable established for high school GPA had *p*-values of approximately zero in each regression, which deemed significance. The beta value was slightly larger for credit hours with $\beta = 0.374$ as oppose to $\beta = 0.334$ for math ACT scores. The difference in beta values transfers to large R^2 since there were no control variables. Credit hours had an $R^2 = 0.140$ and $F(1{,}243) = 39.419$ while math ACT's $R^2 = 0.112$ and $F = 30.562$. Regardless of these differences, both outcomes secure each as a mediator in the compressive analyses.

Table 29

Regression Coefficients for CHEM 184: Regression VI.

	Consequent					
	Credit Hours			Math ACT		
Antecedent	*B*	*SE*	β	*B*	*SE*	β
GPA	12.708**	2.024	0.374	4.592**	0.831	0.334
	R^2 = 0.140**			R^2 = 0.112**		
	F(1,243) = 39.419			F(1,243) = 30.562		

	Consequent					
	CHEM 184 Exams			CHEM 184 Exams		
Antecedent	*B*	*SE*	β	*B*	*SE*	β
GPA	21.708**	3.088	0.452	20.337**	3.114	0.424
Credit Hour	0.125	0.076	0.088	0.139	0.076	0.098
Math ACT	1.067**	0.198	0.305	1.090**	0.197	0.312
Calculus Comp.	1.328	1.266	0.054	1.225	1.255	0.050
Gender	1.832	1.323	0.074	1.973	1.312	0.080
GPA x Calculus	12.895**	4.877	0.134	12.093*	4.843	0.125
GPA × Gender	-16.474**	5.528	-0.172	-14.03*	5.574	-0.147
Credit x Gender	0.312*	0.152	0.109	0.309*	0.15	0.108
PLUS 184	-	-	-	0.390*	0.166	0.118
	R^2 = 0.430**			R^2 = 0.443**		
	F(8,236) = 22,249			F(9,235) = 20.766		
				ΔR^2 = 0.013**		

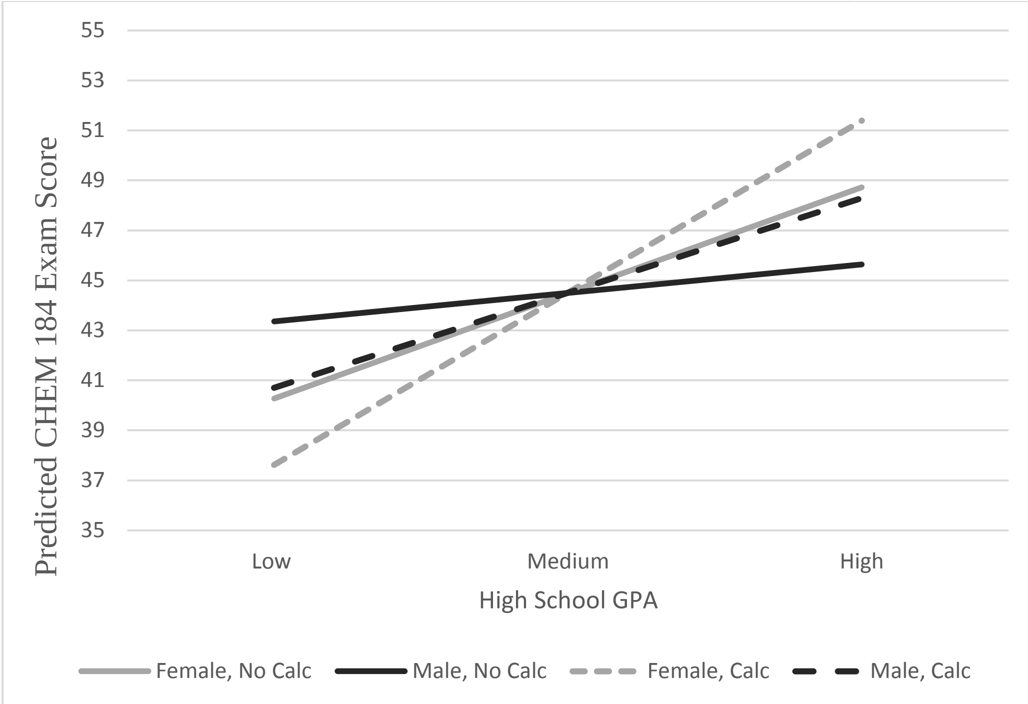
Note: N=245. **p < 0.01 and *p < 0.05 for 2-tailed.

Once the consequent was set to Chemistry 184 exam scores, Regression VI was significant ($p \approx 0.000$) and $F(9{,}235) = 20.766$ with 44.3% of the variance explained by these predictors for average exam scores. The addition of the treatment variable, PLUS attendance, significantly increased the R^2 by 0.013. Like previous comprehensive models, high school GPA was the largest single predictor represented by $\beta = 0.424$, which was followed by math ACT with a $\beta = 0.312$.

On their own, high school credit, calculus, and gender were neither significant nor did they have beta-values large than one tenth. Despite this level of non-significance, each of these variables was part of the complex picture of moderation. High school GPA was doubly moderated by both calculus and gender, demonstrated in Figure 22. The GPA-calculus interaction retained a beta value of 0.125 with the corresponding $b = 12.093$. If student had taken calculus and received a 4.0 in high school, than such a student would on average experience a 1.02% increase to his or her exam scores. This was calculated by the following equation $\hat{y} = 12.093 \times (GPA - 3.8) \times (calculus\ code - 0.58) = 12.093 \times 0.2 \times 0.42 = 1.016$. Since these variables were group mean-centered for the regression, the means must the subtracted off prior to calculating the impact of the interaction.

The GPA-gender interaction was significant at the 0.003 level with a coefficient of -14.03 and the third largest absolute β-value. The negative coefficient implies the interaction would increase predicted y-scores for females with higher than average GPA scores and males with lower than average. The females are presented by the *gray lines* and their corresponding slopes are greater than the males' slopes (*black lines*).

Figure 22
Double Moderation Effect for Calculus and Gender on GPA for Chemistry 184† exam scores.



The last interaction involved credit hours earned in high school moderated by gender. The corresponding p-values was less than 0.05 with $\beta = 0.108$. For every credit hour earned beyond 11.2 hours, male students are predicted on average to preform 0.179% higher on Chemistry 184 exams. Females, on the other hand, performed 0.130% lower for each additional hour beyond the average of 11.2 hours.

As stated above, the treatment variable, PLUS attendance, did have a positive β of 0.118. This predictor was not mean- centered, so for every PLUS session a student attended his or hers expected grade goes up by 0.390. Therefore, if a student attended all 13 session, than he or she should see an average increase of 5.46% or about a half letter grade higher.

Chemistry 184† Predicted Equation. The comprehensive model was represented below in Equation 7. The mean of 3.78 was subtracted off the GPA variable, same with the mean for credit hours, 11.25, to be consistent with grand mean centering. Just over 44% of the variance was accounted for by this regression model.

Equation 7

$$\begin{aligned}\hat{y} = 44.417 + 20.337(GPA - 3.78) + 0.139(Credit\ Hr - 11.25) + 1.528(mACT) \\ + 1.225(Calc) + 1.973(Gender) + 12.093(GPA)(Calc) \\ - 14.03(GPA)(Gender) + 0.309(Gender)(Credit) + 0.390(PLUS\ 184) \\ Note:\ Gender\ code\ for\ males = 0.58\ \&\ females = -0.42. \\ Calculus\ completed\ code\ for\ No = -0.585\ \&\ Yes = 0.415\end{aligned}$$

Direct and Indirect Effects

Conditional Direct Effects. Model B was essentially two of Professor Hayes' models, *5* and *15*, super imposed on each other. *Model 5* contains mediation with a single moderation direct effect with the addition of multiple parallel mediators. *Model 5* would represent the calculus interaction with high school GPA in the current model. However, *Model 15* contains the moderation between the mediator(s) and separately for the dependent variable. Since the two moderators were both dichotomous, there were a total of four direct effects which can be calculated with a single equation. The direct effects equation was compiled adding the moderation component from each *Model 5* and *15*. The direct effects can be formulated with Equation 8, where c_1' was the coefficient for high school GPA, $c_3'W$ was the product of the calculus-GPA interaction coefficient and the calculus variable, and finally $c_5'V$ was the moderation coefficient for gender-GPA multiplied by the gender variable. All coefficients were unstandardized, the variables were grand mean centered and were regressed on Chemistry 188 exam scores.

Equation 8

$$Y = c_1' + c_3' \times + c_5'V = 20.337 + 12.093W - 14.037V$$

The direct effects were calculated by hand and reported in Table 30. To determine the confidence intervals, the conditional effects equations were matched with Hayes' templates. *Model 2* that is Double Moderation provided this framework. The predictors were entered into the PROCESS in a similar manner as the custom regression but with the exception of the two moderations involving high school GPA since the model with add those interactions. The outcome of this regression was identical to the comprehensive model and the direct effects were equal the results from using Equation 8. The standard error and confidence intervals were determine through *Model 2* and provided Table 30.

Table 30
Conditional Direct Effects of High School GPA on 184† Exam Scores.

Calculus	Gender	Effect	*SE*	*LLCI*	*ULCI*
No	Female	19.218**	5.339	8.700	29.737
No	Male	5.182	3.973	-2.645	13.011
Yes	Female	31.311**	5.036	21.391	41.232
Yes	Male	17.275**	4.401	8.605	25.947

Note. N = 245. **p < 0.01 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry 184†

Three significant direct effects are exhibited in the regression analysis, which includes all students who have taken calculus prior to the start of the fall 2012 semester regardless of gender and females who have not taken calculus. These effects are large (effect > 17) with the largest effect seen with females who took calculus with a positive value of 31.31. These three conditions establish partial mediation with high school GPA being influenced by math ACT and credit hours for predicting Chemistry 184 exams scores for the students who completed Chemistry 188.

Males who did not take calculus prior to the start of the course failed to show a direct effect with a value slightly above five. Within this condition (males and not calculus completed), there was no direct effect; as a result, full mediation takes place.

Conditional Indirect Effects. The indirect effects of this analysis are identical to the Chemistry 188 results terms of calculation. Once again, gender moderated the relationship between credit hours and exams scores and no additional moderation occurred with respected to the mediators. GPA would be influenced by both math ACT scores and credits hours for predicting academic achievement on Chemistry 184 exams. The strength of the effect through credit hours would differ between males and females. The calculations were done by hand with Equation 5 for the mediator, credit hours, and Equation 6 for math ACT scores. The results are provided in Table 31. PROCESS *Models 4* and *14* were conducted to confirm the effect and provide the necessary bootstrapping with confidence intervals.

With the equivalent calculation, the results are strikingly similar to the Chemistry 188 conditional indirect effects despite their variation with other moderators and the change in predicted exam scores for Chemistry 184. Once again, the conditional indirect for females failed to be significant for GPA influenced through credit hours. The effect for credit hours in regard to male students was significant at 5.357, which is approximately one-tenth larger than with the previous model. Math ACT scores had an indirect direct effect of 7.465 confirmation mediation since the confidence interval does not contain zero.

Table 31

Conditional Indirect Effects of High School GPA on 184† Exam Scores.

Mediators	Gender	Effect	Boot *SE*	*LLCI*	*ULCI*
Credit Hours	Female	0.148	1.722	-3.204	3.438
Credit Hours	Male	5.357*	1.920	2.166	9.991
Math ACT	Both	7.465*	2.176	3.749	12.353

Note. N = 245. *p < 0.05 for 2-tailed.
Dependent Variable = Average Exam Scores for Chemistry *184†*

Discussion

By regressing only the Chemistry 188 students upon the 184 semester, the difference in the sample were controlled. This research determined that discrepancies were due to change of the sample rather than the transition from the first to the second semester. The 184† regression was analogous to the comprehensive model of Chemistry 188 with one revision, gender no longer moderated PLUS-exam score relationship rather GPA to exam score.

The PLUS coefficient was significant with *B* = 0.390 with no interactions. Therefore if a student chose to participate in all the PLUS sessions then their average exam score would increase by 5.2%. The null hypothesis was rejected, which confirmed once again involvement in PLUS increased exam scores. The magnitude reflected the female average of 1.2% with the non-significant relationship with the males from the Chemistry 188 comprehensive model.

Type II error was a concern with fewer males who participated over the semester for Chemistry 188; however, equal percentages of male and females participated at each level of involvement in the PLUS 184 sessions. The moderation of PLUS by gender with equal variance strongly indicated the possibility of Type II error occurring in the Chemistry 188 Model.

Validation of Models

The three comprehensive regression models were developed to be predictive in nature so administrators, professors, and students would know the impact PLUS sessions had on exam performance. The models were built to be applied to new samples at the University of Kansas and other institutions with programs like PLUS. Validation of these models was essential to verify the model fit was truly explained variance and not that the fit was an artifact of sample variance resulting from an overestimation of model fit due to increases in R^2. In multiple regressions, the addition of predictors cannot lower the model; therefore, validation was performed through a *stepwise* regression.

In SPSS, the *stepwise* method selected the predictor with highest beta weight from the predictor list. The process continued in by adding predictors then removing them in a stepwise manner, in order to determine the next largest predictor. This process continued until the ΔR^2 was no longer significant. *stepwise* regression should always be used with caution since research, causal ordering, and potential interactions were not considered during the selection of variables (Keith, 2006, p. 94).

Chemistry 184 Regression

Full Regression, N = 448. A *stepwise* regression analysis was conducted by adding all variables that were found to be significant in the comprehensive analysis, which included:

(1) GPA

(2) Math ACT

(3) Calculus Completed

(4) Credit Hours

(5) Gender (Maleness)

(6) Pre-Pharmacy Students

(7) GPA x Math ACT

(8) PLUS 184

(9) PLUS x Pharmacy

All variables were mean-centered prior to the regression with the exception of the PLUS 184 variable. The total number of students in this analysis was 448. The six students who were removed as multivariable outliers in the Comprehensive 184 Model were re-instated.

All nine variables were regressed upon the depended variable, Average Chemistry 184 Exam Scores, in a *stepwise* fashion. Six of the variables were added to the regression accounting for 44.9% of the explained variance. The order in which the variables were added to the regression was the following:

(1) Math ACT

(2) GPA

(3) PLUS 184

(4) Calculus Completed

(5) Pre- Pharmacy

(6) PLUS x Pharmacy

Gender and the Gender x Math ACT interactions were not added to the regression and were not significant in the comprehensive regression either. Gender was determined to moderate the GPA to Math ACT interaction and not a predictor when CHEM 184 Exam Scores was the consequent. Credit hours was significant in the comprehensive regression; however, failed to significantly impact the ΔR^2, and therefore was not added in the stepwise regression. Three cases were removed from the analysis as multivariate outliers.

Seventy-Five Percent Regression, n = 334. The cross-validation began by initial sample reduction to approximately seventy-five percent. The samples were randomly selected through SPSS with the "Select Cases" function set at "approximately 75%." The regression was conducted with only the significant predictors determined in the above block *stepwise* regression. Validation of model occurred when the same predictors are selected through the *stepwise* regression. The beta values should be of similar weights, while the R^2 value should be within an absolute value of 0.020. The beta values and the model fit values were compared as shown in Table 32.

By reducing the sample, the number of predictors was the same along with corresponding β-values. All listed β-values were $p < 0.05$. The R^2 values changed from 0.449 in the full regression to 0.442, while the adjusted R^2 values change from 0.441 to 0.432. This validation analysis confirmed overestimation of model fit to the sample was not occurring.

Table 32

Table of Regression β-values for Validation of Chemistry 184.

Variable	Full	75%	50%	50%
GPA	0.235	0.242	0.252	0.172
Math ACT	0.394	0.386	0.375	0.409
Calculus	0.088	0.097	0.141	n.s.
Pre-Pharmacy	0.157	0.166	0.152	0.138
PLUS 184	0.228	0.222	0.239	0.218
PLUS x Pharm	-0.112	-0.126	-	-
N	445	334	223	220
R^2	0.449	0.442	0.486	0.375
Adjusted R^2	0.441	0.432	0.472	0.358

Note. n.s. = non-significant variable.

Split-half Validation. The last form of validation for Chemistry 184 was a regression built with 50 percent of the cases in a *stepwise* model, then the remaining cases were used to validate the model. The computer program selected all four control variables along with the PLUS 184 treatment variable in a *stepwise* regression. The PLUS-pharmacy interaction was not selected in this model. The full results are found in Table 32.

The remaining cases were regressed upon the Chemistry 184 Exam scores with only the selected variables with the method set to *enter*. Several cases have excessively high Mahalanobis distance; however, with removal of these multivariate outliers the calculus completed variable was no longer significant. The explained variance dropped from 48.6 percent to 37.5 percent. In the *stepwise* model, the beta weight increased for GPA and calculus completed compared to the full model while the math ACT score weight decreased. As observed with the split-half *enter* model, when the math ACT scores' β – values decrease, the higher betas were observe for both GPA and calculus completed in this model and in CHEM 188 and 184[†]. This indicated the likelihood that GPA-calculus interactions occur when math ACT scores fell below a particular threshold. This hypothesis was tested and confirmed by a significant interaction GPA-calculus interaction. The calculus completed predictor still impacted the model in a significant way despite its non-significance and therefore should not be removed from the analysis.

In either of the 50 percent validation models, the PLUS and Pre-Pharmacy interaction was not a significant predictor in the multiple regression. Further testing will need to be conducted to determine if this interaction is observed in the sample or a result of Type I error.

Justification for Including Credit Hours in Comprehensive Regression. If the *stepwise* regression was completed in the hierarchical fashion as the research hypothesis intended, then only the control variables would be added in a *stepwise* manner before the addition of the treatment variable. Next, PLUS 184 attendance was added in the second block by *enter* method. This ensured after the control regression, the PLUS attendance added to the regression. Finally, in the third block, the PLUS-pharmacy interaction was added in a *stepwise* manner.

This control regression was performed in SPSS and all five control variables found in the 184 comprehensive model was entered into the *stepwise* regression including high school credit hours, which was omitted in the one block *stepwise* regression above. The PLUS variable was added and then in the following step, PLUS-pharmacy was entered into the regression model. This provided support to the model that no spurious variables were included in the analysis.

Chemistry 188 Regression

Full Regression, N = 249. The *stepwise* regression was analyzed by entering all predictors including interactions from Chemistry 188 comprehensive model with Average Chemistry 188 Exam Scores as the dependent variable. The following predictors were analyzed through a *stepwise* regression:

(1) GPA

(2) Math ACT

(3) Calculus Completed

(4) Credit Hours

(5) Gender

(6) GPA x Calculus

(7) Credit Hours x Gender

(8) PLUS 188

(9) PLUS 188 x Gender

From the above list, six of the seven that were significant in the comprehensive model were also selected through the *stepwise* regression; the excluded predictor was the credit hours-gender interaction. The calculus completed and PLUS 188 attendance variables were in the comprehensive model due to their corresponding interactions, which were significant; however, their variables were not significant in the comprehensive model and were not selected the *stepwise* regression. The order in which the variables were added to the regression was the following:

(1) GPA

(2) Math ACT

(3) PLUS 188 x Gender

(4) GPA x Calculus

(5) Gender

(6) Credit Hours

The β-values and model coefficients are provided in Table 33. The model had a fit of R^2 = 0.390 and the adjusted R^2 = 0.375 with one multivariate outlier removed. This R^2 value was less than the 188 comprehensive regression of R^2 = 0.424, which had one additional significant predictor. The results are provided in Table 32 and all β-values had p less than 0.05.

Seventy-Five Percent Regression, n = 199. The "approximately 75%" case selection randomly choose 199 from the 249 cases. The six significant predictors from the *stepwise* regression were validated through the reduced sample analysis, which resulted in all six variables selected again from a *stepwise* regression. The beta values were of similar weights with the largest difference of 0.040 for GPA between regression models. Both the R^2 and adjusted R^2 were within the two percent of the full *stepwise* regression. No large differences between models were observed. In neither validation regression was the credit hour-gender interaction significant. This variable had the smallest β-value (0.111) as a significant predictor in the 188 comprehensive model. The ΔR^2 failed to be significant, which prohibited credit hour-gender variable from entering the regression.

Table 33

Table of Regression β-values for Validation of Chemistry 188.

Variable	Full	75%	50%	50%
GPA	0.348	0.388	0.481	0.281
Math ACT	0.277	0.252	0.189	0.387
Credit Hours	0.125	0.137	0.203	n.s.
Gender	0.188	0.213	0.205	0.193
GPA x Calculus	0.137	0.165	0.204	n.s.
PLUS x Gender	-0.237	-0.262	-0.171	-0.278
N	249	199	125	124
R^2	0.390	0.397	0.434	0.424
Adjusted R^2	0.375	0.378	0.394	0.385

Note. n.s. = non-significant variable.

Split-half Validation. The split-half validation was performed in a similar manner as the Chemistry 184 validation. In the *stepwise* model, all predictors from the full analysis were added to the regression. Again all six variables were selected by the *stepwise* process with a $R^2 = 0.434$, which was closer to the comprehensive 188 model. The adjusted $R^2 = 0.394$ was nearer to the result observed above in the *stepwise* regressions. The β-values were larger for GPA, credit hours, and the GPA-calculus completed interaction. The PLUS-gender interaction decreased by a magnitude of 0.066. Full validation results are provided in Table 33.

The *enter* 50 percent regression included four of the six variables as significant with the $R^2 = 0.324$ and adjusted $R^2 = 0.385$. The model fit mirrored the *stepwise* despite that the credit hours variable and the GPA-calculus interaction were not significant. In this model, math ACT had the largest beta weight, which may contributed to the non-significant interaction with calculus completed as seen in the 184 split-half validation.

In the 188 comprehensive model, the explained variance for predicting average exam scores was 42.4 percent with an adjusted $R^2 = 0.392$. All validation models have similar adjusted R^2 values. The credit hour-gender interaction was not selected in the *stepwise* regressions; however, as the smallest significant predictor in the comprehensive model, the removal of this variable does not have a substantial impact on the quality of the fit. In future samples, this specific interaction should only remain part of the comprehensive model if a significant ΔR^2 can be observed.

Chapter 6 : Hypothesis II: Item Analysis

To determine the effectiveness of student comprehension of particular chemistry topics, an individual item analysis was conducted for the all eight-midterm exams. The regression hypothesis analyzed PLUS attendance over the course of the each semester as a ratio level variable. While controlling for background variables, the conclusion was that students who attended PLUS sessions performed better than their peers about on average one percent for each PLUS session. Since the inclusive analysis provided fruitful results, a breakdown of individual sessions were examined through item analysis. The treatment variable of PLUS attendance transformed from a continuous to a dichotomous one. "Did the students attend the first PLUS session?" If the student did participate in PLUS, then he or she was in the treatment group. The comparison group consisted of students who choose not to partake. Each PLUS session has its own unique sample of students in the comparison or treatment groups.

Overview of Item Analysis

Item analysis consisted of item difficulty, item discrimination index, and an item-exam total correlation. When comparing two sets of data, the change in item difficulty was recording along with *p*-values from an independent *t-test.* Descriptive statistics was provided for the midterm examinations. The integrity of the item analysis was not employed to investigate the quality or validly of the exam but rather as a means to measure differences in the treatment variable.

The topics of individual exam items were cross-referenced with the PLUS packets. Each item was assigned a number for the corresponding PLUS session; however, if no association was made, then the assigned number was zero. The research would infer the treatment group would perform differently on exams items that corresponded directly to the PLUS sessions and fail to perform differently on items with no relationship.

An item associated with PLUS session 3 would not be analyzed with PLUS session 2 for the reason that the some cases were in the treatment group in one analysis and the comparison in another. Since the sample was contingent on PLUS attendance, only items labeled with a "0" would be analyzed as the non-PLUS items.

This hypothesis was intended to analyze all students who took the general exam regardless of participation in the previous regression investigation. These additional students that make up the full consent sample either did not complete the course, did not take the final exam, had missing background variables, or were removed as outliers in the multiple regression. An independent *t-test* was calculated between the full consent sample and the regression only sample to determine if there was the large magnitude and statistical difference to warrant separate item analysis.

Item Difficulty

Difficulty index essentially is the mean correctness for that specific item with one correct answer. Reporting values range from 0.00 to 1.00. Exam items with low difficulty values translated that most of the class answered the question incorrectly. Conversely, high values indicated high success rates in answering the question correctly.

The desired difficulty for individual items lie between random chance of answering the question correctly and perfect scores. The midterm exams contained five-option multiple choice questions; therefore, random guessing would have a one in five or 0.2 outcome. The midpoint of these item difficulty is 0.6. This value reflects the equidistance between a perfect score and pure chance.

For this analysis, item difficulties that were less than 0.2 were disregarded as being ambiguous, poorly worded question, keying error, or subject matter taught incorrectly since the chance value was not even achieved. Furthermore, items that were too difficult or too easy needed to be removed from the study since neither provide useful information in comparing scores. Determining the upper and lower bounds for item difficulty is inconsistent from analysis to analysis. The extreme item difficulty for this study was set at 0.15, since ranges were from 0.1 to 0.2 in the literature. Therefore, items with a difficulty index great that 0.85 were removed from analysis for being too easy while items with values less than 0.35 were removed as too difficult.

Item Discrimination Index

The item discrimination index reports the item difficulty difference between two subsets of the sample. In this study, the discrimination was established between higher preforming students verse lower preforming students for item analysis.

The top preforming students were identified by the highest exam scores for the top fifty percent of the class on each exam, while the lower preforming students were the remaining students who earned grades from bottom half the exam being studied. The range for possible discrimination values were from negative one to positive one. An index of zero can be interpreted as no difference in correctness on the item between the more knowledge students than the less knowledge students. Item discriminations that approach negative one indicate that the top performing students answer this question more wrongly than the less prepared students. On the contrary, positive index values indicate the upper preforming students answered the item more correctly than the bottom half.

The desired index is positive and greater than or equal to 0.2. Values less than 0.2 can indicate the idea is too easy or too hard resulting in low differences between the subset, a miss-key answer, or students being "tricked" by the complexity of the problem. Items with a discrimination index less than 0.2 were be removed from the study.

Item-Total Correlations

Item-total correlations is a simple Pearson's correlation between the outcome (correctness) of an item and the total exam score. This value relates a particular item to the whole exam. Similar values are desired with item-total correlation as the item discrimination index.

Comparison between Samples, Forms, and Items

Samples

A total of 580 students consented to participate in this research on the first day of class; however, the Chemistry 184 comprehensive model was based on only 442 students. There was systematic approach outlined in Chapter 3 through Chapter 5 to removed cases from the study including missing demographic and academic background variables, completion of the course, and univariate or multivariate outliers. The item analysis varies from the rigid structure of the multiple regression in as much the samples fluctuated with each exam and the comparison and treatment group change within each PLUS session. It was necessary to determine if the full consenting sample performed differently than the reduced, regression only sample. This investigation was conducted by comparing means through an independent *t-test* on exam items and the exam average. If means prove to be statistically significant then results would be provided for each sample.

Exam Forms

Three separate exams forms were written for each midterm exam. On general exam nights, two separate forms were given noted as *Red* and *Green*. See *Testing Conditions* for additional information. These two exams forms contained differences throughout the exam to minimize the potential for academic dishonesty due to close proximity of testing conditions. Some exam items were identical, others provided the item structure with differing numerical values, and finally other provided some other modification. A further detailed explanation will be provided in the next section on *Comparison of Exam Items*. Copies of both forms for Chemistry 184 Exam 1 are provided in Appendix C on 200.

The early exam, often noted as the *Blue* form, was given the night before the general exam for students who had documented scheduling conflicts. The maximum number of students granted permission to take the *Blue* form was 40, which was determined by the capacity of the room. The early exam varied immensely from the general exams to curb cheating tendencies. Because of these item differentials and the fact that the data amounted to less than five percent of the sample led to the decision not to enter the early exam data into the item analysis.

Exam Items

The exam items were compared between the *Red* and *Green* forms to categorize individual items as identical, algorithmic, or disparate.

Identical Items. These items were exactly identical in item, the correct answer, and distractors between the *Red* and *Green* exam. The pound sign (#) indicates items have the answer and distractors in a different order. In theory, identical items should not have statistical difference in item difficulty when random sampling or test distribution occurs. Although test distribution was not random since exams are passed out with alternate forms, students do not get to choose which form they take. Multiple differences seen between identical items may indicated the testing samples are not equivalent.

Identical Items Example. Exam 1, Questions 14.

Green: A **chromium ion, Cr^{3+}**, has
- A. 24 protons and 24 electrons
- B. 27 protons and 24 electrons
- C. 55 protons and 52 electrons
- **D. 24 protons and 21 electrons**
- E. 24 protons and 27 electrons

Red: A **chromium ion, Cr^{3+}**, has
- A. 24 protons and 24 electrons
- B. 27 protons and 24 electrons
- C. 55 protons and 52 electrons
- **D. 24 protons and 21 electrons**
- E. 24 protons and 27 electrons

Identical Items Example#. Exam 2, Questions 25.

Green: Which element would you expect to have the lowest **electron affinity**?
A. Si **B. Ca** C. S D. O E. Se

Red: Which element would you expect to have the lowest **electron affinity**?
A. Ca B. Si C. S D. O E. Se

Algorithmic Items. These items were structured and worded the same; however, have a different numerical value between the two exam forms. For example, one item might be inquiring about 100 grams of lead while the other form asked about 50 grams of lead. The correct answer will not be equivalent and list of distractors may be the same or different. Problems will have the exact same background knowledge and equations to solve this type of problem. When an inverse of the item was being asked, it was only considered an algorithm as long as the list of distractors and correct answer were the exact opposite. For example, items that list four statements and asked to find the true statements on one exam while the false statements of the second exam were considered an algorithm. All items that items that are identified as algorithmic were used in the idea analysis regardless if there was a significant difference by means of testing through an independent *t-test.*

Algorithmic Items Example 1. Exam 3, Questions 8.

Green: The diatomic molecule AB has a dipole moment of 0.41 D and the A–B bond distance is 115 pm. Determine the **magnitude of the partial charges, δ,** (in units of *e*) in the AB molecule.
A. 0.074 B. 0.15 C. 0.22 D. 0.27 E. 0.34

Red: The diatomic molecule AB has a dipole moment of 0.82 D and the A–B bond distance is 115 pm. Determine the **magnitude of the partial charges, δ,** (in units of *e*) in the AB molecule.
A. 0.074 **B. 0.15** C. 0.22 D. 0.27 E. 0.34

Algorithmic Items Example 2. Exam 4, Questions 2.

Green: Which of the following substances would you expect to have the smallest **enthalpy of vaporization?**

A. He	B. Ne	C. Ar	D. Kr	E. Xe

Red: Which of the following substances would you expect to have the greatest **enthalpy of vaporization?**

A. He	B. Ne	C. Ar	D. Kr	**E. Xe**

Disparate Items. All other items that were not categorize in the identical or algorithmic items were considered disparate items in this study. The concepts of may be identical; however, only disparate items with non-significant difference for item difficulty were used in the item analysis.

Chapter 7 : Item Analysis Results & Discussion

Comparison of Samples

The item analysis began with the original students who gave consent totaling 580. Forty-two students did not have item scores and therefore not including in the Chemistry 184 Exam 1 investigation. These individuals may not have taken the exam at all or perhaps took the early exam. This left 538 students in the item analysis study for Exam 1 as the full consent analysis. A total of 415 of the 442 regression students took the *Red* or *Green* form for the first exam.

The full consent sample had a mean Exam 1 score of 67.26 with a standard deviation slightly above 17. The regression only students were 67.41 and 16.943 for a standard deviation. As seen in Table 34, the change between samples was minimal and not statistically significant. In fact, every individual item on this exam failed to reject the null hypothesis from one sample to the next. Independent *t-test* on each item showed there were not statistically differences between the samples of students. Most item difficulty differences were under one percent with the exception of question 8 and 25, where the change was close to 2.5%. The completed exam itemization is reported in Table 34.

With no statistical differences through item difficulty index comparison, only the full consent sample was analyzed.

Table 34

Comparison of Exam 1 Items Full Consent and Regression Students for CHEM 184.

	Full Consent		Regression Only		Change	
Item	Difficulty	Discrm.	Difficulty	Discrm.	Difficulty	*p*-value
E1Q1	0.401	0.184	0.403	0.167	-0.002	0.977
E1Q2	0.587	0.366	0.589	0.368	-0.002	0.926
E1Q3	0.615	0.333	0.618	0.349	-0.003	0.899
E1Q4	0.810	0.243	0.814	0.208	-0.004	0.874
E1Q5	0.972	0.033	0.969	0.034	0.004	0.757
E1Q6	0.807	0.183	0.802	0.170	0.005	0.797
E1Q7	0.496	0.316	0.495	0.330	0.001	0.944
E1Q8	0.675	0.259	0.700	0.247	-0.026	0.427
E1Q9	0.937	0.073	0.928	0.111	0.009	0.490
E1Q10	0.833	0.183	0.845	0.179	-0.013	0.658
E1Q11	0.972	0.011	0.969	0.015	0.004	0.757
E1Q12	0.723	0.215	0.732	0.266	-0.009	0.745
E1Q13	0.665	0.382	0.664	0.426	0.001	0.928
E1Q14	0.913	0.136	0.918	0.131	-0.005	0.869
E1Q15	0.310	0.365	0.307	0.360	0.004	0.885
E1Q16	0.717	0.249	0.705	0.276	0.012	0.641
E1Q17	0.690	0.453	0.688	0.445	0.001	0.925
E1Q18	0.851	0.288	0.860	0.285	-0.009	0.777
E1Q19	0.870	0.229	0.874	0.213	-0.005	0.825
E1Q20	0.467	0.434	0.452	0.456	0.015	0.625
E1Q21	0.586	0.436	0.582	0.474	0.003	0.882
E1Q22	0.388	0.233	0.382	0.191	0.007	0.807
E1Q23	0.502	0.506	0.495	0.513	0.007	0.810
E1Q24	0.554	0.499	0.563	0.455	-0.009	0.816
E1Q25	0.472	0.416	0.498	0.402	-0.025	0.458

Note. Full Consent, N = 538. Regression only, N = 415. Discrim = Item Discrimination. *p*-values are reported for 2-tailed independent *t-test*.

The comparison between samples continued for all remaining exams in Chemistry 184. Once again, the difference for the difficulty of each item and for the mean between the exams was negligible. Exam 2 had mean of 63.4 for the full consent (N = 533) while the regression only student had an exam average of 65.6 (N = 430). An independent *t-test* was performed and the reported *p*-value was greater than 0.05. The full consent sample for Exam 3 and Exam 4 had averages of 66.5 and 73.6 respectively. Their corresponding regression only students' scored within one percent of the average and were not a significant difference.

The sample size varied on average by 100 students from the full consent to the regression only sample for Chemistry 184 or about 20% of the size. The discrepancy was much smaller in the Chemistry 188 semester. The number of full consent student who enrolled in Chemistry 188 was 254 and the comprehensive regression for 188 contained 245 students. This 3.5% change was not large enough to see a substantial difference any of the four exams, therefore, results were not provided.

Chemistry 184 Results

Exam 1

A total of 267 student took the *Green* form and 271 students completed the *Red* form. On the full 25 item exam, the *Red* form has a mean of 68.65, which was 2.81 percent higher than the *Green*. However, the difference was not significant based on an independent *t-test*. The null hypothesis failed to be rejected; therefore, no difference was associated between the completed *Red* and *Green* forms although specific items may differ.

Item Removal Process. First, the quality of items were assessed based on difficulty and discrimination between the higher and lower preforming students. The item difficulty was analyzed, which resulted in six items being removed for excessively high item correctness. They were the following items: 5, 9, 11, 14, 18, and 19. Item 15 was removed for having an item difficulty less than 0.35, while items 1, 6, and 10 were not discriminate enough. Finally, question

22 was dismissed from the research as having a typographical error. The mathematic values were calculated separately for both samples and the items were removed consistently for the same reason.

Next, the exam items that were not removed from the study were separated by exam forms to determine if the individual items were different between forms. Seven of the remaining 15 items were significantly different in item difficulty values from *Red* to *Green*. The individual items results are listed in Table 35. Two additional items, 2 and 25, were removed from the analysis since their classifications were disparate items with statistically different difficulty levels. The only items continuing in the analysis with the classification of disparate items were questions 3 and 7. Four algorithmic items and one identical were not removed despite having *p*-values less than 0.05.

Table 35

Item Analysis Comparing Forms of Exam 1

		Red		Green		Change	
Item	Type	Difficulty	Discrm.	Difficulty	Discrm.	Difficulty	*p*-value
E1Q2	Different	0.652	0.354	0.524	0.409	0.128	0.003**
E1Q3	Different	0.577	0.273	0.653	0.357	-0.076	0.069
E1Q4	Algorithmic	0.648	0.391	0.970	0.059	-0.323	0.000**
E1Q7	Different	0.536	0.382	0.458	0.277	0.078	0.071
E1Q8	Identical[#]	0.655	0.287	0.694	0.261	-0.038	0.344
E1Q12	Identical	0.738	0.203	0.708	0.246	0.029	0.448
E1Q13	Identical	0.618	0.389	0.712	0.327	-0.094	0.021*
E1Q16	Algorithmic	0.644	0.368	0.790	0.142	-0.145	0.000**
E1Q17	Algorithmic	0.689	0.492	0.690	0.386	-0.001	0.982
E1Q20	Algorithmic	0.468	0.481	0.465	0.425	0.003	0.940
E1Q21	Algorithmic	0.633	0.48	0.539	0.439	0.094	0.027*
E1Q23	Algorithmic	0.513	0.500	0.491	0.535	0.022	0.605
E1Q24	Algorithmic	0.502	0.432	0.605	0.542	-0.103	0.016*
E1Q25	Different	0.423	0.508	0.520	0.343	-0.097	0.024**

Note. Green form, n = 267. Red form, n = 271. Discrim = Item Discrimination.
p-values are reported for 2-tailed independent *t-test*.

Classify Items with PLUS sessions. The 12 items were matched with corresponding PLUS sessions. Session one was attended by 45 student and covered topics ranging from unit conversion, significant figures, and basic dimensional analysis. Items 3 and 7 related to PLUS session one. Seventy-five percent of the students who attended PLUS answered item 7 correctly while comparison group was substantially lower at 47%. The difference was about eight percent for item 3; however, not significant.

The students who attend the second PLUS session discussed models for the early atom, subatomic particles, and how formation of ions. PLUS Packet 2 found on page 208. Corresponding items on *Exam 1* were 8, 12, and 13 with an increase in item difficulty values of 0.26, 0.13, and

0.106 respectively. Items 8 and 12 had significant differences. The average item difficulty significantly increase from 0.665 to 0.833 to items related to PLUS session 2.

The last session to relate with the first exam was PLUS session 3 in which 112 student attended. Five items (17, 20, 21, 23, and 24) on the exam were similar in nature of the concepts studied including introduction to the mole and molar conversions, balancing chemical equations, and limiting reagents. Three of the five items on average had PLUS student with the correct answer more often. When all five exam items were averaged together, the PLUS students' change in item difficulty was 9.1% (p-value ≈ 0.000). Specific item results can be found in Table 36.

Table 36

Treatment Item Analysis for Chemistry 184, Exam 1

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 1					
	E1-Q3	0.609	0.689	0.080	0.290
	E1-Q7	0.473	0.756	0.283	0.000
PLUS 2					
	E1-Q8	0.638	0.905	0.267	0.000
	E1-Q12	0.705	0.838	0.133	0.017
	E1-Q13	0.651	0.757	0.106	0.053
PLUS 3					
	E1-Q17	0.667	0.762	0.094	0.045
	E1-Q20	0.451	0.516	0.064	0.205
	E1-Q21	0.561	0.667	0.106	0.035
	E1-Q23	0.483	0.563	0.080	0.114
	E1-Q24	0.529	0.635	0.106	0.037

Note. N = 538. PLUS 1 (n = 45), PLUS 2 (n = 74), and PLUS 3 (n = 112).
p-values are reported for 2-tailed independent *t-test*.

Comparison of PLUS and Non-PLUS Items. The culmination of item analysis concluded with the investigation of the collective PLUS items compared with the non-PLUS items within each PLUS session. The exam items were averaged together for each the comparison group and the treatment group. Also, the mean item difficulty for non-PLUS were consistent items within the exam frame; however, the values varied due to the oscillation of students within the sample from PLUS session to PLUS session. Discrimination values were reported between the treatment and comparison sub-samples with its corresponding *p*-value from a heteroscedastic error, independent *t-test*.

Only two items, 4 and 16, on the first exam were not linked to any pre-planned and documented PLUS discussion. The flexibility of PLUS allowed for questions and dialogue involving material not presented in the packets, so concepts or problems might have been discussed in a peer to peer capacity. These two items were averaged together, which represented the Non-PLUS items. In PLUS session 1, the PLUS students performed on average ten percent higher than their peers on the Non-PLUS items as seen in Table 37. This was a significant increase as noted by a *p*-values of 0.033. PLUS 2 and 3 did not have a statistical change in item difficulty as expected between the comparison and the treatment group.

Exams 2 through 4

The item analysis began in a similar way for Chemistry 184 *Exam 2*. No statistical difference was noted between the full sample of 533 students and the regression only sample of 430. The mean for the second exams was 63.39 with a standard deviation of 17.29. The students who took the *Green* form (n = 276) did not perform differently on the overall exam than the 257 students who took the *Red* form. The results from the item analysis are provided in Table 44. Similar results were discovered for *Exam 3* and *Exam 4* and the sample size went down with each additional test.

The removal of items began with those that were too easy (17 and 20) with item difficulties greater than 0.85 and item 1 for being too difficult. Additionally items 12 and 22 were removed for the analysis for having an item discrimination less than 0.2. Of the 20 remaining items, seven had notable item difficulties with four being higher on the *Green* exam and three on the *Red* exam. Items 5, 18, 19, and 23 were categorized as disparate with these differences and therefore removed from the study. The remaining items were crossed referenced with PLUS packets five through seven to begin analysis on *Exam 2*. PLUS session four was within the time frame of *Exam 2*; however, the material discussion was a review of dimensional analysis and balancing chemical equations. Exam questions 2, 9, 14, 21 were not linked with any PLUS sessions, so these items made up on the non-PLUS average for PLUS session five through seven. The itemization for *Exam 2* is located in Table 45.

PLUS attendance reached its highest volume prior to Exam 2. Weekly attendance soared above 110, which did not reflect the additional student who engaged in PLUS but did not sign consent forms. Individual item analysis did prove substantial difference for 10 of the 12 PLUS items over the three PLUS sessions.

The 25-items from *Exam 3* were reduced by ten items that failed to meet the criteria necessary for this analysis. The majority of the items were inconsistent from the *Red* to *Green* form despite no difference in overall exam score, which is seen in Table 46. The experimental analysis is provided in Table 47 with PLUS session eight through ten. All exam items corresponded to one of the three sessions, therefore, a non-PLUS average did not accompany Exam 3's PLUS average in Table 37.

The last exam of Chemistry 184 was *Exam 4*, which had a mean of 73.6 and a standard deviation just above 18. Only 493 student took the *Red* or *Green* form and results are listed in Table 48. This exam had five items with difficulty above the 0.85 cut-off and one addition item was removed for lack of item discrimination. PLUS participation dwindled as the semester can come to an end. However, those students who attended performed significantly higher on all selected PLUS exam items, which ranged from a 12% to 23% increase in correct answers.

Table 37
Average Item Analysis for PLUS Sessions Associated Chemistry 184

	Item		Difficulty		
Session	Type	Quantity	Comparison	PLUS	Δ
PLUS 1					
	PLUS	2	0.540	0.725	0.182**
n = 45	Non-PLUS	2	0.758	0.856	0.098*
PLUS 2					
	PLUS	3	0.665	0.833	0.168*
n = 74	Non-PLUS	2	0.761	0.784	0.023
PLUS 3					
	PLUS	5	0.538	0.629	0.091**
n = 122	Non-PLUS	2	0.753	0.801	0.048
PLUS 5					
	PLUS	6	0.611	0.736	0.124**
n = 92	Non-PLUS	4	0.649	0.742	0.093**
PLUS 6					
	PLUS	2	0.635	0.792	0.157**
n = 137	Non-PLUS	4	0.579	0.611	0.032
PLUS 7					
	PLUS	4	0.624	0.743	0.119**
n = 110	Non-PLUS	4	0.579	0.616	0.037
PLUS 8					
	PLUS	6	0.740	0.845	0.106**
n = 92	Non-PLUS	0	-	-	-
PLUS 9					
	PLUS	3	0.643	0.793	0.149**
n = 111	Non-PLUS	0	-	-	-
PLUS 10					
	PLUS	6	0.614	0.778	0.164**
n = 88	Non-PLUS	0	-	-	-
PLUS 11					
	PLUS	2	0.653	0.853	0.201**
n = 58	Non-PLUS	7	0.671	0.772	0.101**
PLUS 12					
	PLUS	6	0.735	0.874	0.139**
n = 74	Non-PLUS	7	0.668	0.766	0.098**
PLUS 13					
	PLUS	4	0.642	0.786	0.144**
n = 76	Non-PLUS	7	0.670	0.756	0.086**

Note. PLUS Sessions 1, 2, and 3 correspond to Exam 1 with N = 538. PLUS Sessions 5, 6, and 7 correspond to Exam 2 with N = 533. PLUS Sessions 8, 9, and 10 correspond to Exam 3 with N = 512. PLUS Sessions 11, 12, and 13 correspond to Exam 4 with N = 493. $^{**}p < 0.01$ and $^{*}p < 0.05$ for 2-tailed.

Chemistry 188 Results

Exam 1, 2, and 4

The item analysis for Chemistry 188 followed the 184 protocol for comparison between forms and item removal. In this analysis, *Exam 1* was taken by 244 students with a mean of 64.5. An equal amount of students took the *Green* and *Red* forms with exam means of 61.3 and 65.9, respectively. This approximately three percent difference was not significant. The full results for *Exam 1* can be found Table 50. Some of the results gleaned from this table include deleting items 1, 2, and 8 for being too high on the difficulty index, while 24 was too low. Additionally, three items were statistically different from one form to another and thus removed.

The first three PLUS session provided supplemental instruction for *Exam 1*. With the smaller 188 sample, PLUS attendance dropped to roughly 50 students per week during this exam. Two of the four items for PLUS 1 and all items for PLUS 2 were significantly higher than the comparison group. Individual item analysis is found in Table 50. Items 20, 23, and 25 covered the concepts of calculating equilibrium constants and Le Châtelier's principle and have a change in item difficulty index listed in order of 0.167, 0.221, and 0.103. The change in Item 25 was not significant.

The PLUS, non-PLUS averages were moderately consistent with the findings from Chemistry 184. In the first session, the average of items that related to PLUS was 0.668 for the comparison while the treatment students' difficulty index was substantially higher at 0.792. The seven non-PLUS items were also significantly higher for *PLUS 1 and 2*; however, the amount of change in order was less at 0.073 and 0.084 compared to the PLUS difference at 12.4% and 16.1%.

Only the PLUS average was significant for session three. Average item analysis for Chemistry 184 is located in Table 38.

Exam 2 had a very high overall average of 72.3 and the difference between the *Red* and *Green* forms was one-tenth of a percent. Fourteen individual items analyzed were separated with four in *PLUS 4*, three in *PLUS 5*, and seven items in the non-PLUS average. Even though only two of the four items, 15 and 19, had significant differences, the overall *PLUS 4* item difficulty averages increased significantly by 10% with the treatment group. The non-PLUS average was comparable by the increase but only half as much. Session five did see a dramatic item difficulty gain of 0.143 with averaged PLUS. No notable difference was calculated between sub-samples on the Non-PLUS items.

The study included 236 examinees for the final Chemistry 188 exam. The overall mean was 70.2 and no differences were discovered between the various forms. Just over half the items were investigated in the item analysis study. Item 11 which corresponded to PLUS 9 had a positive difficulty change of 0.250, the single largest difference in Chemistry 188. The PLUS item difficulty averages increased by 0.151 and 0.134 for PLUS 9 and 10, respectively. Differences were not observed for either session's Non-PLUS average.

Table 38

Average Item Analysis for PLUS Sessions Associated Chemistry 188

	Item		Difficulty		
Session	Type	Quantity	Comparison	PLUS	Δ
PLUS 1					
	PLUS	4	0.668	0.792	0.124**
n = 42	Non-PLUS	7	0.539	0.612	0.073*
PLUS 2					
	PLUS	4	0.709	0.870	0.161**
n = 50	Non-PLUS	7	0.536	0.620	0.084**
PLUS 3					
	PLUS	3	0.538	0.702	0.164**
n = 46	Non-PLUS	7	0.482	0.522	0.039
PLUS 4					
	PLUS	4	0.774	0.875	0.101*
n =22	Non-PLUS	7	0.755	0.805	0.050*
PLUS 5					
	PLUS	3	0.627	0.770	0.143**
n = 42	Non-PLUS	7	0.709	0.746	0.037
PLUS 9					
	PLUS	4	0.626	0.777	0.151**
n = 29	Non-PLUS	5	0.604	0.672	0.068
PLUS 10					
	PLUS	4	0.719	0.853	0.134**
n = 34	Non-PLUS	5	0.567	0.618	0.051

Note. PLUS Sessions 1, 2, and 3 correspond to Exam 1 with N = 244. PLUS Sessions 4 and 5 correspond to Exam 2 with N = 234. PLUS Sessions 9 and 10 correspond to Exam 4 with N = 236. **p < 0.01 and *p < 0.05 for 2-tailed.

Exam 3

Unfortunately, the Chemistry 188 Exam 3 data was corrupted with coding errors, which resulted in nonsensical data. Some students raw answer selections, did not match up with either the *Red* or *Green* answer keys and then with their corresponding exam score. Several attempts were made to diagnosis and correct the discrepancies; however, no single resolution was established. To prevent presenting wrong or miss leading results, the items analysis was not conducted on *Exam 3*. PLUS sessions *6* through *8* corresponded to this exam.

Discussion

Participation in PLUS led students on average to answer significantly more items correctly when linked to corresponding sessions. All 12 PLUS sessions in Chemistry 184 and seven sessions in Chemistry 188 observed students with better successful outcomes compared to their classmates with a discrimination index of nearly 0.15 for the majority of sessions. A grand total was not calculated do to inconsistent sample size and the comparison- treatment groups were dynamic over the course of the each semester. These results reject the null hypothesis and consequently accept the research's, which stated there would be a difference on the item for student performance on PLUS related material. This self-selected intervention was positive which indicated PLUS assisted students in performing higher on exams than the comparison group.

The complementary hypothesis of comparing the treatment group for each PLUS session to exam items that were not formally discussed produced an array of outcomes. The research and null hypothesis were identical, which stated regardless of participation in PLUS, students would perform in a similar manner on non-PLUS exams items. The results were more complex since nearly half saw no difference in item difficulty between the comparison and the treatment group, while the others did see a notable difference.

Several explanations that may have contributed to the PLUS students out preforming the comparison group, were sample size, motivation, and more effective time studying. In Chemistry 184, the first PLUS session had 45 students or about eight percent of the study participating in the treatment group, where the largest session was *PLUS 6* with student participation at 137 or roughly 25% of the class. As mentioned in variable analysis, a general caution was recommended for variables representing under ten percent of the sample due to increase error. Fewer cases could result in a type I error or rejecting the true null hypothesis. In weeks with participation of more than 100 students, there was not a significant difference in item difficulty between PLUS or non-PLUS students.

In the Chemistry 188 analysis, *PLUS 4* was the only session that did not meet the ten percent requirement for analysis with only 22 students in the treatment group. The item difficulty difference was measured at 0.05 and a *p*-value of 0.048.

The second theory for more PLUS attendees answering the Non-PLUS questions at a higher success rate was due to higher levels motivation. The first PLUS session was held during the first week of class for Chemistry 184 and did have an increase just under 10% for the two non-PLUS items. These students took advantage of an opportunity to assist in their learning immediately and did not wait for several reminders before attending sessions. Significant differences were also seen at the end of the semester with sessions *11* through *13*. At this point in the course, many students were fatigued, busy with the holidays, and excitedly chattered about dropping *Exam 4* during the course lecture. The students who continued through the program potentially had more motivation than students who participated during middle of the semester.

Disappointingly, the results did not parallel with the Chemistry 188 semester in terms of amount of significant changes. More significant differences in non-PLUS averages were determined in the beginning rather than the end of the year. Without the data from non-PLUS items on either *Exam 3*'s PLUS sessions, the transition because impossible to discern.

Another potential reason why PLUS students performed higher on non-PLUS related items could be observed through an indirect study effect. PLUS sessions allowed students to digest several key concepts in an hour guided by knowledgeable peer leaders and problem-solving with their peers. From previous results, these students did have a stronger grasp of the PLUS topics which might have left more time on concepts not discussed in their personal study.

Regardless of reasons why some sessions had significant differences and others did not, the magnitude for the change in item difficulty index played a vital role as well. The level of success between the comparison groups to the PLUS students was always lower on non-PLUS related items than on PLUS items. In fact for Chemistry 184, the average change was around half or less of the PLUS item discrimination for all but two sessions (5 and 12). This trend continued into the Chemistry 188 semester with exam. PLUS attendees regularly had discrimination index twice as high for PLUS items verses non-PLUS when compared with their peers who did not participate in PLUS.

This helped to solidify that despite differences some sessions observed in the non-PLUS items averages, PLUS student still performed at a higher success rate on concepts interconnected to PLUS than material not exposed to during a session.

Chapter 8 : Conclusions and Future Research

Conclusions

Supplemental instruction comes in varying programs with unique attributes to assist student in enhancing academic achievement and generating better conceptual understanding. The Peer Led Undergraduate Supplements began in the Foundations of Chemistry II course in spring 2010 with packet development and peer leader and graduate teaching assistant training. PLUS adapted to meet student needs at KU by allowing students to partake in sessions as much or as little as they pleased with no negative consequences.

Multiple Regression Findings

The least linear squares multiple regression painted a complex model of predictors for achieving success in Foundations of Chemistry I and II. Preliminary results showed students who participated in PLUS preformed higher on course exams than the class average. These findings carried little weight with professors given lack of rigorous testing and control for academic background variables. The research design was developed to address these specific concerns: (1) was the PLUS program assisting students in academic achievement beyond their normal capabilities? (2) If a difference was noted in PLUS, then did certain groups of students experienced a greater impact?

A hierarchical regression while controlling for demographic and academic variable was developed to analyze the magnitude and direction of PLUS attendance on average exam scores. A quasi-experimental design was conducted to maintain the flexibility for students to attend the supplemental instruction on their own accord without penalizing or limiting the perceived benefit to only part of the class.

Several variables including first-time freshman status and completion of high school chemistry were predicted to increase the explained variance of the model; however, they failed to do so. All demographic variables relating to race and ethnicity either did not have a large enough sample size to be entered into the regression or were not found to be significant. Self-reported professional aspirations was investigated for students intending to be medical doctors, engineers, and pharmacists.

Regressions were performed separately for Chemistry 184, 188, and 184†. All models had significant predictors of high school GPA, credit hours earned in high school, math ACT scores, calculus completed, gender, and the treatment variable, PLUS attendance. High school GPA contained parallel mediators of math ACT and credit hours when regressed on the chemistry exam scores. However, these models were only partially mediated; significant direct effects or conditional direct effects were observed. Indirect effects were calculated through PROCESS confirming mediation, high school GPA affected Chemistry scores through math ACT and high school credit hours.

The Chemistry 184 model took the dual mediation scaffolding model and added gender, which moderated the GPA to math ACT relationship. Calculus and pre-pharmacy students were significant predictors and were controlled prior to the addition of PLUS 184 attended. Pre-pharmacy students did moderate the effect of PLUS attendance on chemistry achievement, essentially revealing pre-pharmacy student experienced no exam score increase for attending

PLUS sessions like their peers did. PLUS and its corresponding interaction increased the explained variance by just over five percent, an average of a one percent increase in exam score for each PLUS sessions attended.

The Chemistry 188 regression exhibited a number of key differences. First, pre-pharmacy students no longer contributed to the model either directly or through its interaction with PLUS. Next, gender still moderated within the mediation; however, the interaction involved credit hours with Chemistry 188 scores and not GPA with math ACT scores. Consequently, gender and its corresponding interaction with credit hours entered the regression with average exam scores as the consequent. The PLUS relationship to the average exam scores was still moderated, but with gender as opposed to pre-pharmacy. Finally, the variable calculus completed was no longer just a control, but rather was involved in the path analysis by moderating the direct effect. Regardless of whether a student took calculus, the conditional direct effects were significant, indicating a partially mediated model; however, those who did complete calculus had conditional direct effect 3.5 times larger. Females who attended PLUS session on averaged increased their Exam 188 scores by 1.2 percent per session, while males did not report any difference. Fewer males participated in PLUS sessions especially those attending more than five the sessions during the semester, which may contribute to the lack of significant results.

Due to the prominent changes from the 184 to 188 models, a third regression was undertaken to study the performance in CHEMCHEM 184 of only those students who eventually progressed to CHEM 188[†]. The chief modification noted in this study was gender no longer moderates the PLUS 184[†,] but rather moderates the direct relationship along with calculus completed. The PLUS attendance did significantly increase the model fit by R^2 = 0.0013 and a regression coefficient of $B = 0.390$. If students attended all PLUS sessions, their course exam grades could increase by an average of five percent.

The greatest impact noted in this study was that students attending PLUS chemistry sessions report a measurable increase in exam performance, while controlling for previous academic background for the majority of students. The flexibility of attendance for the PLUS model did not cause a lack of results; however, it was possible students did not gain the full potential of the PLUS intervention. Certain groups within the sample including pre-pharmacy students in 184 and males in 188 did not appear to increase their exam scores by attending PLUS sessions. The pre-pharmacy students had exam scores higher than students identifying with other professional choices, clearly demonstrating that student participation in PLUS is not the only factor favoring better student achievement in exams scores. The impact and attendance of PLUS sessions appears to diminish throughout the second semester; however, additional research will be needed to confirm this trend.

Effects beyond student grades could include continued funding from the university to support and expand supplemental instruction with PLUS or a similar structured model. These results might persuade a hesitant instructor to foster positive greater partnership with those involved in PLUS and encourage students to participate. Lastly with additional testing over several semesters, these regression models could be applied to future students for predicting chemistry success with the hopes of early intervention for high-risk students, allowing personal students to receive personal referrals to the program from an administrator or professor.

Item Analysis Research

The item analysis determined students who participated in PLUS session on average answered the items correctly 15 percent more often when exposed to concepts during their PLUS session than their peers who did not attend. On the material not discussed in PLUS, a much greater range was observed. The majority of sessions saw no significant differences between the comparison and treatment sample; however, other items have PLUS attendees performing up to ten percent higher on the non-PLUS related items. In all PLUS session observed, the average PLUS related items had a higher item discrimination index (PLUS students minus comparison) than non-PLUS items. Several potential explanations on why the null hypothesis was not observed for the comparison of non-PLUS items were the following: (1) more motivated students attended PLUS, (2) students gained confidences on concepts discussed in PLUS, and therefore, had more time to study different material on their own, and (3) limited sample size of the treatment group for several session which increase the chance of type II error.

One of the positive impacts of performing an item analysis includes indirect constructive criticism on the quality of packets. On exams with a large number of non-PLUS items, these sessions should strongly be evaluated to determine if material was well aligned with the course. Involving the instructor to give feedback about key learning objectives to improve the supplemental session as being commentary to the course lecture. The intention was not to teach to the professor’s exam rather to identify holes in the content of the PLUS program. Also addressing the course within the first week of class to convey these results could lead to greater PLUS attendance and more students assisted through supplemental learning.

Future Research

Research on the PLUS program could take numerous paths in the future. This paper provided the analysis for Foundations of Chemistry I & II; however, PLUS O-CHEM is offered for students in Organic Chemistry and PLUS Bio for student in Principles of Molecular and Cellular Biology and Principles of Organismal Biology. By expanding the research to these courses, a more complete assessment of this PLUS program can be conducted.

Additional research conducted within the PLUS chemistry model might including the following:

(1) expand the current variables to include social support, motivation, and self-efficacy related to science and math fields.

(2) cross-validate new samples with current comprehensive models

(3) perform a pre-test on students to determine a more accurate assessment of math and chemistry capabilities.

(4) develop and analyze results from an exit survey.

(5) conduct a longitudinal study to integrate several semesters of regressions models.

(6) implement a multi-dimensional study, which would involve tracking students over all courses with PLUS to include retention in the sciences and at the university .

Another point of interest with current data is to determine if the development of single regression model yields meaningful results. Aggregation of all three individual analyses, particularly with the extensive use of moderators in a single equation, would reduce the need for three conditional regression, though results may become exceedingly complicated with conditional effects.

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Appendix A

Quasi-Experimental Analysis of Student Performance and Retention in Peer Led Undergraduate Supplements
INTRODUCTION

The Department of Chemistry and at Office for Diversity of Science Training the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this study is to evaluate the effectiveness of the Peer Led Undergraduate Supplements (PLUS) program by measuring academic performance of students who attended PLUS sessions to their peers who did not.

PROCEDURES

Students have the option of attending PLUS sessions through the semester in general chemistry. The sessions times are available through course blackboard site, PLUS website: http://www2.ku.edu/~plus/chemistry.shtml, and by announcements made in class. These sessions provide a packet of material covering topics presented in the lecture course from the previous week. Students are encouraged to engage with the material, work in small group for problem solving, and different hands-on activities.

A performance analysis will be conducted to determine if students who attend PLUS session have a difference in their exam scores as their peers, who did not attend PLUS sessions.

RISKS

There should be no risks associated with participation in this study.

BENEFITS

This program is designed to assist students to increase performance in chemistry through academic progress and conceptual understanding of topics. PLUS sessions are open to all students enrolled in the course free of charge. Students may participate as much or little as they see fit.

PAYMENT TO PARTICIPANTS

Students will not be paid for participations in this study.

PARTICIPANT CONFIDENTIALITY

Your name will not be associated in any publication or presentation with the information collected about you or with the research findings from this study. After the completion of the course, the researcher(s) will use a study number or a pseudonym rather than your name. Your identifiable information will not be shared unless required by law or you give written permission.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose further information collected about you, in writing, at any time, by sending your written request to: *Linda Gardner, Dept. of Chemistry,1251 Wescoe Hall Drive, 2010 Malott Hall, Lawrence KS 66045.*

If you cancel permission to use your information, the researchers will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s) listed at the end of this consent form.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or (785) 864-7385, write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

_______________________________ _____________________

Type/Print Participant's Name Date

____

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Appendix B

Table 39

Quantitative SAT scores converted into Math ACT scores.
(“College Entrance Examination Board,” 1999)

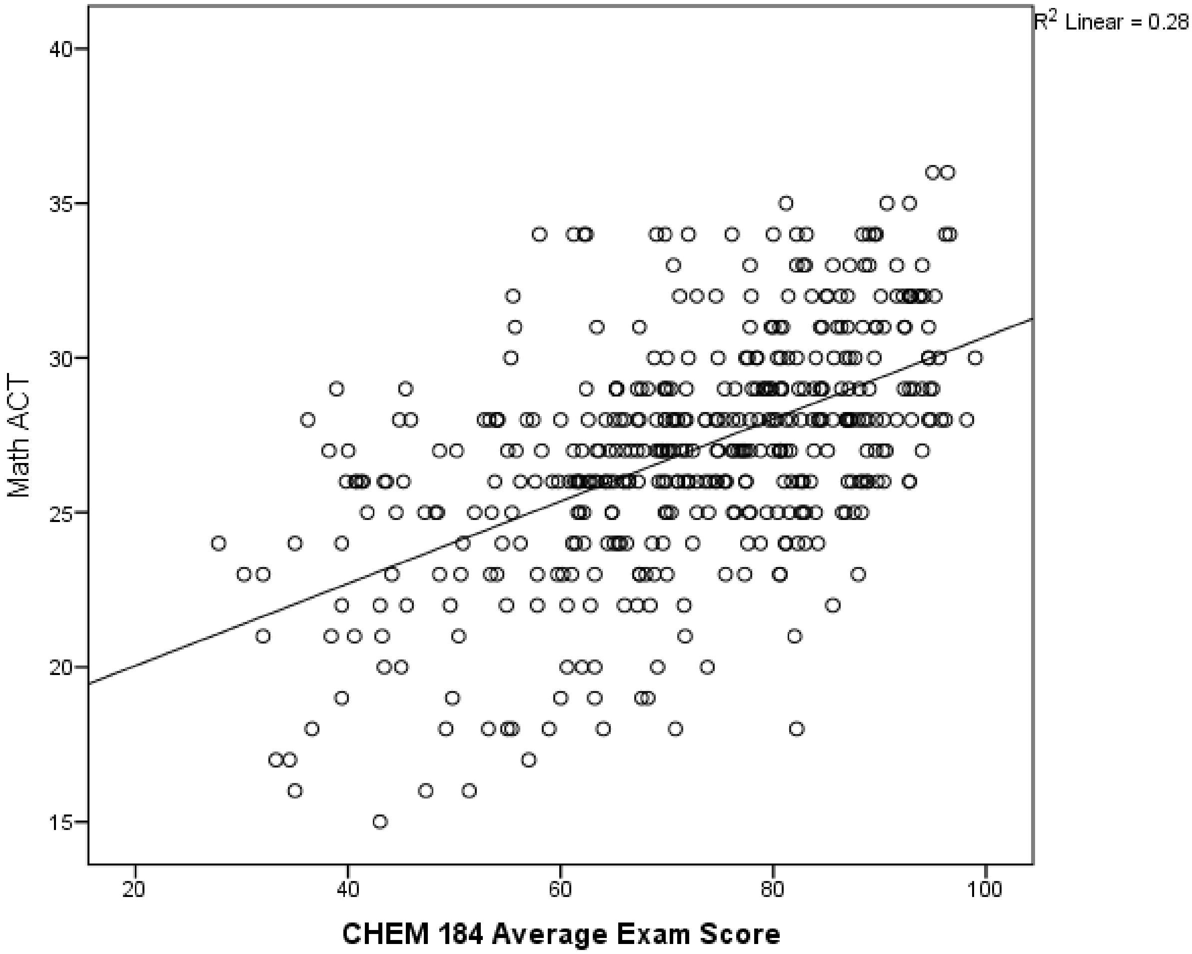
SAT Quantitative	ACT Math
800	36
790	35
770-780	34
740-760	33
720-730	32
690-710	31
670-680	30
650-660	29
630-640	28
610-620	27
590-600	26
570-580	25
560	24
540-550	23
520-530	22
500-510	21
480-490	20

Table 40
Self-Reported Professional Aspiration of Students on Day 1.

	Chemistry 184		Chemistry 188	
Profession	Number	Percentage	Number	Percentage
Biologist	2	0.45	0	0.00
Business	4	0.89	1	0.39
Chemist	1	0.22	15	5.86
Dentist	21	4.69	11	4.29
Dentist Assistant	1	0.22	0	0.00
Engineering	57	12.72	0	0.00
Government	5	1.12	1	0.39
Medical Doctor	168	37.50	110	42.96
Medical Research	21	4.69	14	5.46
Meteorologist	2	0.45	1	0.39
Nursing	8	1.79	3	1.17
Occupational Therapist	2	0.45	61	23.82
Optometrist	4	0.89	9	3.51
Personal Trainer	4	0.89	4	1.56
Pharmacist	72	16.07	3	1.17
Physic	3	0.67	0	0.00
Physical Therapist	18	4.02	1	0.39
Physician's Assistant	7	1.56	0	0.00
Psychologist	1	0.22	0	0.00
Teacher	6	1.34	3	1.17
Undecided	36	8.04	1	0.39
Vet	5	1.12	18	7.03
Total	448	100.00	256	100.00

Figure 23

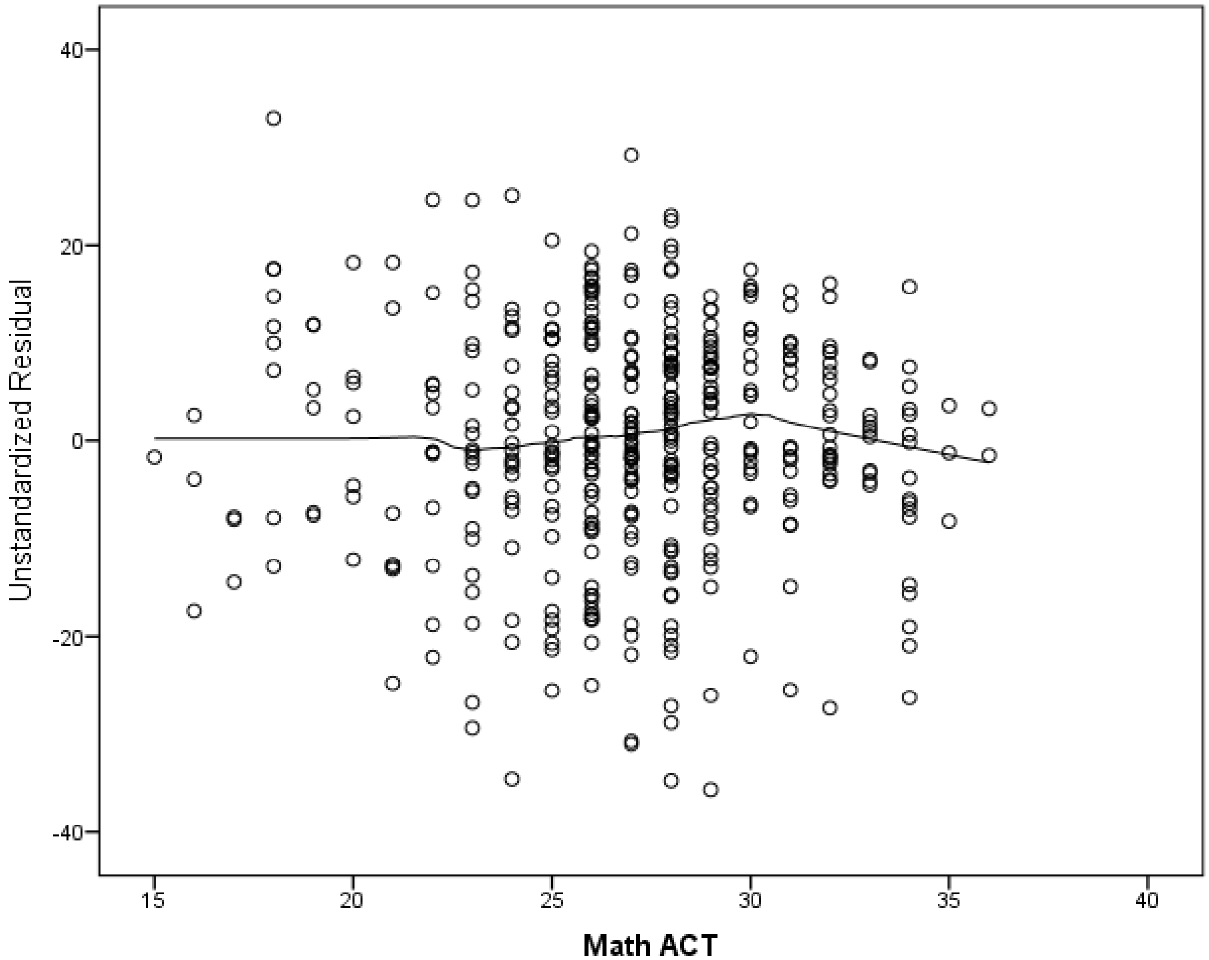
Bivariate Scatterplot of Math ACT Scores and Chemistry 184 Exam Scores.



Note. N = 448.

Figure 24

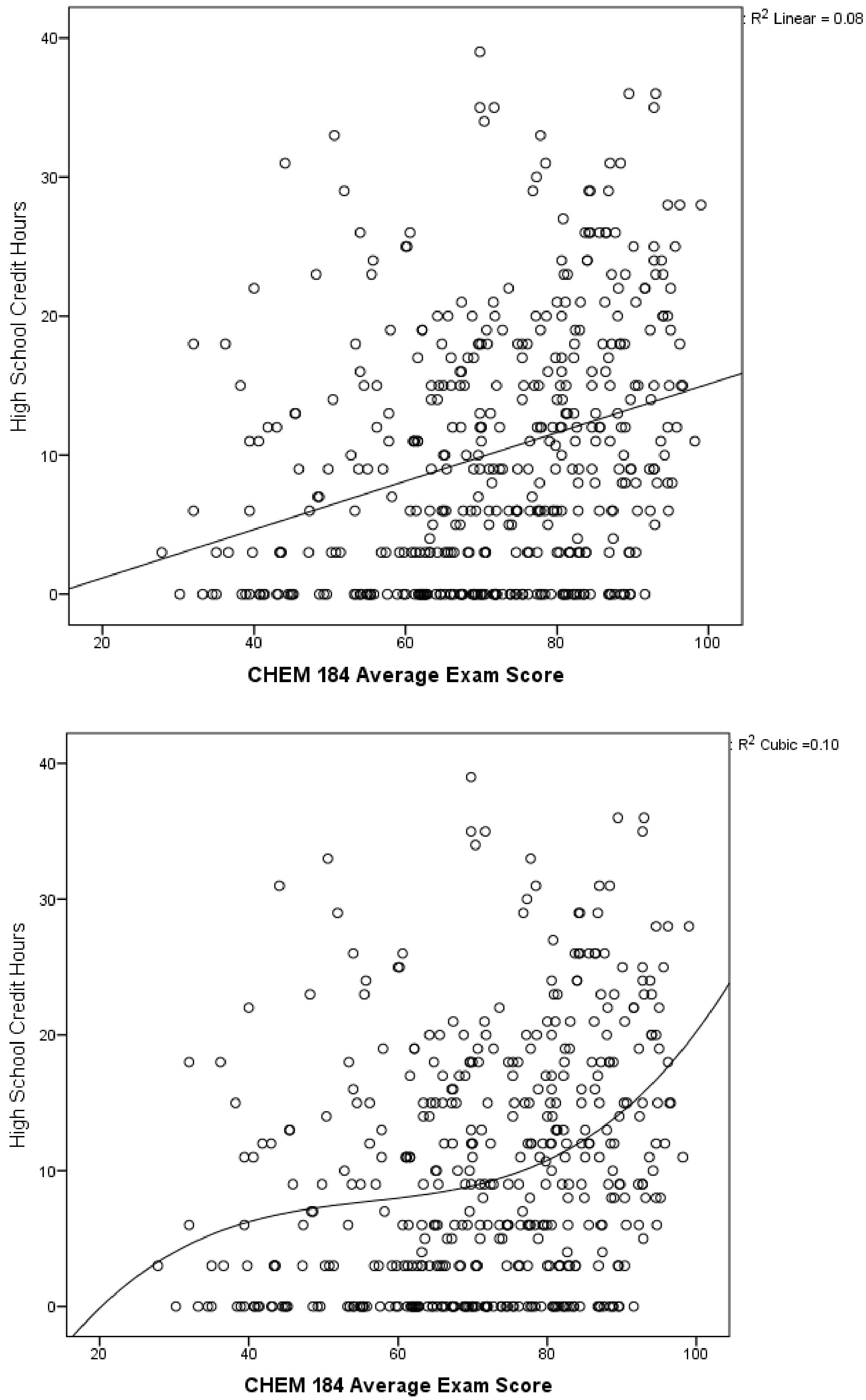
Bivariate Scatterplot of Math ACT and Residuals from CHEM 184 Multiple Regression.



Note. N = 448.

Figure 25

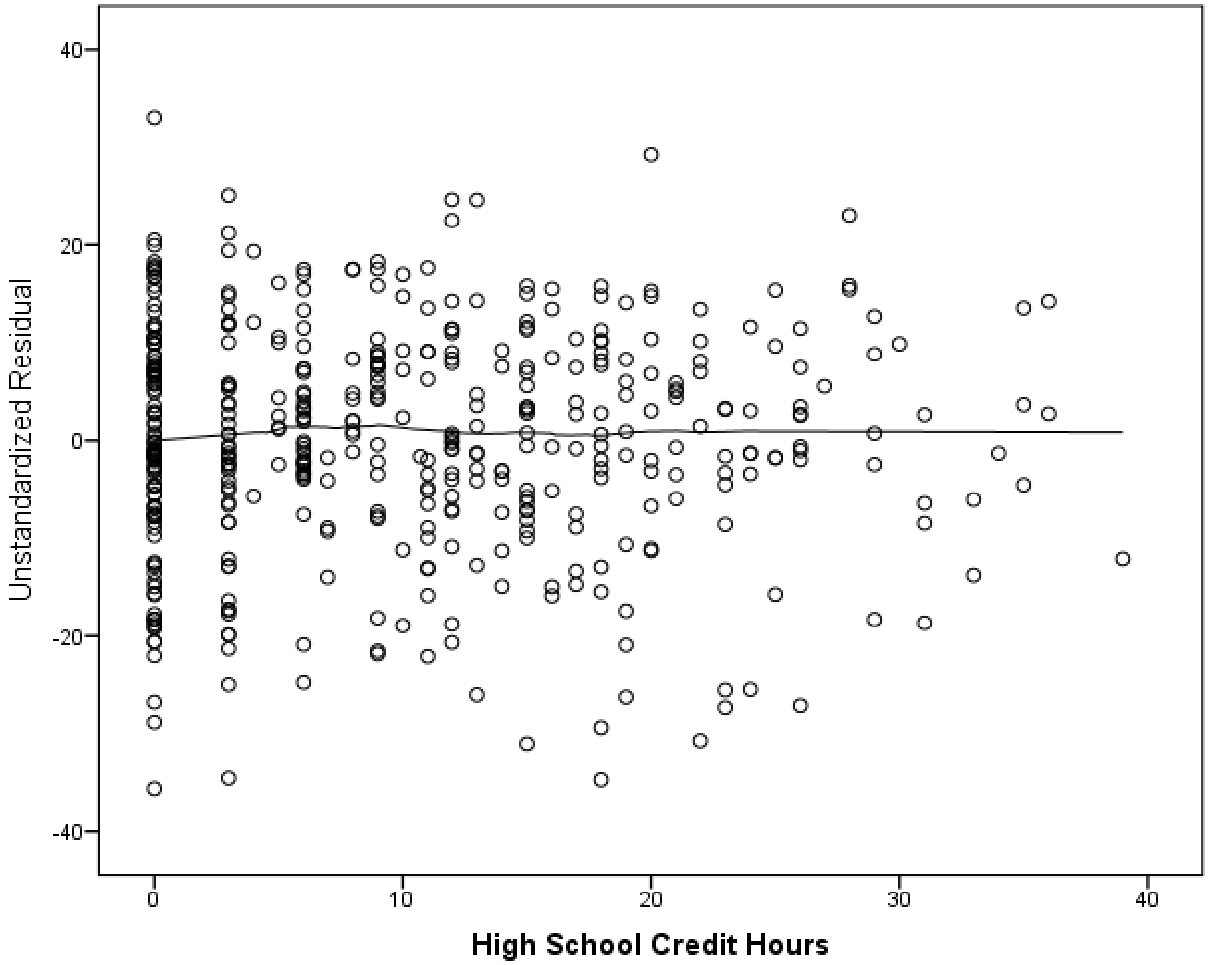
Bivariate Scatterplots of Credit Hours and Chemistry 184 Exam Scores.



Note: N = 448. Upper figure has the linear trendline, while the lower figure has the cubic trendline.

Figure 26

Bivariate Scatterplot of Credit Hours and Residuals from CHEM 184 Multiple Regression.



Note. N = 448.

Figure 27

Bivariate Scatterplot of PLUS 184 Attendance and Chemistry 184 Exam Scores.

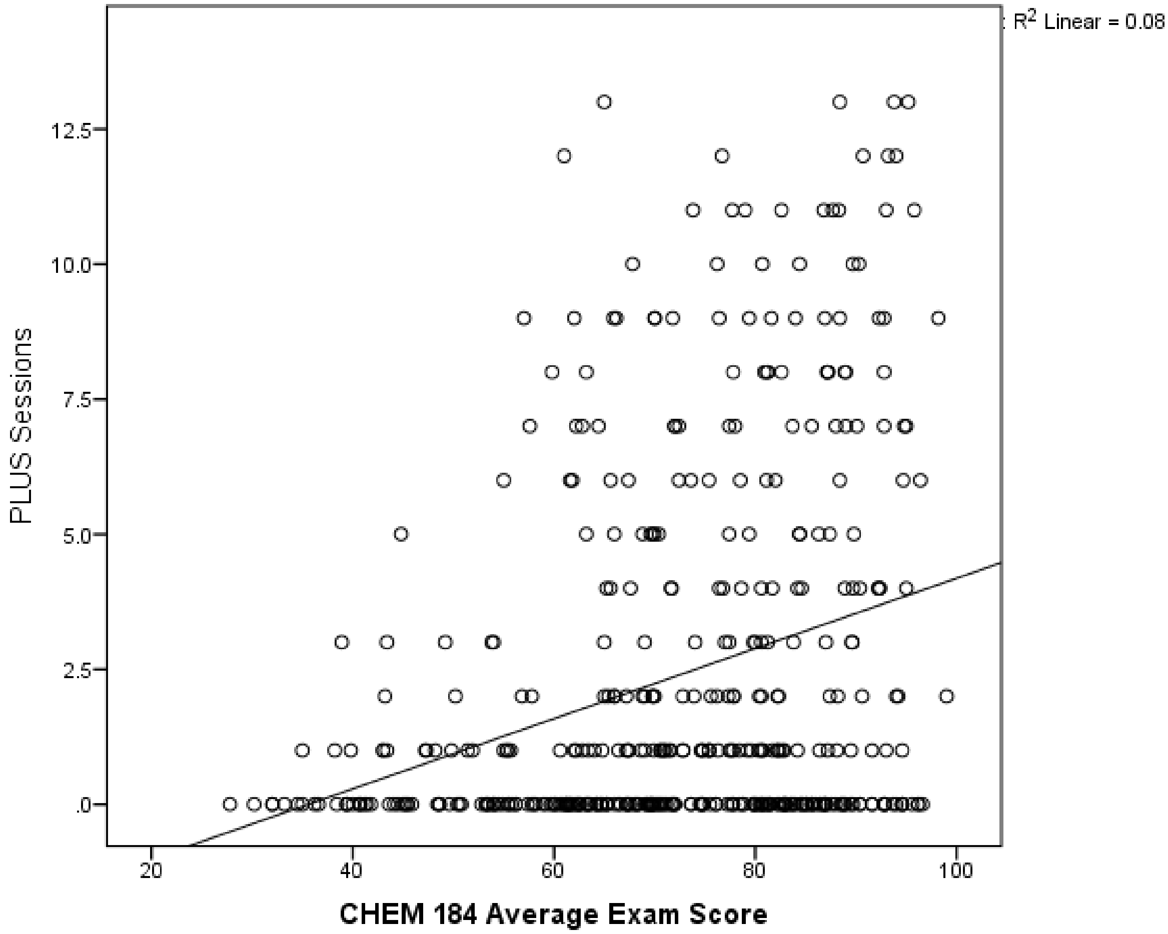
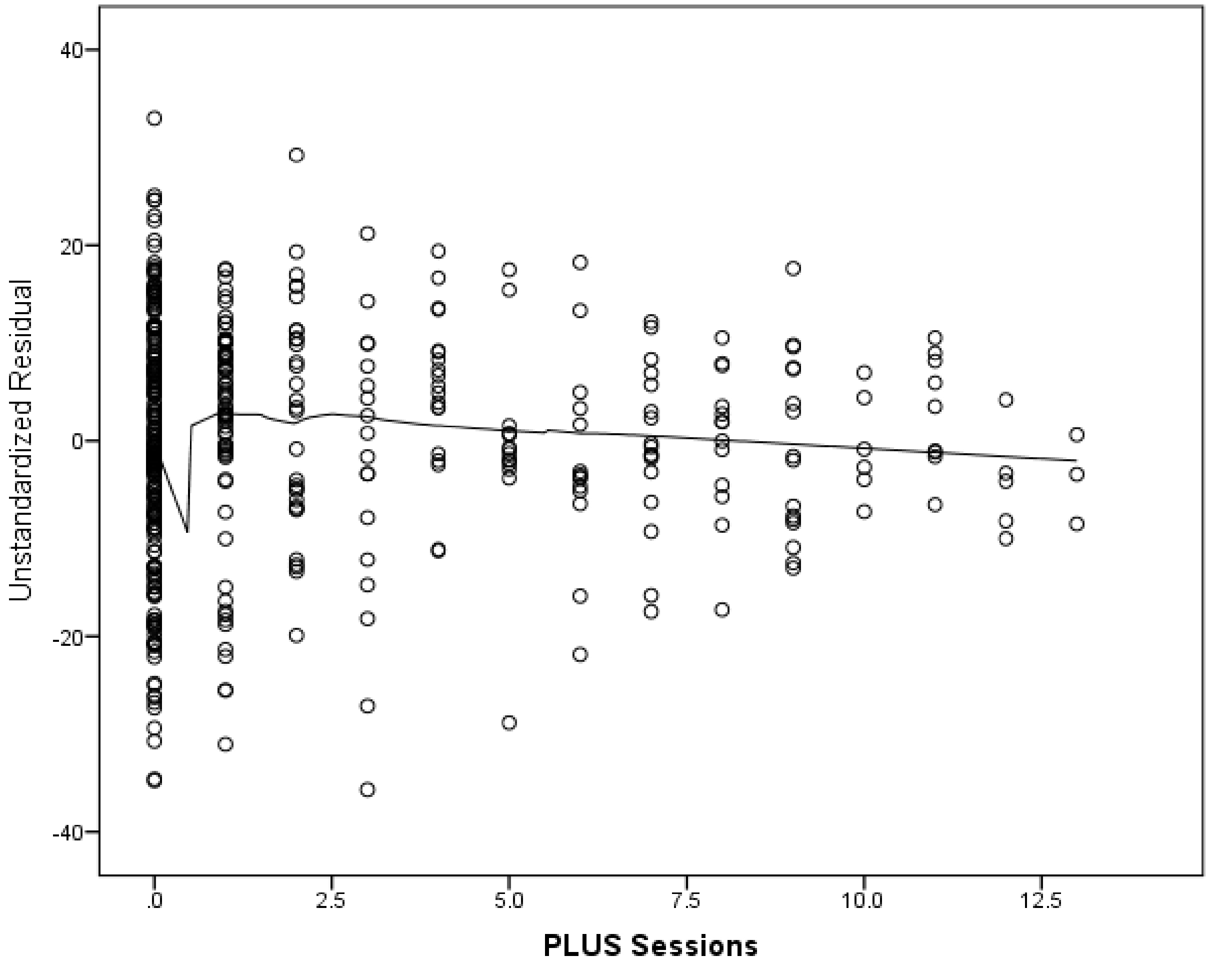


Figure 28

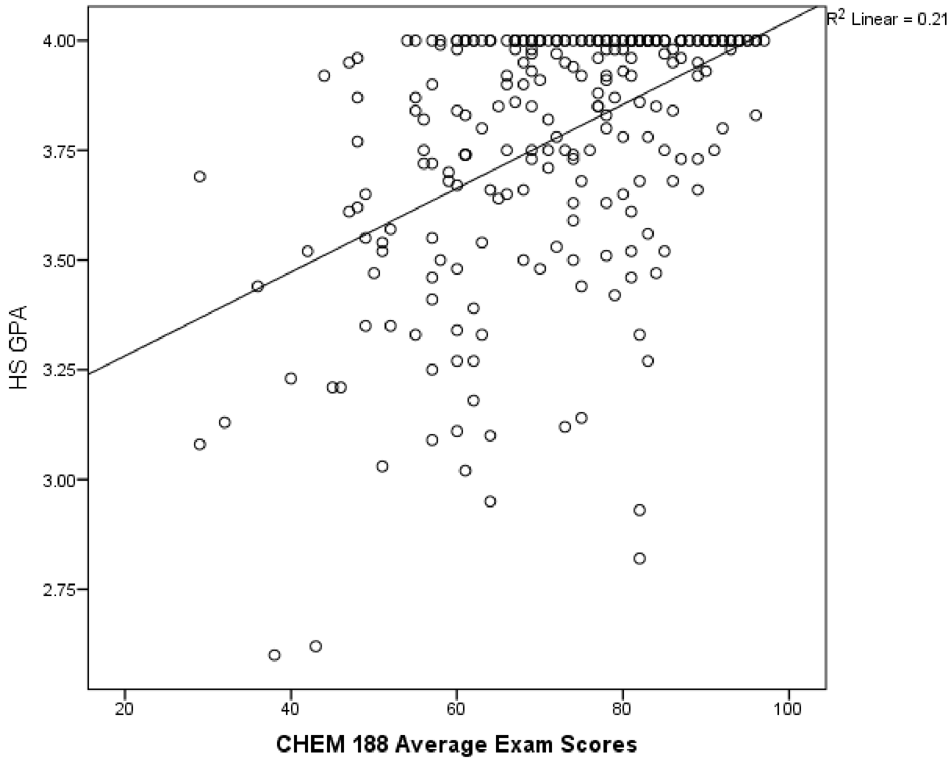
Bivariate Scatterplot of PLUS Sessions and Residuals from CHEM 184 Multiple Regression.

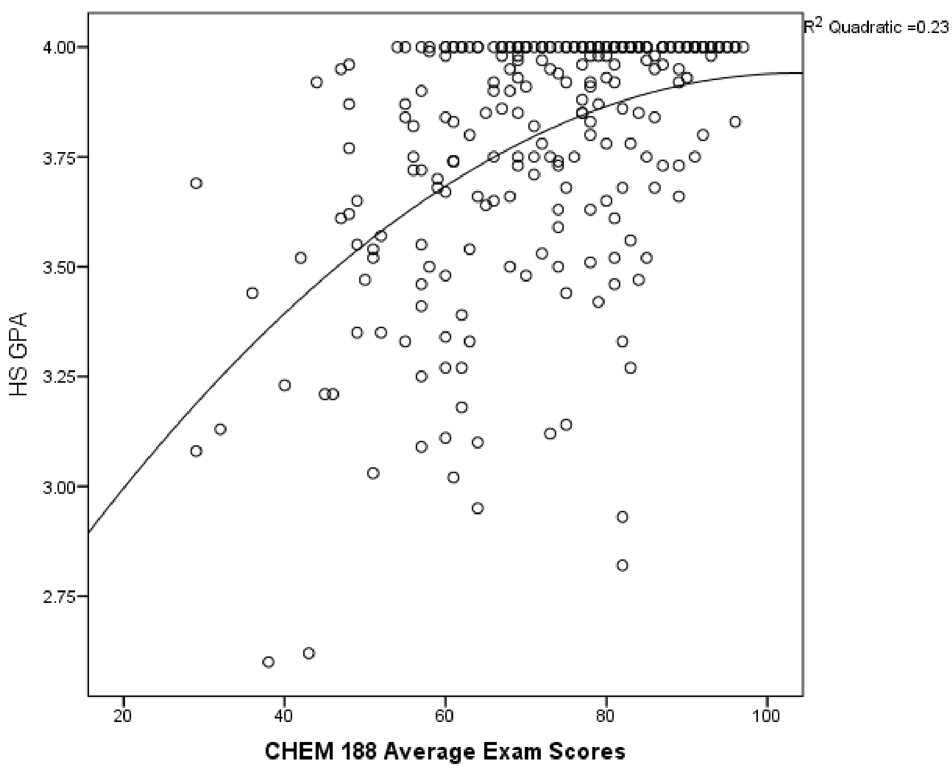


Note. N = 448.

Figure 29

Bivariate Scatterplots of High School GPA and Chemistry 188 Exam Scores.

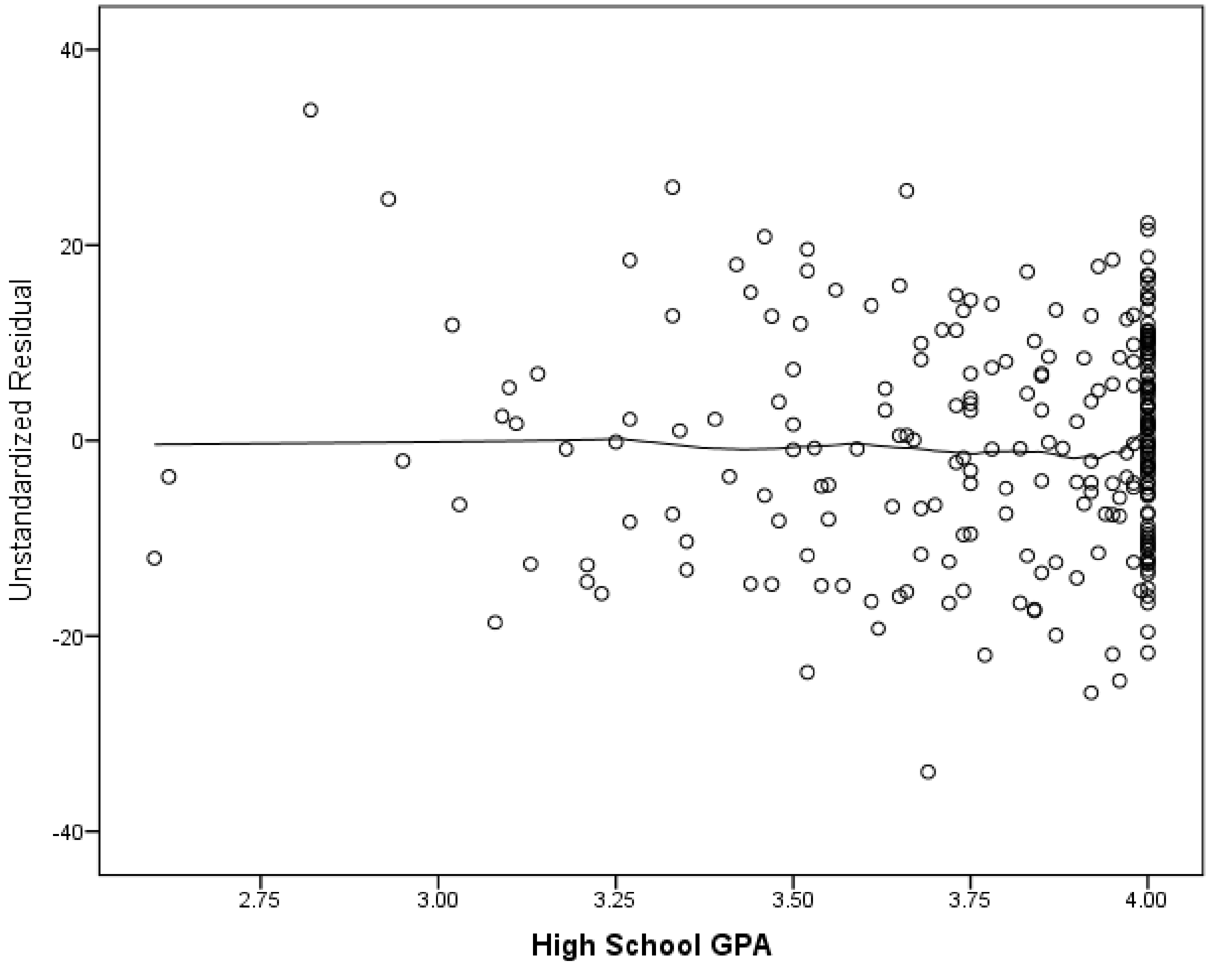




Note. N = 250. Upper figure has the linear trendline, while the lower figure has the quadratic trendline.

Figure 30

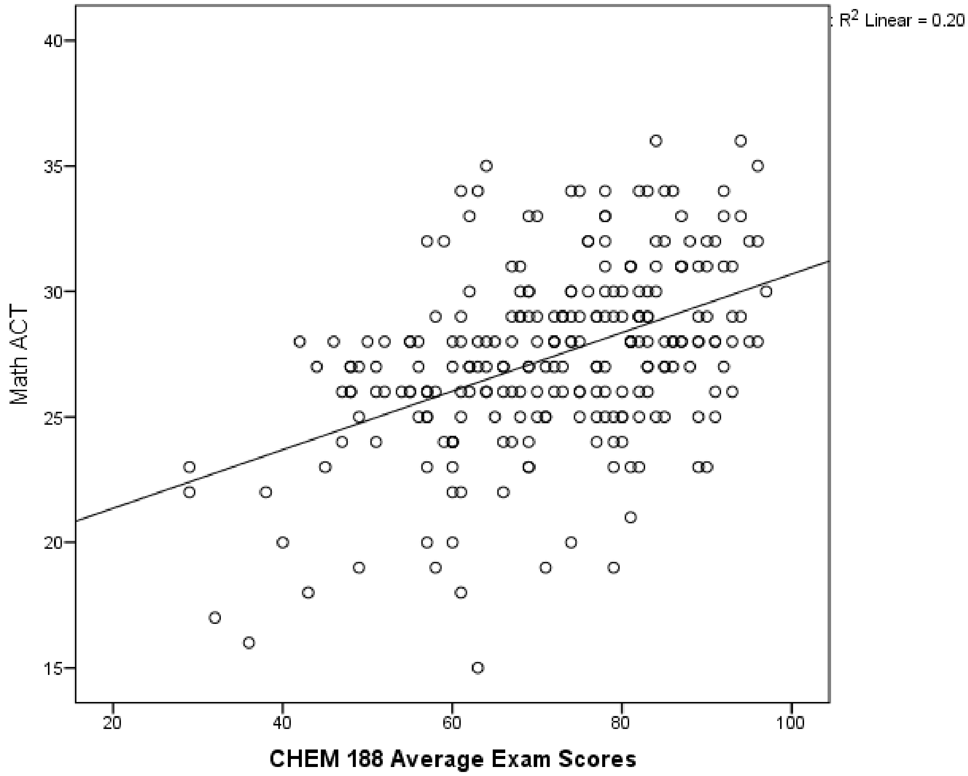
Bivariate Scatterplot of GPA and Residuals from CHEM 188 Multiple Regression.

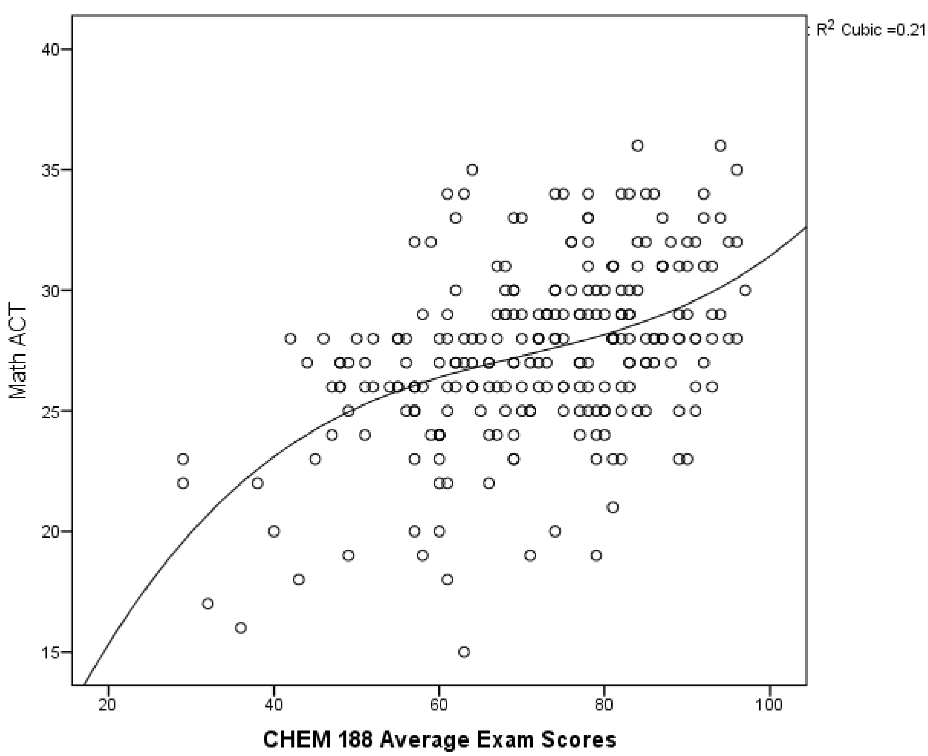


Note. N = 250.

Figure 31

Bivariate Scatterplots of High School GPA and Chemistry 188 Exam Scores.

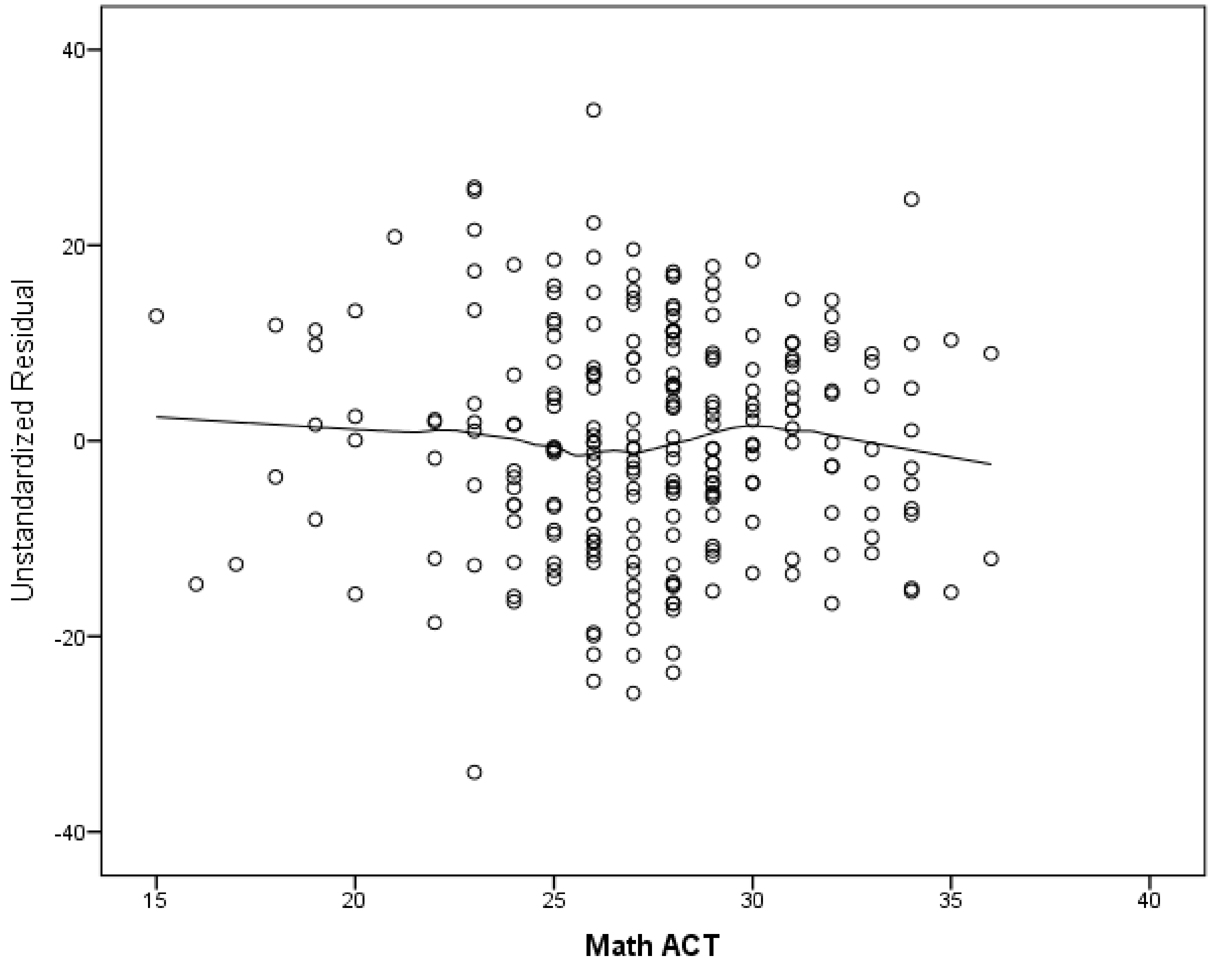




Note. N = 250. Upper figure has the linear trendline, while the lower figure has the cubic trendline.

Figure 32

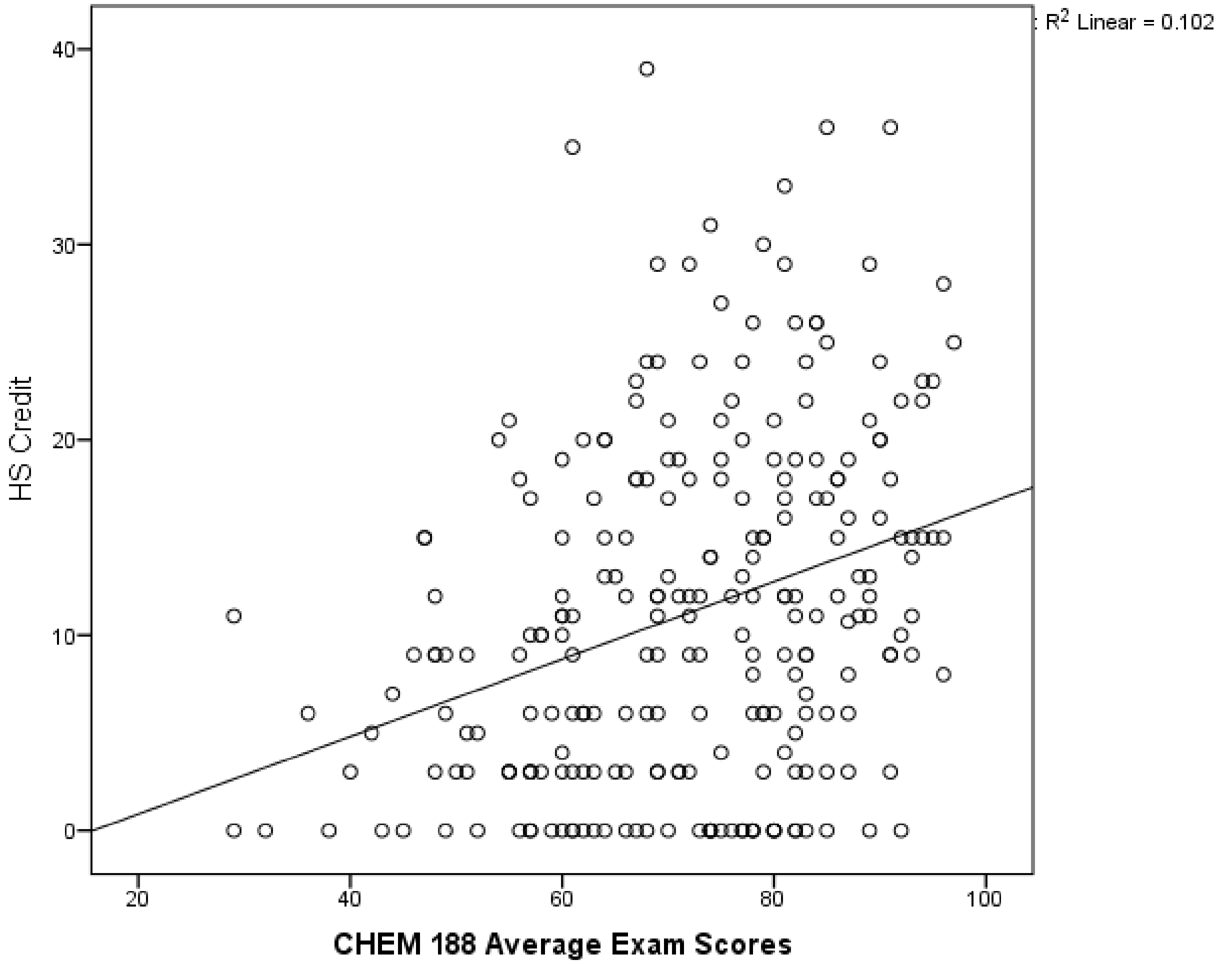
Bivariate Scatterplot of Math ACT Scores and Residuals from CHEM 188 Multiple Regression.



Note. N = 250.

Figure 33

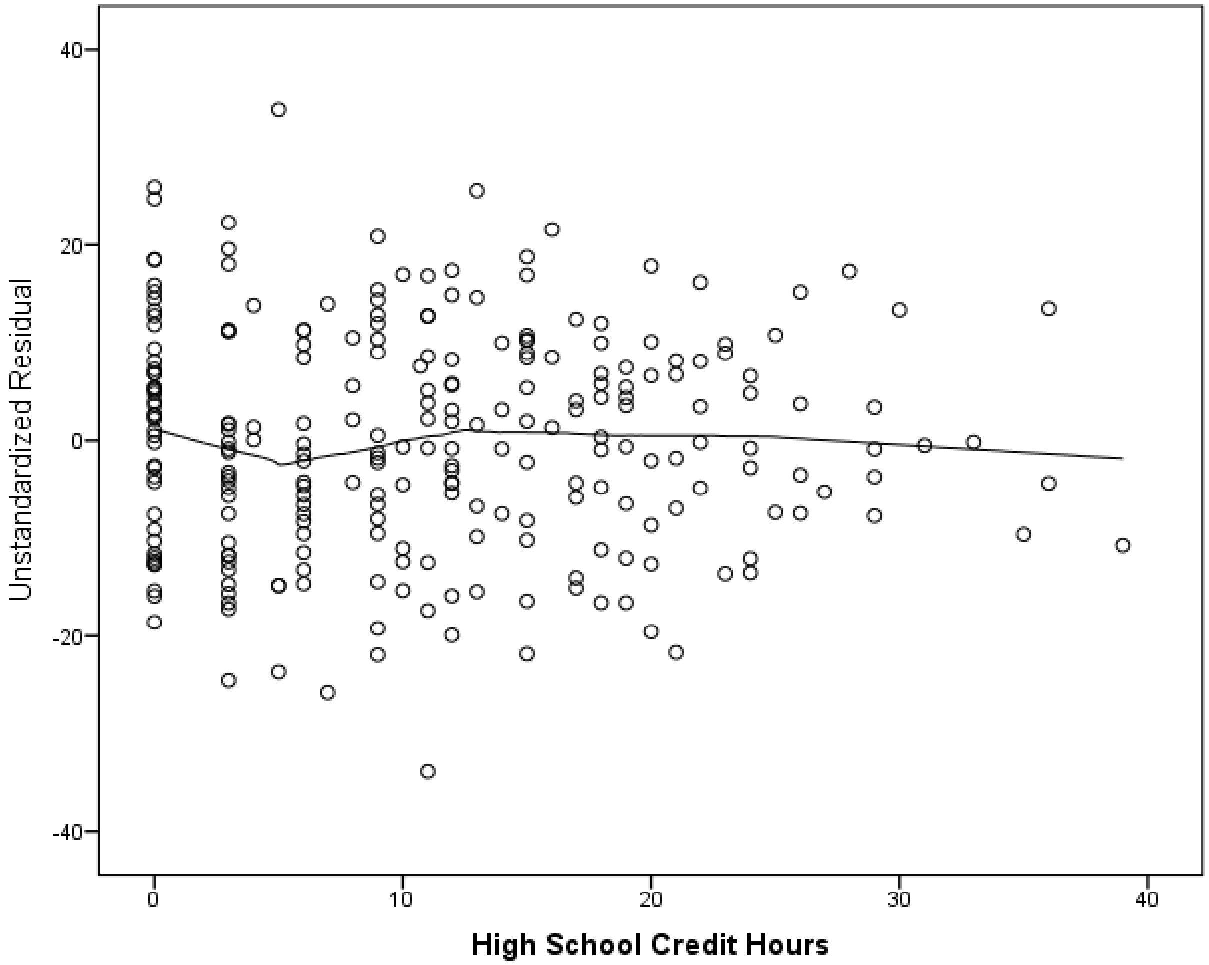
Bivariate Scatterplots of High School Credit Hours and Chemistry 188 Exam Scores.



Note. N = 250.

Figure 34

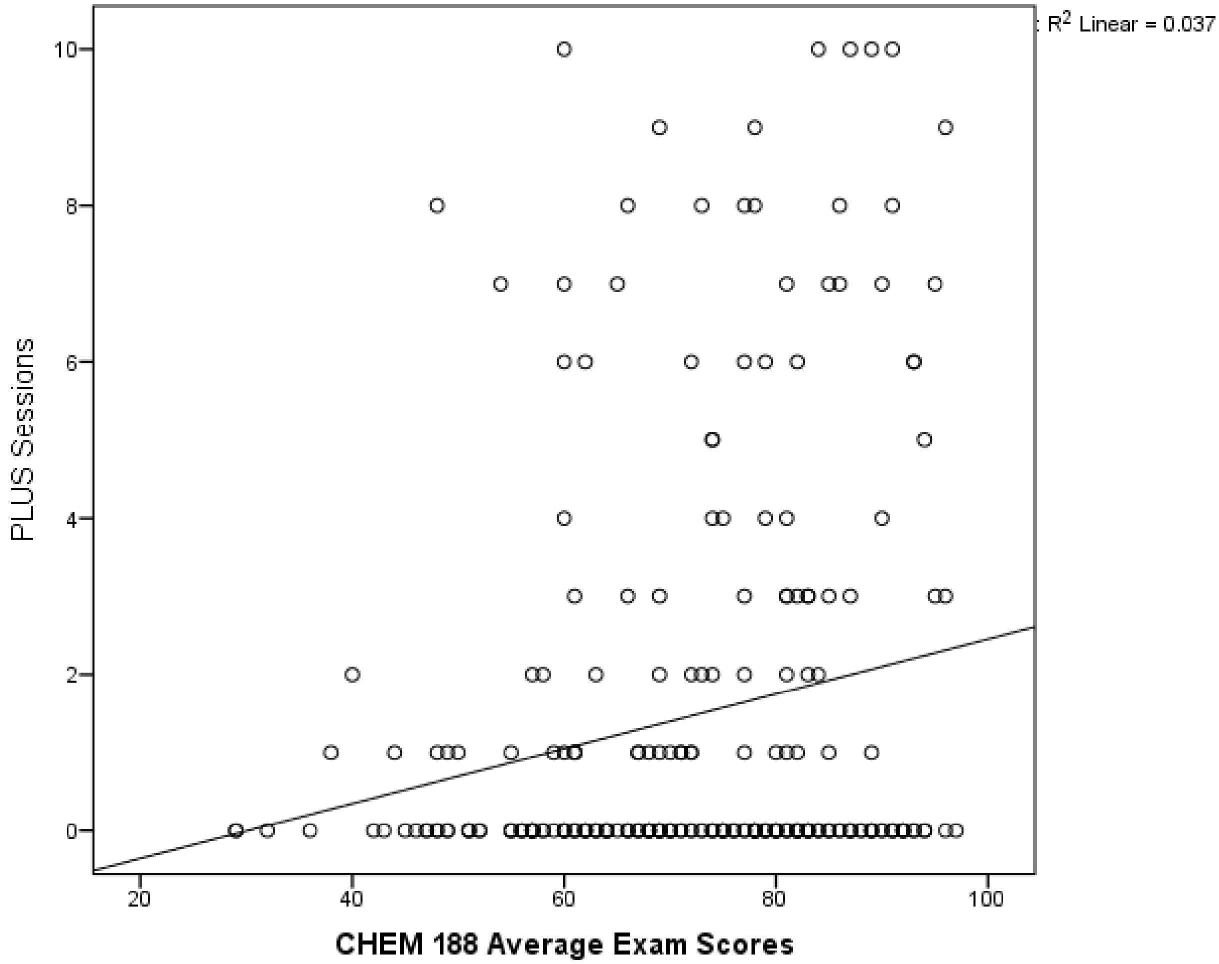
Bivariate Scatterplot of Credit Hours and Residuals from CHEM 188 Multiple Regression.



Note. N = 250.

Figure 35

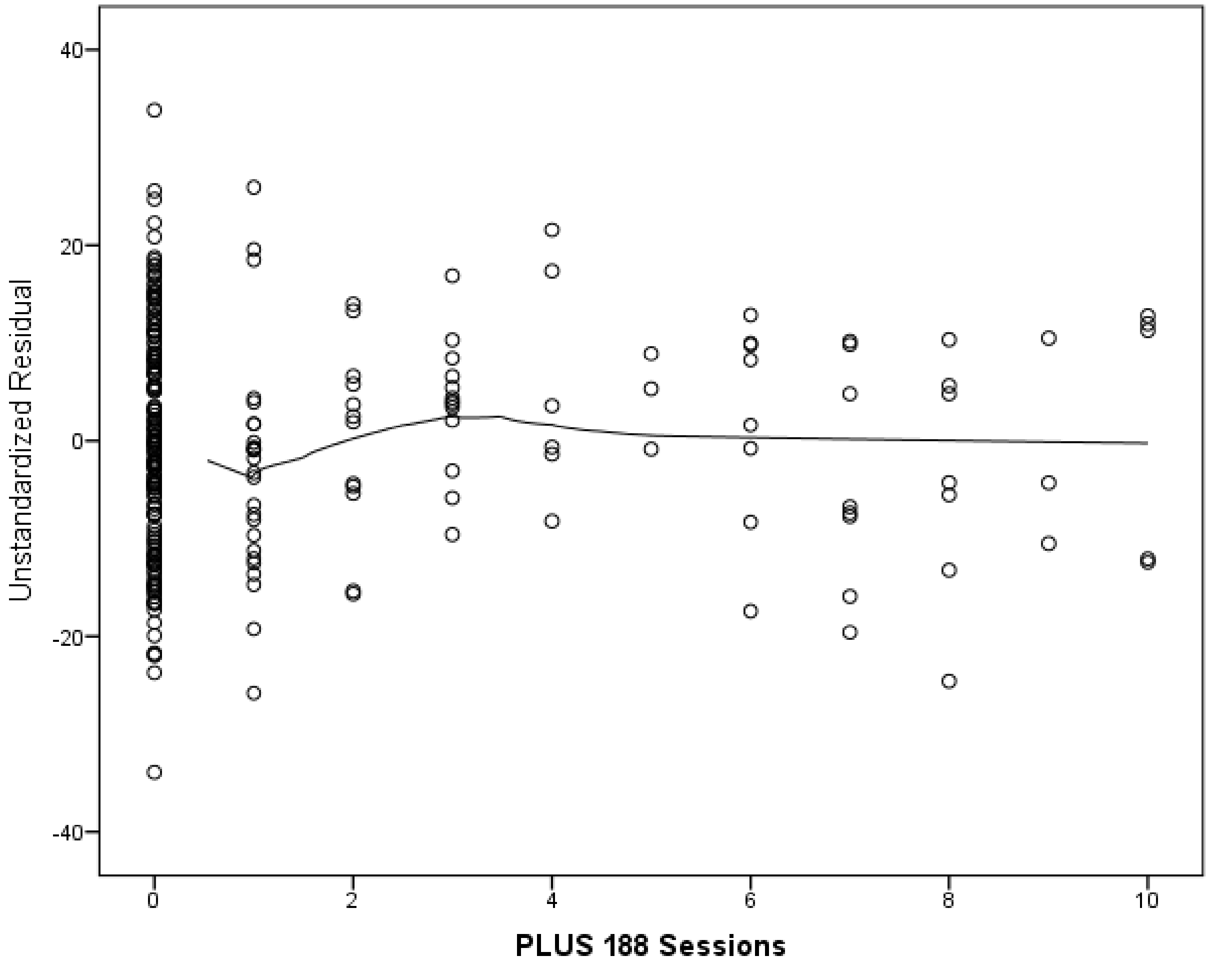
Bivariate Scatterplots of PLUS 188 Sessions and Chemistry 188 Exam Scores.



Note. N = 250.

Figure 36

Bivariate Scatterplot of PLUS 188 and Residuals from CHEM 188 Multiple Regression.



Note. N = 250.

Table 41
Regression Coefficients for CHEM 184 PROCESS, Model 1.

Moderator	Independent Variable	*B*	*p*	R^2	ΔR^2
Calculus					
	Freshman	0.018	0.998	0.184**	0.000
	Gender	-4.172	0.137	0.087**	0.005
	Credit Hour	0.111	0.460	0.157**	0.001
	HS GPA	3.734	0.330	0.246**	0.002
	Math ACT	-0.436	0.200	0.296**	0.003
	Pharmacy	-2.424	0.535	0.112**	0.001
	PLUS 184	-0.197	0.630	0.163**	0.000
Freshman					
	Gender	2.282	0.448	0.080**	0.001
	Credit Hour	-0.313	0.111	0.144**	0.005
	HS GPA	-2.353	0.580	0.249**	0.001
	Math ACT	0.227	0.532	0.289**	0.001
	Pharmacy	3.155	0.687	0.089**	0.000
	PLUS 184	-0.624	0.242	0.145**	0.003
Gender					
	Credit Hour	0.218	0.157	0.097**	0.004
	HS GPA	-14.105	0.000	0.250**	0.021**
	Math ACT	-0.323	0.318	0.287**	0.002
	Pharmacy	4.456	0.287	0.023*	0.002
	PLUS 184	-1.104	0.010	0.103**	0.014**
Credit Hour					
	HS GPA	-0.003	0.970	0.099**	0.000
	Math ACT	0.001	0.964	0.308**	0.000
	Pharmacy	-0.173	0.233	0.108**	0.001
	PLUS 184	-0.017	0.454	0.168**	0.001
HS GPA					
	Math ACT	0.784	0.049	0.350**	0.006*
	Pharmacy	1.877	0.799	0.220**	0.000
	PLUS 184	-0.905	0.217	0.265**	0.003
Math ACT					
	Pharmacy	-0.171	0.729	0.293**	0.000
	PLUS 184	-0.015	0.760	0.348**	0.000
Pharmacy					
	PLUS 184	-1.600	0.002	0.121**	0.018**

Note: N = 448. Dependent Variable = Average Exam Scores for Chemistry 184
**$p < 0.01$ and *$p < 0.05$ for 2-tailed.

Table 42

Regression Coefficients for CHEM 188 PROCESS, Model 1.

Moderator	Independent Variable	*B*	*p*	R^2	ΔR^2
Calculus					
	Freshman	-5.310	0.134	0.077**	0.009
	Gender	-4.683	0.199	0.050*	0.007
	Credit Hour	0.063	0.758	0.131**	0.000
	HS GPA	21.825	0.001	0.281**	0.036**
	Math ACT	0.575	0.264	0.195**	0.004
	PLUS 188	1.175	0.094	0.081**	0.011
	Pre-Pharmacy	0.052	0.990	0.043*	0.000
Freshman					
	Gender	-3.988	0.246	0.025	0.005
	Credit Hour	0.143	0.536	0.107**	0.001
	HS GPA	1.624	0.747	0.232**	0.000
	Math ACT	0.109	0.804	0.181**	0.000
	PLUS 188	0.477	0.446	0.056**	0.002
	Pre-Pharmacy	-1.424	0.806	0.023	0.000
Gender					
	Credit Hour	0.407	0.043	0.117**	0.015*
	HS GPA	-6.875	0.299	0.258**	0.003
	Math ACT	0.209	0.668	0.185**	0.001
	PLUS 188	-2.080	0.002	0.070**	0.036**
	Pre-Pharmacy	5.190	0.238	0.007	0.006
Credit Hour					
	HS GPA	-0.403	0.406	0.251**	0.002
	Math ACT	-0.032	0.264	0.230**	0.004
	PLUS 188	0.011	0.806	0.130**	0.000
	Pre-Pharmacy	-0.020	0.935	0.102**	0.000
HS GPA					
	Math ACT	-0.290	0.711	0.309**	0.000
	PLUS 188	-1.543	0.320	0.253**	0.003
	Pre-Pharmacy	-7.781	0.342	0.238**	0.003
Math ACT					
	PLUS 188	-0.015	0.863	0.207**	0.000
	Pre-Pharmacy	-0.054	0.926	0.181**	0.000
PLUS 188					
	Pre-Pharmacy	-1.724	0.035	0.052**	0.018*

Note: N = 248. Dependent Variable = Average Exam Scores for Chemistry 188.
**$p < 0.01$ and *$p < 0.05$ for 2-tailed.

Table 43

Regression Coefficients for CHEM 184† PROCESS, Model 1.

Moderator	Independent Variable	*B*	*p*	R^2	ΔR^2
Calculus					
	Freshman	1.743	0.673	0.092	0.001
	Gender	-4.388	0.162	0.053**	0.008
	Credit Hour	0.074	0.673	0.138**	0.001
	HS GPA	16.100	0.003	0.285**	0.027**
	Math ACT	-0.148	0.729	0.252**	0.000
	PLUS 184	0.482	0.258	0.081**	0.005
	Pre-Pharmacy	1.832	0.621	0.046*	0.001
Freshman					
	Gender	3.506	0.403	0.041*	0.003
	Credit Hour	-0.385	0.143	0.127**	0.008
	HS GPA	-12.872	0.030	0.272**	0.014**
	Math ACT	-0.411	0.384	0.247**	0.002
	PLUS 184	-0.579	0.302	0.071**	0.004
	Pre-Pharmacy	6.909	0.295	0.044*	0.004
Gender					
	Credit Hour	0.109	0.533	0.105**	0.001
	HS GPA	-19.900	0.000	0.305**	0.038**
	Math ACT	-0.232	0.568	0.251**	0.001
	PLUS 184	-1.150	0.009	0.063**	0.027**
	Pre-Pharmacy	5.605	0.139	0.009	0.009
Credit Hour					
	HS GPA	-0.664	0.073	0.276**	0.010
	Math ACT	-0.032	0.166	0.294**	0.006
	PLUS 184	-0.023	0.331	0.142**	0.003
	Pre-Pharmacy	-0.164	0.446	0.105**	0.002
HS GPA					
	Math ACT	-1.322	0.043	0.377**	0.011*
	PLUS 184	-1.632	0.053	0.273**	0.011
	Pre-Pharmacy	-2.331	0.738	0.247**	0.000
Math ACT					
	PLUS 184	0.025	0.622	0.280**	0.001
	Pre-Pharmacy	0.253	0.531	0.245**	0.001
PLUS 184					
	Pre-Pharmacy	-1.005	0.040	0.053*	0.017*

Note: N = 245. Dependent Variable = Average Exam Scores for Chemistry 184.
**p < 0.01 and *p < 0.05 for 2-tailed.

Table 44
Total Sample and Form Item Analysis for Chemistry 184, Exam 2.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E2-Q1	0.182	0.096	0.185	0.127	0.241	-0.114**	Disparate
E2-Q2	0.764	0.275	0.367	0.746	0.782	-0.036	Identical#
E2-Q3	0.621	0.288	0.382	0.609	0.634	-0.026	Identical
E2-Q4	0.473	0.283	0.349	0.471	0.475	-0.004	Algorithmic
E2-Q5	0.713	0.368	0.472	0.659	0.770	-0.111**	Disparate
E2-Q6	0.552	0.351	0.385	0.551	0.553	-0.002	Identical
E2-Q7	0.762	0.361	0.545	0.699	0.829	-0.130**	Algorithmic
E2-Q8	0.642	0.390	0.500	0.620	0.665	-0.046	Algorithmic
E2-Q9	0.463	0.399	0.409	0.460	0.467	-0.007	Identical
E2-Q10	0.690	0.376	0.484	0.736	0.642	0.093*	Algorithmic
E2-Q11	0.749	0.372	0.560	0.746	0.751	-0.005	Algorithmic
E2-Q12	0.392	0.188	0.222	0.395	0.389	0.006	Identical
E2-Q13	0.660	0.353	0.438	0.688	0.630	0.058	Algorithmic
E2-Q14	0.379	0.229	0.288	0.406	0.350	0.056	Disparate
E2-Q15	0.689	0.222	0.311	0.692	0.685	0.007	Identical
E2-Q16	0.758	0.309	0.453	0.739	0.778	-0.039	Disparate
E2-Q17	0.916	0.123	0.409	0.909	0.922	-0.013	Identical
E2-Q18	0.826	0.249	0.445	0.761	0.895	-0.134**	Disparate
E2-Q19	0.765	0.241	0.329	0.888	0.634	0.253**	Disparate
E2-Q20	0.872	0.224	0.525	0.855	0.891	-0.036	Disparate
E2-Q21	0.743	0.203	0.300	0.801	0.681	0.120**	Algorithmic
E2-Q22	0.463	0.114	0.139	0.420	0.510	-0.089*	Identical
E2-Q23	0.625	0.341	0.427	0.580	0.673	-0.093*	Disparate
E2-Q24	0.326	0.326	0.391	0.304	0.350	-0.046	Disparate
E2-Q25	0.822	0.302	0.534	0.833	0.809	0.024	Identical#

Note. N = 533. Green form, n = 276. Red form, n = 257. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation.
p-values are reported for 2-tailed independent t-test.

Table 45

Treatment Item Analysis for Chemistry 184, Exam 2.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 5					
	E2-Q3	0.596	0.739	0.143	0.006
	E2-Q4	0.449	0.587	0.138	0.016
	E2-Q6	0.535	0.630	0.095	0.091
	E2-Q7	0.744	0.848	0.104	0.017
	E2-Q8	0.612	0.783	0.170	0.001
	E2-Q11	0.732	0.826	0.094	0.039
PLUS 6					
	E2-Q10	0.667	0.759	0.092	0.035
	E2-Q13	0.604	0.825	0.221	0.000
PLUS 7					
	E2-Q15	0.664	0.782	0.118	0.011
	E2-Q16	0.723	0.891	0.168	0.000
	E2-Q24	0.314	0.373	0.058	0.259
	E2-Q25	0.794	0.927	0.133	0.004

Note. N = 533. PLUS 5 (n = 92), PLUS 6 (n = 137), and PLUS 7 (n = 110). *p*-values are reported for 2-tailed independent *t-test*. Non-PLUS Total = mean of items (2, 9, 14, 21).

Table 46

Total Sample and Form Item Analysis for Chemistry 184, Exam 3.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E3Q1	0.816	0.188	0.328	0.876	0.757	0.119**	Disparate
E3Q2	0.576	0.363	0.376	0.636	0.518	0.118**	Disparate
E3Q3	0.275	0.270	0.362	0.240	0.314	-0.073	Identical#
E3Q4	0.789	0.227	0.410	0.756	0.824	-0.068	Disparate
E3Q5	0.738	0.266	0.389	0.725	0.753	-0.028	Identical#
E3Q6	0.826	0.262	0.518	0.857	0.796	0.061	Identical#
E3Q7	0.572	0.441	0.501	0.566	0.580	-0.015	Identical#
E3Q8	0.746	0.352	0.464	0.764	0.729	0.034	Algorithmic
E3Q9	0.768	0.332	0.467	0.760	0.776	-0.017	Identical
E3Q10	0.598	0.336	0.424	0.686	0.510	0.176**	Disparate
E3Q11	0.682	0.395	0.491	0.702	0.663	0.038	Disparate
E3Q12	0.537	0.285	0.373	0.488	0.588	-0.099*	Disparate
E3Q13	0.811	0.324	0.505	0.826	0.796	0.030	Identical
E3Q14	0.535	0.375	0.487	0.516	0.557	-0.041	Identical
E3Q15	0.598	0.375	0.407	0.667	0.529	0.137**	Disparate
E3Q16	0.709	0.410	0.529	0.721	0.698	0.023	Disparate
E3Q17	0.656	0.383	0.475	0.651	0.663	-0.012	Algorithmic
E3Q18	0.758	0.273	0.451	0.729	0.788	-0.060	Identical
E3Q19	0.816	0.328	0.580	0.829	0.804	0.026	Identical
E3Q20	0.490	0.371	0.457	0.310	0.675	-0.364**	Disparate
E3Q21	0.777	0.266	0.412	0.888	0.667	0.220**	Disparate
E3Q22	0.621	0.477	0.565	0.508	0.737	-0.229**	Disparate
E3Q23	0.852	0.234	0.404	0.837	0.867	-0.029	Identical
E3Q24	0.689	0.340	0.465	0.659	0.722	-0.063	Disparate
E3Q25	0.389	0.488	0.544	0.399	0.380	0.019	Identical#

Note. N = 512. Green form, n = 257. Red form, n = 255. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation.
p-values are reported for 2-tailed independent t-test.

Table 47

Treatment Item Analysis for Chemistry 184, Exam 3.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 8					
	E3-Q4	0.789	0.819	0.030	0.444
	E3-Q5	0.738	0.855	0.117	0.002
	E3-Q6	0.826	0.904	0.077	0.015
	E3-Q7	0.572	0.759	0.187	0.000
	E3-Q8	0.746	0.880	0.134	0.000
	E3-Q9	0.768	0.855	0.088	0.019
PLUS 9					
	E3-Q11	0.661	0.757	0.096	0.044
	E3-Q13	0.783	0.910	0.127	0.000
	E3-Q14	0.486	0.712	0.225	0.000
PLUS 10					
	E3Q16	0.686	0.818	0.132	0.006
	E3Q17	0.623	0.818	0.196	0.000
	E3Q18	0.738	0.852	0.114	0.010
	E3Q19	0.790	0.943	0.153	0.000
	E3Q24	0.660	0.830	0.169	0.000
	E3Q25	0.358	0.534	0.176	0.003

Note. N = 512. PLUS 8 (n = 92), PLUS 9 (n = 111), and PLUS 10 (n = 88).
p-values are reported for 2-tailed independent *t-test*.

Table 48

Total Sample and Form Item Analysis for Chemistry 184, Exam 4.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E4Q1	0.765	0.277	0.478	0.758	0.770	-0.012	Disparate
E4Q2	0.848	0.240	0.349	0.818	0.875	-0.058	Algorithmic
E4Q3	0.588	0.241	0.279	0.627	0.553	0.075	Disparate
E4Q4	0.907	0.179	0.458	0.903	0.911	-0.008	Disparate
E4Q5	0.675	0.310	0.408	0.661	0.689	-0.028	Identical#
E4Q6	0.850	0.252	0.532	0.835	0.864	-0.029	Identical
E4Q7	0.716	0.285	0.421	0.703	0.728	-0.024	Identical
E4Q8	0.734	0.386	0.463	0.784	0.689	0.095*	Algorithmic
E4Q9	0.801	0.277	0.406	0.818	0.786	0.032	Disparate
E4Q10	0.497	0.302	0.331	0.458	0.533	-0.075	Identical
E4Q11	0.724	0.318	0.469	0.712	0.735	-0.024	Disparate
E4Q12	0.763	0.297	0.434	0.742	0.782	-0.041	Algorithmic
E4Q13	0.878	0.179	0.436	0.886	0.872	0.014	Algorithmic
E4Q14	0.811	0.337	0.571	0.809	0.813	-0.004	Algorithmic
E4Q15	0.698	0.419	0.544	0.653	0.739	-0.087*	Algorithmic
E4Q16	0.824	0.175	0.354	0.784	0.860	-0.076*	Disparate
E4Q17	0.880	0.215	0.551	0.864	0.895	-0.031	Algorithmic
E4Q18	0.799	0.281	0.558	0.814	0.786	0.028	Algorithmic
E4Q19	0.907	0.146	0.483	0.886	0.926	-0.040	Algorithmic
E4Q20	0.903	0.179	0.472	0.915	0.891	0.024	Algorithmic
E4Q21	0.781	0.366	0.531	0.754	0.805	-0.051	Algorithmic
E4Q22	0.611	0.448	0.507	0.534	0.681	-0.147**	Algorithmic
E4Q23	0.513	0.367	0.397	0.487	0.537	-0.050	Algorithmic
E4Q24	0.456	0.327	0.335	0.441	0.471	-0.030	Identical#
E4Q25	0.467	0.363	0.361	0.394	0.533	-0.139**	Algorithmic

Note. N = 493. Green form, n = 236. Red form, n = 257. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation.
p-values are reported for 2-tailed independent t-test.

Table 49

Treatment Item Analysis for Chemistry 184, Exam 4.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 11					
	E4Q1	0.745	0.914	0.169	0.000
	E4Q3	0.561	0.793	0.232	0.000
PLUS 12					
	E4Q6	0.831	0.959	0.129	0.000
	E4Q7	0.695	0.838	0.143	0.004
	E4Q8	0.716	0.838	0.122	0.013
	E4Q10	0.702	0.851	0.150	0.002
	E4Q14	0.792	0.919	0.127	0.001
	E4Q15	0.673	0.838	0.165	0.001
PLUS 13					
	E4Q18	0.777	0.921	0.144	0.000
	E4Q21	0.760	0.895	0.135	0.001
	E4Q22	0.590	0.724	0.134	0.021
	E4Q25	0.441	0.605	0.164	0.009

Note. N = 493. PLUS 11 (n = 58), PLUS 12(n = 74), and PLUS 13 (n =76).
p-values are reported for 2-tailed independent *t-test*. Non-PLUS Total = mean of items (2,5,9,11,12,23,24).

Table 50

Total Sample and Form Item Analysis for Chemistry 188, Exam 1.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E5-Q1	0.949	0.051	0.252	0.934	0.964	0.030	Disparate
E5-Q2	0.897	0.188	0.369	0.910	0.884	-0.026	Disparate
E5-Q3	0.645	0.282	0.408	0.631	0.661	0.030	Identical#
E5-Q4	0.603	0.299	0.373	0.615	0.589	-0.025	Disparate
E5-Q5	0.573	0.359	0.420	0.615	0.527	-0.088	Identical#
E5-Q6	0.769	0.342	0.523	0.721	0.821	0.100	Identical#
E5-Q7	0.774	0.265	0.366	0.631	0.929	0.297**	Identical#
E5-Q8	0.872	0.205	0.431	0.836	0.911	0.075	Algorithmic
E5-Q9	0.816	0.248	0.406	0.820	0.813	-0.007	Identical
E5-Q10	0.590	0.462	0.500	0.557	0.625	0.068	Disparate
E5-Q11	0.778	0.308	0.489	0.721	0.839	0.117*	Disparate
E5-Q12	0.564	0.239	0.318	0.631	0.491	-0.140*	Disparate
E5-Q13	0.825	0.265	0.416	0.820	0.830	0.011	Identical
E5-Q14	0.714	0.368	0.523	0.689	0.741	0.053	Identical
E5-Q15	0.846	0.205	0.365	0.828	0.866	0.038	Disparate
E5-Q16	0.402	0.256	0.375	0.328	0.482	0.154*	Disparate
E5-Q17	0.675	0.291	0.350	0.598	0.759	0.160**	Algorithmic
E5-Q18	0.355	0.265	0.324	0.361	0.348	-0.012	Identical
E5-Q19	0.534	0.470	0.590	0.492	0.580	0.089	Identical
E5-Q20	0.547	0.462	0.513	0.500	0.598	0.098	Disparate
E5-Q21	0.385	0.376	0.468	0.410	0.357	-0.053	Disparate
E5-Q22	0.500	0.436	0.501	0.484	0.518	0.034	Disparate
E5-Q23	0.547	0.581	0.620	0.549	0.545	-0.005	Identical
E5-Q24	0.346	0.162	0.224	0.467	0.214	-0.252**	Disparate
E5-Q25	0.620	0.214	0.301	0.648	0.589	-0.058	Identical#

Note. N = 244. Green form, n = 122. Red form, n = 122. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation. *p*-values are reported for 2-tailed independent t-test.

Table 51
Treatment Item Analysis for Chemistry 188, Exam 1.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 1					
	E5Q4	0.578	0.714	0.136	0.090
	E5Q5	0.552	0.667	0.115	0.167
	E5Q6	0.745	0.881	0.136	0.025
	E5Q9	0.797	0.905	0.108	0.050
PLUS 2					
	E5Q10	0.549	0.740	0.191	0.010
	E5Q13	0.799	0.920	0.121	0.015
	E5Q14	0.674	0.860	0.186	0.003
	E5Q15	0.815	0.960	0.145	0.000
PLUS 3					
	E5Q20	0.513	0.681	0.167	0.032
	E5Q23	0.503	0.723	0.221	0.004
	E5Q25	0.599	0.702	0.103	0.190

Note. N = 236. PLUS 1 (n = 42), PLUS 2 (n = 50), and PLUS 3 (n = 46).
p-values are reported for 2-tailed independent *t-test*. Non-PLUS Total = mean of items (3,7,17,18,19,21,22).

Table 52
Total Sample and Form Item Analysis for Chemistry 188, Exam 2.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E6Q1	0.932	0.103	0.351	0.895	0.967	0.071*	Disparate
E6Q2	0.662	0.318	0.336	0.663	0.662	0.000	Algorithmic
E6Q3	0.726	0.309	0.463	0.732	0.726	-0.006	Identical
E6Q4	0.735	0.266	0.304	0.741	0.735	-0.007**	Algorithmic
E6Q5	0.885	0.197	0.424	0.890	0.885	-0.005*	Identical
E6Q6	0.731	0.334	0.469	0.738	0.731	-0.007	Algorithmic
E6Q7	0.970	0.060	0.392	0.972	0.970	-0.001	Algorithmic
E6Q8	0.816	0.316	0.549	0.824	0.816	-0.007**	Algorithmic
E6Q9	0.880	0.188	0.479	0.889	0.880	-0.009	Algorithmic
E6Q10	0.949	0.103	0.528	0.950	0.949	-0.001	Algorithmic
E6Q11	0.808	0.197	0.291	0.810	0.808	-0.002**	Algorithmic
E6Q12	0.953	0.094	0.493	0.959	0.953	-0.006	Algorithmic
E6Q13	0.825	0.333	0.595	0.838	0.825	-0.013	Algorithmic
E6Q14	0.923	0.154	0.460	0.924	0.923	-0.001	Algorithmic
E6Q15	0.846	0.257	0.524	0.854	0.846	-0.008**	Algorithmic
E6Q16	0.833	0.316	0.570	0.833	0.833	0.001*	Algorithmic
E6Q17	0.855	0.205	0.369	0.863	0.855	-0.008	Algorithmic
E6Q18	0.880	0.205	0.260	0.875	0.880	0.005	Algorithmic
E6Q19	0.808	0.265	0.288	0.793	0.808	0.014	Identical
E6Q20	0.654	0.369	0.489	0.663	0.654	-0.009	Algorithmic
E6Q21	0.470	0.209	0.225	0.475	0.470	-0.004	Identical
E6Q22	0.675	0.335	0.482	0.680	0.675	-0.005	Algorithmic
E6Q23	0.479	0.158	0.211	0.483	0.479	-0.004**	Disparate
E6Q24	0.726	0.300	0.433	0.738	0.726	-0.011*	Algorithmic
E6Q25	0.573	0.267	0.275	0.572	0.573	0.001	Algorithmic

Note. N = 234. Green form, n = 119. Red form, n = 115. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation. *p*-values are reported for 2-tailed independent t-test.

Table 53

Treatment Item Analysis for Chemistry 188, Exam 2.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 4					
	E6-Q2	0.660	0.682	0.021	0.842
	E6-Q8	0.807	0.909	0.102	0.145
	E6-Q15	0.835	0.955	0.120	0.028
	E6-Q19	0.792	0.955	0.162	0.004
PLUS 5					
	E6-Q6	0.688	0.929	0.241	0.000
	E6-Q20	0.635	0.738	0.103	0.187
	E6-Q25	0.557	0.643	0.086	0.307

Note. N = 234 . PLUS 4 (n = 22) and PLUS 5 (n = 42).
p-values are reported for 2-tailed independent t-test. Non-PLUS Total = mean of items (3,4,13,16,21,22,24).

Table 54

Total Sample and Form Item Analysis for Chemistry 188, Exam 4.

	Total Sample			Green	Red	Change	
Item	Diff.	Discrim.	Item-Total	Diff.	Diff.	Diff.	Type
E8Q1	0.864	0.189	0.387	0.795	0.927	0.133**	Disparate
E8Q2	0.754	0.241	0.273	0.830	0.685	-0.145**	Algorithmic
E8Q3	0.513	0.186	0.280	0.527	0.500	-0.027	Identical
E8Q4	0.958	0.069	0.330	0.946	0.968	0.021	Algorithmic
E8Q5	0.627	0.227	0.377	0.652	0.605	-0.047	Algorithmic
E8Q6	0.890	0.137	0.300	0.893	0.887	-0.006	Identical
E8Q7	0.682	0.336	0.514	0.625	0.734	0.109	Identical #
E8Q8	0.924	0.052	0.291	0.955	0.895	-0.060	Algorithmic
E8Q9	0.691	0.353	0.440	0.670	0.710	0.040	Identical
E8Q10	0.869	0.146	0.195	0.884	0.855	-0.029	Identical
E8Q11	0.530	0.288	0.343	0.500	0.556	0.056	Identical
E8Q12	0.877	0.180	0.493	0.857	0.895	0.038	Algorithmic
E8Q13	0.873	0.189	0.387	0.902	0.847	-0.055	Algorithmic
E8Q14	0.610	0.346	0.386	0.741	0.492	-0.249**	Algorithmic
E8Q15	0.847	0.274	0.430	0.857	0.839	-0.018	Algorithmic
E8Q16	0.814	0.224	0.398	0.786	0.839	0.053	Algorithmic
E8Q17	0.903	0.146	0.283	0.902	0.903	0.001	Disparate
E8Q18	0.445	0.289	0.412	0.402	0.484	0.082	Identical #
E8Q19	0.331	0.333	0.360	0.286	0.371	0.085	Identical #
E8Q20	0.847	0.223	0.433	0.857	0.839	-0.018	Algorithmic
E8Q21	0.589	0.354	0.401	0.563	0.613	0.050	Algorithmic
E8Q22	0.597	0.219	0.213	0.634	0.565	-0.069	Disparate
E8Q23	0.814	0.139	0.318	0.777	0.847	0.070	Identical #
E8Q24	0.360	0.392	0.428	0.259	0.452	0.193**	Algorithmic
E8Q25	0.195	0.031	0.080	0.125	0.258	0.133**	Identical #

Note. N = 236. Green form, n = 123. Red form, n = 113. Diff. = Item Difficulty. Discrim. = Item Discrimination. Item-Total = Item-Total Pearson's Correlation. *p*-values are reported for 2-tailed independent t-test.

Table 55

Treatment Item Analysis for Chemistry 188, Exam 4.

PLUS Session	Item	Comparison Difficulty	PLUS Difficulty	Δ Difficulty	*p*-value
PLUS 9					
	E8Q2	0.755	0.750	-0.005	0.957
	E8Q7	0.663	0.821	0.158	0.058
	E8Q11	0.500	0.750	0.250	0.009
	E8Q14	0.587	0.786	0.199	0.026
PLUS 10					
	E8Q15	0.832	0.941	0.109	0.028
	E8Q16	0.792	0.941	0.149	0.004
	E8Q18	0.431	0.529	0.099	0.298
	E8Q20	0.822	1.000	0.178	0.000

Note. N =236. PLUS 9 (n = 29) and PLUS 10 (n = 34).
p-values are reported for 2-tailed independent *t-test*. Non-PLUS Total = mean of items (5,9,21,22,24).

Appendix C

CHEM 184 – Fall, 2012
Hour Exam 1 (Green)
September 6, 2012
Professor: Peter Hierl

Instructions:

Your scantron answer sheet must show your **NAME**, **STUDENT 7-DIGIT KUID NUMBER**, and **LAB SECTION**. (Begin these entries at the LEFT end of the space provided.)

In answering the questions, be careful to fill in the corresponding circles on the answer sheet according to the number of the question on the exam. USE A SOFT (No. 2) PENCIL.

Note that a **periodic table** of the elements is attached at the end of the exam.

Useful information: Avogadro's constant **N_A = 6.02 x 10^{23} mol^{-1}**

---

1. Which of the following is(are) a **heterogeneous mixture?**

    1. concrete
    2. an alloy of two metals
    3. bread
    4. helium gas
    5. mixture of alcohol and water

    A. 1 only B. 2 only C. 1 & 2 D. 1 & 3 E. 2 & 5

2. The diameter of an atom is approximately 0.1 nanometers. How many **picometers** is this?
    A. 1000 pm B. 100 pm C. 10 pm D. 0.01 pm E. 0.001 pm

3. If a car were traveling at 60 miles per hour, what would be its speed in units of **decimeters per second**? (1 mile = 1.609 km)

    A. 2.7 B. 27 C. 270 D. 2,700 E. 27,000

4. The density of mercury is 13.6 g/mL. What **mass** of mercury will occupy a volume of 3.00 L?

    A. 40.8 g B. 68.0 g C. 40.8 kg D. 68.0 kg E. 95.2 kg

5. A piece of metal with a mass of 125 g occupies a volume of 31.0 mL. What is the **density** of the metal?

A. 5.00 g/cm^3 B. 4.03 g/cm^3 C. 2.23 g/cm^3 D. 1.51 g/cm^3 E. 0.25 g/cm^3

6. The temperature on a cold winter day is 10°F. What is this temperature on the **Celsius scale**?

A. – 19°C B. –12°C C. 18°C D. 38°C E. none of the above

7. How many significant figures does the following sum contain? **5.6 + 6.1214**
A. 3 B. 4 C. 5 D. 6 E. 7

8. Which scientist is credited with having discovered the **neutron**?
A. Marie Curie B. J. J. Thomson C. Ernest Rutherford D. Albert Einstein E. James Chadwick

9. An atom of the isotope **bromine-79** consists of how many protons, neutrons, and electrons? (p = proton, n = neutron, e = electron)

A. 34 p, 45 n, 34 e B. 35 p, 44 n, 44 e C. 44 p, 35 n, 44 e D. 35 p, 44 n, 35 e E. none of these

10. What is the appropriate **symbol** for the isotope whose nucleus contains 18 protons and 20 neutrons?

A. $^{20}{}_{18}Ar$ B. $^{18}{}_{20}Ar$ C. $^{38}{}_{18}Ar$ D. $^{37}{}_{20}Ar$ E. none of these

11. Which one of the following lists gives the **correct symbols** for the elements phosphorus, potassium, silver, chlorine, and sulfur in that order?

A. K, Ag, Po, Cl, S
B. P, Po, Ag, Cl, S
C. Ph, K, Ag, S, Cl
D. P, K, Si, S, Cl
E. P, K, Ag, Cl, S

12. Which of the following elements is a **metalloid**?

1. Boron (B)
2. Nitrogen (N)
3. Magnesium (Mg)
4. Silicon (Si)
5. Sulfur (S)

A. 1 only B. 3 only C. 5 only D. 1 & 4 E. 2, 4 & 5

13. Which pair of elements would be most likely to form an **ionic compound**?

A. Mg and Br   B. N and O   C. C and O   D. C and S   E. Al and Rb

14. A **chromium ion, Cr^{3+}**, has
A. 24 protons and 24 electrons
B. 27 protons and 24 electrons
C. 55 protons and 52 electrons
D. 24 protons and 21 electrons
E. 24 protons and 27 electrons

15. What is the formula for the ionic compound formed by **aluminum ion** and **nitrate ion**?
A. Al_3NO_3 B. Al_2NO_3 C. $AlNO_3$ D. $Al(NO_3)_2$ E. $Al(NO_3)_3$

16. The two naturally occurring isotopes of carbon, ^{12}C and ^{13}C, have atomic masses of 12.0000 amu and 13.00335 amu, respectively. If the average atomic mass of carbon is 12.0107 amu, the **natural abundance** of the ^{12}C isotope must be

A. 92.75%   B. 95.61%   C. 97.33%   D. 98.93%   E. 99.87%

17. One nanogram doesn't seem like a very large number. How many **hydrogen atoms** are there in 1.00 ng of hydrogen?

A. 2.91×10^{12} B. 1.08×10^{13} C. 5.56×10^{13}
D. 1.50×10^{14} E. 5.97×10^{14}

18. What is the **mass** (in milligrams) of 6.05×10^{19} atoms of sulfur?
A. 3.22 mg   B. 6.44 mg   C. 12.9 mg   D. 25.8 mg   E. 51.5 mg

19. How many **moles** of benzene, C_6H_6, are there in 15.6 g of C_6H_6?
A. 0.050   B. 0.10   C. 0.20   D. 0.45   E. 0.67

20. How many **oxygen atoms** are there in 25.0 g of $CaCO_3$?
A. 1.51×10^{23} B. 4.52×10^{23} C. 7.22×10^{23}
D. 9.93×10^{23} E. 1.26×10^{24}

21. How many **moles** of H atoms are there in 6.00 g of NH_3?
A. 0.342   B. 0.70   C. 1.06   D. 2.11   E. 3.17

22. What is the **empirical formula** of a compound containing C, H, and O if combustion of a 1.75 g sample of the compound yields 1.67 g of CO_2 and 1.37 g of H_2O?

A. CH_2O B. CH_3O C. C_2H_2O D. C_2H_4O E. CH_2O_2

NOTE: This question had a typographical error. The mass of H_2O should have been 0.69 g.

23. Calculate the **mass of iodine** (I_2) that will react completely with 10.0 g of aluminum (Al) to form aluminum iodide (AlI_3). (Hint: write and balance the reaction.)

A. 141 g B. 212 g C. 282 g D. 423 g E. 564 g

24. Given an excess amount of H_2, what is the **minimum amount of N_2** required to produce 25.0 g of NH_3 *via* the reaction

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

A. 20.6 g B. 41.1 g C. 61.7 g D. 82.3 g E. none of the above

25. How many **grams of Cl_2** can be prepared from the reaction of 4.00 g of MnO_2 and 25.0 g of HCl according to the following chemical equation?

$$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O$$

A. 3.26 g B. 6.52 g C. 9.79 g D. 12.1 g E. 13.1 g

CHEM 184 – Fall, 2012

Hour Exam 1 (Red)

September 6, 2012

Professor: Peter Hierl

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   5. mixture of alcohol and water

   A. 4 only B. 5 only C. 2 & 5 D. 4 & 5 E. 2, 4 & 5

2. The diameter of an atom is approximately 100 picometers. How many **centimeters** is this?
   A. 1 x 10^{-14} cm B. 1 x 10^{-12} cm C. 1 x 10^{-10} cm
   D. 1 x 10^{-8} cm E. 1 x 10^{-6} cm

3. If a car were traveling at 60 miles per hour, what would be its speed in units of **centimeters per second**? (1 mile = 1.609 km)

   A. 2.7 B. 27 C. 270 D. 2,700 E. 27,000

4. The density of mercury is 13.6 g/mL. What **mass** of mercury will occupy a volume of 2.00 L?

   A. 27.2 kg B. 34.0 kg C. 47.6 kg D. 54.4 kg E. 61.2 kg

5. A piece of metal with a mass of 125 g occupies a volume of 56.1 mL. What is the **density** of the metal?

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6. The temperature on a mild spring day is 65°F. What is this temperature on the **Celsius scale**?

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19. How many **moles** of benzene, C_6H_6, are there in 3.96 g of C_6H_6?
A. 0.050 B. 0.10 C. 0.20 D. 0.45 E. 0.67

20. How many **oxygen atoms** are there in 40.0 g of $CaCO_3$?
A. $2.41 \text{ x } 10^{23}$ B. $4.52 \text{ x } 10^{23}$ C. $7.22 \text{ x } 10^{23}$
D. $9.93 \text{ x } 10^{23}$ E. $1.26 \text{ x } 10^{24}$

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CHEMISTRY

Packet 2

Keywords: ***This is not a complete list but a list of some of the important terms you should know.***

Atom	Atomic Number	Anion
Cation	Electron	Empirical Formula
Ion	Isotope	Mass Number
Metal	Metalloid	Molecular Formula
Molecule	Neutron	Nonmetal
Nucleus	Proton	

Group Discussion – Brainstorm the keywords and following with your peers:

The Atomic Theory
Who came up with the Atomic Theory? List the four main principles of the Atomic Theory.

The Structure of the Atom and Key Experiments
Match the following experiments to the correct scientists, then discussion how the experiment worked:

1) ____ Used cathode ray tube to discover electrons
2) ____ Discovered the electron charge by the oil-drop experiment
3) ____ Discovered the radioactive particles Alpha (α), Beta (β), and Gamma (γ)
4) ____ Developed nuclear model from scattering alpha particle experiment
5) ____ Discovered neutron by studying nuclear transformations

A) Ernest Rutherford
B) Robert Millikan
C) James Chadwick
D) J.J. Thompson
E) Rontgen, Bequerel, and M. Curie

<u>Ions</u>

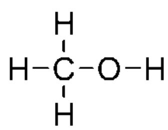
How many protons and electrons are in Al^{3+}?

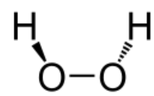
How many protons and electrons are in Se^{2-}?

<u>Molecular and Empirical Formulas</u>

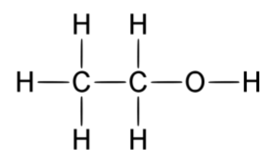
Write the molecular formula for the following:

Methanol





Ethanol



Write the empirical formula for the following compounds:

1. Al_2Br_6 →
2. $K_2Cr_2O_7$ →
3. N_2O_5 →
4. $Na_2S_2O_4$ →

<u>Ionic and Molecular Compounds</u>

Which of the following compounds are likely to be Ionic? Which are likely to be Molecular?

1. $BaCl_2$→
2. $SiCl_4$ →
3. C_2H_4 →
4. BaF_2 →
5. NF_3 →

Complete the table:

ISOTOPES	MASS (AMU)	PROTONS	NEUTRONS	ELECTRONS	$^{A}_{Z}X$
		56	74		
	202			80	
Uranium	235	92			
			146	92	
Carbon	14				

Dimensional Analysis

How many meters are in 1.26×10^{-7} pm

Convert 289 nm to centimeters

Conversion of the Mole:

How many kilograms of carbons are composed of 8.3×10^{30} atoms of carbon?

How many moles are there in 29.2 g of methane, CH_4?