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Impact of an Online Homework Program on the Achievement of College Students Enrolled in First Semester General Chemistry

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I would like to dedicate this work to my parents,

Daniel Allen Huesgen and Ann Marie Teresa Leicht Huesgen.

Everything I accomplish in life can be traced back to you.

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Abstract

Technology is finding an ever increasing role in university level courses. One area of particular interest is the use of online or computer based homework programs. This study investigated the potential impact of one of the leading commercial chemistry homework management systems on the performance of students in a first semester general chemistry course. Two groups of students were identified, one which used a basic homework program and one which used a Web-based, customizable, problem-grading application that was provided prompt feedback. The 2005 American Chemical Society First Semester General Chemistry Exam as the benchmark of understanding general chemistry. No statistically significant difference was found between the scores of the two groups. A statistically significant correlation between performance on the homework assignments and the final exam was noted, but seemed to disappear when analysis was particularized.

Keywords: homework, electronic, chemistry

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Chapter One

Introduction

There is a long history of unfulfilled promises for technology in the field of education. In1922, Thomas Edison believed that motion pictures would deliver education. He wrote "…the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks." He added that "The education of the future, as I see it, will be conducted through the medium of the motion picture, a visualized education, where it should be possible to obtain one hundred percent efficiency"(Oppenheimer, 2003). Edison may have been correct about the disappearance of textbooks, but he was at least ninety years off on the timetable.

Computers have come to dominate nearly every facet of our society, including education, with millions of dollars spent each year by school districts, governments, and families on educational software and hardware (Cambre & Hawkes, 2004). While their presence has surely influenced our teachers and students, the benefits (or lack of) of these new technologies have on learning are a source of research and debate. In Larry Cuban's "Oversold and Underused: Computers in the Classroom" his examination of the use of computers in education found that while there is some evidence for modest positive changes in the educational system through technology, he questioned whether it was worth the investment that was made (Cuban, 2001). Cuban suggested that the problem comes from the implementation of technology in the classroom and the lack of familiarity of teachers with how to integrate the software into teaching strategies. However, some educators think that the inability of computer technology to make significant, obvious improvements (so far, anyway), may have a more fundamental root.

As availability of computers, connectivity, and processing power have increased, so have the uses of the accompanying technology, including online homework programs. Homework, with all its benefits and deficiencies, has been the traditional mechanism to encourage students to interact with the material outside of class (Cooper, 1989). While homework can easily be managed in small classes, the consistent grading of large classes that have many sections poses both pedagogical and logistical challenges. Textbook publishers have seized upon this and many of them have developed homework systems that instructors can incorporate into the course. These homework systems require little effort on the part of the instructor, usually requiring only the selection of assigned problems from a pre-written bank; the management system administers and grades the resulting work, provides hints for the development of correct solutions and tutorials for some key concepts. In large classes, this circumvents the manpower necessary to collect and grade hundreds of problems.

Considering that these programs are becoming increasingly available and popular, and the cost of the programs is ultimately borne by students, it is important to know what effect, if any, these tools have on students' achievement. It should be determined if the programs are worth the investment of time and money for both the institution and the student.

Overview of the Study

Purpose

The purpose of this study is to determine the effect of student use and performance with the online homework program “MasteringChemistry” on knowledge and understanding of the material in first semester general chemistry at University of Missouri-St. Louis.

The following questions will be addressed:

Research Question 1: Does the use of this online homework management program affect student’s understanding of the content of the course?

Research Question 2: Are there specific areas of the course where the program has a greater impact on students understanding?

Research Question 3: Did use of Mastering Chemistry have a larger impact on lower-performing students or higher-performing students?

Significance

There has been a continuing dialog on the use and effects of online homework programs, especially in the teaching of science and mathematics. Some have found a positive correlation between use of the programs and student performance. A study by Grimstad and Grabe in 2004 found that an online homework program had a positive impact on student performance in a university-level chemistry course (Grimstad & Grabe, 2004). Other studies have found no significant impact on student learning or performance (Harter & Harter, 2004) or mixed results (Shimazu, 2005).

It is important to remember that new technologies often evolve quickly, especially in their early years, and online homework programs are no exception. Textbook publishers continue to redevelop their software and release newer versions with additional features, and competitors are now marketing online teaching systems based on artificial intelligence, that are significantly more sophisticated, individualized, and adaptive than those that were extant just a few years ago.

One such program is the Assessment of Learning in Knowledge Space (ALEKS) program. ALEKS is an online based program developed at New York University and the University of California – Irvine to assess students' understanding of mathematical concepts and to assist them in further developing their math skills. At the heart of this ALEKS is a sophisticated "artificially intelligence" system that relies on constant assessment. ALEKS begins by asking the students a series of mathematic questions, depending on the level of the student and the course in question, based on the student responses it will determine the students' level of understanding and then develop a course of work geared to their level. As the student moves through the program ALEKS continues to assess and modify the program to assist the student with their learning. Most research looking at the effectiveness of ALEKS has found modest increase in student understanding of concepts and performance. (Hagerty & Smith, 2005; Taylor, 2008; Nwaogu, E., 2012).

As an example of how important the features of an online homework management system may be, based on his work with an online homework program in a college calculus class, Zerr found that the ability to provide rapid feedback to students on their performance on a problem contributed to the effectiveness of a program (Zerr, 2007). Without this added component there was little benefit the online programs offer when compared to simple pen and paper work.

Since the programs are being routinely updated and modified, no single study (or group of studies) can make definitive statements about the effectiveness of this class of programs in general. Research will need to accompany the development of software to determine if current versions are effective. With data at hand instructors who are interested in using software may make informed decisions by examining the literature. Savings in time and money can be made by adopting effective coursework and rejecting ineffective programs. (Shepherd, 2009)

Further research into the effectiveness of online homework programs will likely prove useful to developers who are interested in making improvements in their products. If strategies that make these programs effective can be determined, they can be included in other systems. Conversely, ineffective programs can be improved or abandoned.

Chapter Two

Literature Review

"Our belief in the value of homework is akin to faith"
- Kralovec & Buell, 2000

Homework

The most widely accepted definition of homework was offered by Dr. Harris Cooper in his 1989 publication *Homework*. He defined it as "… any task assigned by schoolteachers intended for students to carry out during nonschool hours." (Cooper, 1989) This covers any assignment given to students, with the expectation that it is to be completed outside normal class hours, and does not include assignments such as laboratories, which may not be a part of the normal class experience but is included in course time. Whether or not reading counts as homework often varies depending on the author and in what context homework is being discussed. For most research purposes homework usually only counts assignments that involve some action on students part beyond reading.

Homework has long been seen as a method for encouraging, or forcing students to engage with material outside of the classroom. Whether or not homework is necessary or effective has long been a subject of debate, and has come in and out of fashion. (Cooper & Valentine, 2001;Kralovec & Buell, 2000; Vatterott, 2007; Vatterott, 2009)

Professor Cathy Vatterott lists a brief timeline of attitudes towards homework in her book "Becoming a Midlevel Teacher". She suggests that in the late 19th century homework was viewed positively, as it was seen as a way to train the students' minds and assist in memorization and rote learning. Later, in the 1930's, homework fell out of fashion as progressive reforms took hold, and schoolwork outside of the class was seen as having a negative effect on children's well being. After Sputnik, American students were viewed as lacking in the knowledge and skills necessary to compete internationally, and homework was seen as a way to increase students' learning. Sentiment shifted again in the 1960's against homework, but after the publication of *Nation at Risk*, calls were heard for an increase in testing and homework. Another trend has been seen emerging since 2000, with both pro and anti homework views rising, although with the passage of No Child Left Behind pro-homework forces have been gaining steam. (Vatterott, 2007; Vatterott, 2009). In *Rethinking Homework*, Vatterott attributes the beliefs in the value of homework to a combination of moralistic views, behaviorism, and the elevation of intellectual activities over social and physical interactions. (Vatterott, 2009) Since homework is considered valuable, this leads to the belief that the more rigorous curricula and better teachers, would require more homework by students. If this assumption were true, then educational systems that assign more homework should outperform others. However, German and Japanese, which continually outperform American students on measures of content knowledge, despite being assigned less homework on average. (American Teacher, 2009) While Japanese students do spend more time engaged in school work outside the classroom, this is not confined to homework. Tutoring, music lessons, and private summer instruction accounted for much of this time, and may have a large impact on student success. (Cooper, Valentine, Nye, & Lindsay, 1999; Trautwein & Koller, 2003) Further, longer school days and weeks may obviate the need for work outside of the classroom. Many of these studies have been of students in middle school and high school settings; their applicability to post-secondary education may be questioned.

What does the research literature say about the effectiveness of homework?

A consensus on whether or not homework has an effect on student achievement cannot be found in the literature. For any review that concludes that homework has a positive impact on student performance (Cooper, Robinson, Patall, 2006) there is another that suggests no connection (Trautwein & Koller, 2003). In Harris Cooper's 1989 review, he found eleven reviews of literature between 1960 and 1987, six of which concluded there was no evidence of a positive connection between homework and achievement, while five concluded that there was evidence of a positive effect. (Cooper, 1989) As Cooper and Valentine stated in 2001, "… homework research is plentiful enough that, based on probability alone, studies can be found to promote whatever position is desired, whereas the counterevidence is ignored." (Cooper & Valentine, 2001)

In a 1985 review of fifteen homework related studies involving elementary and secondary students Walberg, Paschal, and Weinstein determined that there was conclusive evidence to suggest that homework had a positive effect on student learning. In their analysis they claimed that when homework is assigned, students' achievement improves from "the 50th percentile to the 60th percentile." (Walberg, Paschal, and Weinstein, 1985) And when feedback on assignments is given a more significant increase in performance was noted (50th to 79th percentile). They also found a difference in how homework affected different areas of study, with larger effects noted for social studies and reading. These benefits were realized, they suggested, because of an increase in the amount of time a student spent engaged with the material. Their conclusion was that homework had a definite positive impact on students learning, and that increased homework, coupled with higher standards, would improve American students' achievement. (Walberg, Paschal, and Weinstein, 1985)

In *Homework*, Cooper suggests that comparing studies of classes in which homework was assigned compared to those where it was not, would suggest there was a difference in achievement. (Cooper, 1989) In comparing seventeen separate studies he found a weak positive effect for those students who completed assigned homework when compared to those who did not. Cooper also noted that the magnitude of the effect increased in strength as the grade level of the student progressed. His review also suggested that there was modest variation in the effect of homework based on content area (math vs. reading) and the type of learning (rote vs. conceptual), which supports a similar conclusion by Walberg, Paschal, and Weinstein. (Cooper, 1989; Walberg, Paschal, and Weinstein, 1985)

Cooper again looked at homework in a later review that studied the relevant literature from 1987 to 2003. (Cooper, Robinson, Patall, 2006) Applying a statistical model, Cooper reviewed over thirty articles and looked for correlation between homework and achievement. Overall, they found evidence that homework had a positive impact on student achievement, if defined by grades and performance on exams. Although these correlations were strongest when tested in the short term, and the strength of the positive impact weakened when analyzed by long term measures. Similar to the conclusion Cooper reached in *Homework*, there appeared to be a correlation between the age of students and an increasing positive effect of homework on achievement. They theorized this could reflect an improvement in study habits of older students; as students age they were able to identify homework problems that were more beneficial to learning or that they were more likely to use homework to test themselves while studying, as opposed to younger students. This could also reflect the purpose of the homework assigned, where teachers of early grades assigned homework to develop ancillary skills (such as time management) instead of material that would have a direct impact on performance on graded work. Unlike the earlier reviews, Cooper *et al.* found significant difference between subjects (math, reading, social studies, etc.) and the effect of homework, though the sample for comparison between subjects was small. The authors did note that there were flaws with many of the studies (particularly those comparing samples with no homework and assigned homework), and they suggested guidelines for further studies. (Cooper, Robinson, Patall, 2006)

Alfie Kohn used the Cooper, Robinson , and Patall article as an example of how educational research can be misused in his article *Abusing Research.* (Kohn, 2006) In it, Kohn suggests numerous problems with the methods employed by Cooper, such as applying a statistical analysis to research articles and attempting to draw effect sizes from the resulting data. Other problems were noted, such as the use of grades as an indicator of achievement, especially if the score on the homework is included in the final grade. Kohn suggests that “At best, most homework studies show only an association, not a causal relationship. “ (Kohn, 2006)

Trautwein and Koller’s reached a different conclusion than Cooper. In their analysis they found that much of the research on homework is flawed, and riddled with inherent methodological problems. They suggested that much of the variability in results comes from non-random sampling, inability to control outside variables, and improper identification of dependant/independent variables. These weaknesses, they argued, thwart any attempt to draw definitive conclusions from the literature. (Trautwein & Koller, 2003)

Despite the large body of research existing on homework, interest remains high and is ongoing. More recent studies include:

Radhakrishman, Lam, and Ho attempted to determine if assigning incentives (points) to homework had a positive impact on student performance in a university psychology course. (Radhakrishman, Lam, & Ho, 2009) Three separate courses taught by the same instructor were used; two courses had homework assigned that was worth 0.45% of the total grade, and one course increased the value of the homework to 1.25%. After comparing the two groups Radhakrishman found that the group with the higher homework incentive achieved higher academic performance, as measured by grades on presentations for the course. They suggested that this resulted from student’s increase in motivation to complete homework that had a higher point value placed on it. Seemingly at odds with this finding, they did not find a statistically significant relationship between homework completion and academic performance, which would suggest that other factors may have affected the increase in performance for the high incentive group. The researchers also found that, contrary to expectations, there was no statistically significant difference between the levels of homework compliance between the higher incentive and lower incentive groups. This could also be attributed to the rather low (1.25% and 0.45%) contributions to the final grade the homework represented.

Cuadros, Yaron, and Leinhardt found similar results in their study of an introductory chemistry class at a large research university. A total of 102 students from the class agreed to have their homework copied and used for analysis. They found that students do receive a benefit when required to do homework, as demonstrated by the differences between scores on pretests, homework, and exams. Scores on pretests had no correlation to scores on homework, which suggests that students' prior knowledge do not significantly impact homework performance – there must be other learning occurring while the assignment is being completed. (Cuadros, Yaron, & Leinhardt, 2007)

Trautwein, Schnyder, Niggli, Neumann, and Ludtke used data from a study on the effect of homework on 8th grade students in a French as a second language course in Switzerland. (Trautwein, Schnyder, Niggli, Neumann, & Ludtke, 2009) Looking for effects at three levels (class comparisons, between students, and within student) they found a variance between effects, but that at each level homework had a positive impact on student learning. Two additional self-reported factors did have a negative relation to achievement, time spent on homework and a negative perception of homework. The first suggests that while homework may have a positive relationship with performance, it is not necessarily just the time spent on task that is valuable. The simple act of struggling, without guidance, is not intrinsically beneficial. The authors went on to suggest that the second factor may display a codependent relationship where those students who hold negative views of homework also typically have low achievement, and that those students who perform poorly also tend to have a low opinion of homework. (Trautwein, Schnyder, Niggli, Neumann, & Ludtke, 2009)

Harwell et al. conducted a qualitative analysis of seventh grade science students to determine what factors might have an impact on homework and on student achievement.

(Harwell, D., Brown, K., Caldwell, A., Frazier, W., & McGee, T., 2009) Using a case study methodology they identified five “high achieving” students and assigned a researcher to each. Using interviews, surveys, and artifact collection they found that the most consistent theme that emerged parallel to student homework achievement was a structured home environment with adult interaction. They also found no difference in parental involvement in homework based upon the gender of the child, though the small sample size (three males, two females), affected the generalizability of this observation. They did find that, for their sample, the teachers overestimated the amount of time needed to complete the homework assigned. Though this could reflect that the teachers were assigning homework for all students, and the sample under study was comprised of high achievers. (Harwell et al, 2009)

Kitsantas and Zimmerman found that homework can have a positive effect on college students. A total of 223 students agreed to participate and were asked to complete a demographic questionnaire, a self-efficacy assessment, and a survey on homework. Comparing the results from the three assessments, they found that the quality of a student’s homework correlated with a students’ grades, regardless of gender. They also found that homework has a positive effect on self-efficacy and that it encouraged the students to take more responsibility for their learning. (Kitsantas & Zimmerman, 2009)

Online Homework

Web applications offer the possibility of making homework more effective and efficient for instructors and students. One of the barriers to assigning graded homework, particularly in large college classes, is that it takes faculty and staff time in collection, sorting, grading, and returning assignments, and delays in feedback to students are inevitable. Computers can take on this role while grading the homework more accurately and uniformly, and have the added benefit of giving students feedback immediately. (Harris, 2009) Computers can also allow for the randomization of variables or questions, with the possibility of making it more difficult for students to obtain answers from others. Feedback on assignments has long been noted as an important step in the learning process, and with increasing sophistication computers can offer feedback to students. (Clark & Dwyer, 1998; Mory, 1992)

These characteristics have encouraged rapid growth in use and development of online homework programs. But beyond the obvious benefit of saving instructors time, do online homework programs offer any benefit to students?

Peng conducted a study of online homework usage in a freshmen level university accounting course. (Peng, 2009) The system provided instant feedback to students, alerting them to incorrect responses, and allowing them to correct their work and resubmit. After distributing a survey at the end of the semester to students who volunteered, Peng found that students with low motivation reported putting more effort into homework because it was online, while highly motivated students reported no significant difference in effort but reported a higher level of appreciation. This suggests that online homework, and the ability to resubmit homework, at least offers additional motivation to lower performing students, who arguably need most to engage in additional work. Their results also suggested that students who viewed themselves as more "computer competent" put more effort into the homework and had higher satisfaction levels compared with students who rated their computer skills low. (Peng, 2009)

Another study of freshmen accounting students using online homework was undertaken at Belmont University. (Dillard-Eggers, Wooten, Childs, & Coker, 2008) Eight separate accounting principles classes, with four different instructors, were provided with access to an unspecified homework program that provided them with problems. For 149 of the 223 students the online homework was graded, while in the other classes the homework was suggested but did not contribute to the final grade. Controlling for student's prior GPA they found a positive correlation between homework completion and higher course grades. Whether or not the homework contributed to the final course grade was not significant, and the researchers summarized that the online homework did have a positive impact on student performance. In addition, Dillard-Eggers et al. surveyed their students at the end of the semester to obtain feedback on the system. They found that most students (69%) reported having few technical problems with the system, 54% rated their experience as positive, and 49% of students reported a preference for online homework over traditional pen and paper. Additionally, a negative relationship was found between the age of the student and their perception of online homework and a positive relationship between age and reported difficulties. This would suggest that older students may have experience a learning curve with respect to using the software. (Dillard-Eggers, Wooten, Childs, & Coker, 2008)

Roth, Ivanchenko, and Record conducted a study on student usage patterns with WeBWorK, an open source online homework program. Over the course of three years they sampled students in several mathematics courses during the Fall semesters using a survey administered to students. They found that students responded positively to the online homework program and most felt the best feature of the program was that it allowed for instant feedback. The most common complaint was difficulties relating to the syntax of answers that the program required. By tracking responses and keystrokes, Roth et al. decided that by incorporating a "preview" function students could input an answer and then view how it appeared before submitting. After incorporation of this feature input problems decreased. (Roth, Ivanchenko,& Record, 2008)

Burch and Kuo, in their study comparing traditional and online homework in multiple sections of university College Algebra courses, found that students using online homework out performed students using traditional homework on final exams in the course. (Burch & Kuo, 2010) Over two semesters, five separate sections of College Algebra were studied: three sections used traditional pen and paper homework while two sections used the program MyMathLab. Only two sections' final exam scores were compared though, as only one section of traditional homework (21 students) and one section of online homework (31 students) used the same final exam. Burch and Kuo attributed the increase in achievement for the online homework group to the hints MyMathLab would offer while students were working problems and with the ability of online students to rework and resubmit problems they answered incorrectly, both of which the traditional homework group lacked. Another difference, though not directly related to achievement, between the groups that the authors noted was that the online homework sections had a higher retention of students (86%) compared to traditional homework (58%), though whether or not this was a result of using online homework was not discussed. (Burch & Kuo, 2010)

Demirci conducted a study in two university General Physics 1 courses looking for differences between perception of online homework and pen and paper homework and the effect of homework on grades in the course. One section of the class was assigned traditional paper based homework while the other section had homework that was assigned and submitted through an online "quiz" system. Regardless of style, the assignments contributed about 20% to the students' final grade. Demirci also developed a 21 item survey to assess the perception of homework and preferences for online or traditional. For the attitudinal survey no significant differences between the groups in either preferences or attitudes, positive or negative, towards homework was found. In terms of effect, no significant difference was found on final grades for the class between online or traditional homework groups. This would suggest that, at worst, assigning the homework online did not have a negative effect on student learning. But a significant difference was observed in the final homework scores for the two groups with the traditional group having a higher overall homework total. (Demirci, 2007)

Another comparison between traditional and online homework was done by Bonham, Deardorff, and Beichner. (Bonham, Deardorff, & Beichner, 2001; Bonham, Deardorff, & Beichner, 2003) Two sections of introductory physics, taught by the same lecturer, were assigned homework. One section was assigned homework using WebAssign, a web based homework system, and the other had traditional homework graded by graduate students. Using exams, quizzes, experiments, and homework scores as an indicator of achievement, they found no significant difference between students using either method. They summarized that while online homework offered advantages to the students, such as instant feedback, this may have been negated by the fact that traditional homework students received more feedback, as online students needed to only submit a numerical answer where as the traditional students had to show work for each step, which was commented on by graders. But this benefit may have been mitigated to some extent by traditional students not reviewing returned work. (Bonham, Deardorff, & Beichner, 2001; Bonham, Deardorff, & Beichner, 2003)

In their comparison of graded WebAssign homework to traditional ungraded homework, Allain and Williams found that there was no conclusive evidence that the online homework program was superior. (Allain & Williams, 2006) Four sections of Astronomy were studied; one using WebAssign all semester, two using it half of the semester, and one using only traditional homework. Those sections that used the online homework program had it count towards 10% of their total grade, while the traditional homework sections assignments were not graded. Using test scores as a metric of achievement, they found no conclusive evidence that WebAssign had a positive impact on student performance. After analyzing the results of a survey distributed to students, the only trend they noted was that students using online homework consistently reported spending more time outside of class engaged with it. (Allain & Williams, 2006) This could reflect that the online homework sections had points assigned to the work, and were thus more likely to spend more time and effort ensuring it was completed properly.

As part of the process for developing their own online assignments Jungic, Kent, and Menz surveyed a series of college level calculus students to determine which factors students found useful. (Jungic, Kent, & Menz, 2012) They suggest that online homework program should be used in conjunction with traditional “pen and paper” assignments. Based on results of their study and a review of the literature they suggest that pen and paper assignments should be used to allow students to develop more abstract thinking and complex problem solving, while online homework programs are more effectively used as a cheap and quick assessment tool. Online assignments, they posit, can only be one component of a successful teaching regime. (Jungic, Kent, & Menz, 2012)

Online Homework in Chemistry

Chemistry instructors have long recognized the possible advantages offered by combining technology and homework for their classes. Faced with the problem of grading large amounts of homework by hand, John Connolly developed a program in 1972 using an IBM 360 Model 50 to grade homework submitted by students. Students submitted the homework, which was passed on to a secretary who was “an excellent keypunch operator”. (Connolly, 1972) The program compared submitted answers to the correct ones and printed out a comparison which was given to the students. This required only “6-8 hours of keypunching and 2-4 hr sorting and stapling. The computer time…is about 2 minutes.” (Connolly, 1972) Connolly stated that this allowed for assigning more homework to students, while decreasing the amount of time spent grading by faculty and teaching assistants. (Connolly, 1972)

In the 1990’s, James Spain developed a software package that contained many of the functions that we would currently recognize as integral parts of online homework programs. (Spain, 1996) Spain’s program, ChemSkill Builder, was developed with the intent of providing randomized questions to mitigate against cheating, providing students with immediate results on which responses were correct, allowing students to resubmit incorrect answers, and to decrease the burden of grading on faculty and staff. The program was sold on three floppy disks and accompanied by a 120 page guide giving students instructions on how to best use the 24 separate programs that were included, along with additional data necessary to complete the assignments.

After completion, students would receive a report showing their score, which they would then submit to the instructor. Spain reported that the system was effectively implemented in the General Chemistry courses, and that evidence of a correlation of computer assisted instruction and student achievement would be later published. (Spain, 1996) Later reviews suggested positive feedback for ChemSkill Builder from students as well. (Peck, 1998)

Citing an interest in providing students with immediate feedback, but noting a lack of effective homework programs for use in organic chemistry, Penn and Nedeff at West Virginia University developed their own program, WE_LEARN. Organic chemistry often deals with complex structures, something that programs at the time (1995-1998) were not able to render accurately. Using existing software they developed WE_LEARN to allow instructors to draw molecules and include them in online assignments. Even though there was no grade incentive for students to use the system, after its' introduction to the course Penn and Nedeff reported an increase in exam averages and that scores on practice exams increased as students made repeated attempts on the system. (Penn & Nedeff, 2000)

Hall et al. at Louisiana State University examined the effects of online homework that allowed students to submit work multiple times. With the assistance of LSUs' Measurement and Evaluation Center the researchers developed an HTML- based program that would allow the instructors to develop their own questions, responses to incorrect answers, and guidelines for student usage. (Hall, Butler, Kestner, & Limbach, 1999; Hall, Butler, McGuire, McGlynn, Lyon, Reese, & Limbach, 2001) The "second chance" option allowed students who answered a question incorrectly the first time to receive feedback on why their answer was wrong, and then make a second attempt to answer it correctly. Using data from first semester general chemistry they found that, on most assignments, about 70% of students made use of the second chance function, and by the end of the course over 90% of their students had used it at some point. They found that the additional points earned lifted many of their students' final grades by a letter, even though it counted for only 15% of the total points for the course. Student responses to the system were positive, and they concluded that the program was effective in engaging students in the course. (Hall, Butler, McGuire, McGlynn, Lyon, Reese, & Limbach, 2001)

Freasier, Collins, and Newitt used a customizable program called WWWAssign in their first year chemistry courses and found most of their students were willing to take quizzes beyond what was required by the course. When surveyed, most students claimed that the quizzes helped them learn the material better, and rejected the idea that they were simply memorizing correct answers to input. They reported that amongst the tutors and graders for the course there was the perception that the program was helping the students learn. The program also allowed for electronic storage of data and allowed for more effective communication to tutors, allowing them to access up to date information the achievement of each student. (Freasier, Collins, & Newitt, 2003)

Numerous computer-based homework programs for chemistry exist, though unlike previous programs described above they are typically Web-based. A recent review in the *Journal of Chemical Education* discussed the various features of ARIS, WileyPLUS, Mastering Chemistry, OWL, SmartWork, and WebAssign, and found numerous similarities between the programs. (Frech, 2009)

A study by Cole and Todd looked at possible benefits that immediate feedback might generate in general chemistry courses. (Cole & Todd, 2003) Separating a large first semester chemistry class by sections, roughly half the students were assigned traditional homework while the rest of the class worked with online homework. The online homework sections used WebCT, a system that allows for instructors to enter multiple choice questions, while the traditional homework sections turned their homework in on paper and had it graded by teaching assistants. Both sections had the same questions and had it count for the same number of points, the biggest difference between the sections was that the WebCT sections received a second chance to submit their homework and would receive instant feedback on their performance. Using total points in the course, exam scores, quiz scores, and performance on labs as their dependent variable no statistically significant difference was noted between the two groups. (Cole & Todd, 2003) Like previous studies, this suggests that changing the medium of the homework does not significantly impact performance and receiving instant feedback does not benefit students.

Fynewever also compared the effects of traditional homework versus online homework on two semesters of general chemistry. (Fynewever, 2008) Both groups received the same homework questions, with the online group interacting with the questions using WebCT. The online homework group received instant feedback while traditional homework students experienced a delay of two days in having work returned. Using pre-tests and post-tests, Fynewever found that both groups experienced gains that correlated to the assigned homework, but noted no significant difference between the two groups. Qualitative data obtained from the students suggested that both groups had positive views of the homework, with the online group reporting that they appreciated the instant feedback that the program provided. (Fynewever, 2008)

Similar to Penn and Nedeff’s program, Chamala et al. examined EPOCH, that allows students and instructors to utilize a graphic structural designing program. (Chamala, Ciochina, Grossman, Finkel, Kannan, & Ramachandran, 2006) Unlike WE_LEARN, EPOCH provides feedback to the student as to what they did wrong, even on “free response” questions, where incorrect answers are limited only by the imagination and misconceptions of the student. With a sample of 200 first semester organic chemistry students the researchers found a weak correlation between student scores on EPOCH questions and the scores on exams, though they attributed this mainly to the inclusion on exams of questions not related to those covered on the homework. A survey was also distributed to students (179 responded anonymously) and they found that 66% of students thought EPOCH was superior to questions from their textbook, 91% reported liking or enjoying the program, and an astonishing 98% reported that the program was either very or somewhat helpful. (Chamala et al, 2006)

In assessing the impact of using WebCT in general chemistry courses Charlesworth and Vician noted that while the scores of students on online exams and quizzes were higher than traditional paper based exams this mirrored the performance of the same students on those written assessments. If a student performed well on online WebCT exams and quizzes they also performed well on written, and students who performed poorly on WebCT performed similarly on written. Charlesworth and Vician suggested that students who perform well will do so regardless of the assistance they receive, and that the WebCT program was not beneficial for poorer students. (Charlesworth & Vician, 2003)

There is a potential difference between the genders in the effects on online homework in general chemistry. Richards-Babb and Jackson conducted a study in a large first semester general chemistry course, substituting online assignments for in class quizzes. (Richards-Babb & Jackson, 2011) They reported an increase in student understanding and performance in the class, with male students showing a significantly greater increase compared to female students. A survey of student attitudes towards the online homework assignments showed that female students reported a greater level of satisfaction with the programs. Although the study was limited to one course, they reported that student retention in the course was improved over previous semesters, which they attributed to the incorporation of the online assignments. (Richards-Babb Jackson, 2011)

Richards-Babb received similar results from a second study that was not gender- specific, comparing results across a decade of second semester general chemistry courses. (Richards-Babb et al, 2011) By replacing in class quizzes with online assignments the researchers observed a statistically significant improvement in overall course scores and final exam scores. Student responses to a survey found that students were generally positive towards the WileyPLUS homework system that they used. (Richards-Babb et all, 2011)

While not homework, Donovan and Nakhleh studied the effects of an online tutorial website on five separate general chemistry classes at Purdue University in the spring and fall semesters of 1999. The website "Visualization and Problem Solving for General Chemistry" included detailed instructions on how to complete various types of chemistry problems, 3D depictions of VSPER and Lewis dot structures, audio on the correct pronunciation of molecular names, and tutorials on other software students might use in general chemistry. Use of the program was voluntary, though one section received an assignment directly covering coordination compounds - a topic covered by the website. Survey responses were mostly positive, with most students being particularly appreciative of the 3D VSPER structures the website provided. (Donovan and Nakhleh, 2001) Analysis of the concept maps from the group that received a homework assignment directly related to the website found that the chemistry knowledge of the students who used the website was weaker than the group that did not make use of the website. They suggested this could reflect that weaker students sought out the website for help, and students with a better understanding did not. Using information gained from this study they later expanding their interview pool of students and found that students' perceived the website as being helpful, and concept map analysis suggested similar levels of understanding between users and non-users. The only notable difference being students who used the website made more links between different concepts when compared to non-users. (Donovan and Nakhleh, 2007)

Dissertations and Theses Dealing with Online Homework in Chemistry Courses

A dissertation by Wassim El-Labban at the University of Southern Mississippi assessed the impact of online homework on students in college chemistry classes by comparing it to a traditional homework group. Students in a first semester general chemistry course for the fall semesters of 1998 and 2000, were assigned traditional homework while students from the fall semesters of 2001 and 2002 had homework assigned through the commercially available OWL program. Using the 1995 American Chemical Society Final Exam as an assessment tool, El-

Labban found that there was no statistically significant difference between the two groups' scores on the ACS exam, which would suggest that the online homework did not have an appreciable effect on student learning. (El-Labban, 2003) El-Labban did find a significant correlation between scores on the OWL homework program and scores on the ACS final exam, which he suggested was evidence that the program did have a positive effect on student learning. Surveys given to students who used the program suggest that students found the program useful to their understanding of chemistry, though about one third of students felt that the program was overly "picky" with respect to what answers it would accept and what it would not. (El-Labban, 2003)

In a similar dissertation, Dr. Christopher Deeter studied the effect of online "quizzes" on high school chemistry students learning. Using a group of students from private parochial school, Deeter created three groups, which rotated throughout the semester. After completing an assigned reading one group would take a multiple choice online quiz, another would take a paragraph quiz, and the third would have no quiz. Using student performance on end of chapter exams as a measure of student learning Deeter found no significant differences between the groups performance. (Deeter, 2008) Interviews conducted with the students suggest that this may be because the questions on the quizzes were significantly easier then questions on the test and that the questions on the quizzes required students to only recall information and not use it. This last statement coupled with the admission from many students about simply looking up answers for online quiz questions in the book rather than solving them, may explain why no effect was observed. (Deeter, 2008)

While many different online homework programs directed at chemistry exist, there seems to be little difference between the effects they have on a students' final grade. Dr. Brian Belland from Utah State University compared four different online homework programs, OWL, SmartWork, CATALYST, and MasteringChemsitry in six separate first semester general chemistry courses taught, which one exception, by the same instructor. Three semesters used the

OWL program, and one semester each using SmartWork, CATALYST, and MasteringChemistry. Using final course grades as a comparison Belland found no statistically significant difference between the sections. He did note that according to pre-tests the group using SmartWork entered with a higher level of prior chemistry knowledge when compared to other sections, and yet did not have the highest mean of final grades. Belland suggested this may reflect on negatively on Smartwork, and suggested that instructors approach the program with caution. (Belland, 2009)

Summation

From this survey of the literature, there is no conclusive evidence regarding the effectiveness of homework, online or otherwise. Much of the literature comparing online to traditional assignments suggests that there is no significant difference between the two. This runs contrary to expectations that consistent, automated grading, the inclusion of instant feedback and better visualizations would positively impact student learning. Qualitative data collected from students would suggest that while students report favorable views of online homework, this is not reflected significantly in their achievement.

No single study could hope to definitively answer this question. The purpose of the following research was to add to the ongoing discussion about online homework and help inform users and developers by assessing the impact of one program on one class.

Chapter Three

Methods

Introduction

This study examines the effects of an online homework program on student understanding of material in university level general chemistry. To determine whether or not these programs have an effect on student performance, data from two groups will be used; a group that used the online homework program Mastering Chemistry, and another that used a less sophisticated program. The students' performance on the standardized ACS General Chemistry final examination, which both groups took, will be used as a measure of their understanding of the material.

Delimitations

Data for the study was collected from two separate classes, Fall Semester 2005 and Fall Semester 2007, of the General Chemistry I course at the University of Missouri-Saint Louis. Both semesters were taught by the same instructor, using the same textbook (though different editions), and using similar teaching techniques. The FS 2007 course used the online homework program "Mastering Chemistry" marketed by Pearson Publishing as an "ancillary" to the textbook, Chemistry, 5th Edition by John E. McMurry and Robert C. Fay, which was adopted for the semesters of the course used in this study. During the Fall semester of 2005, a less sophisticated online program was used, one that included no helping hints or tutorials, used a strictly multiple choice format, and with delayed feedback. Both groups were given the American Chemical Society First

Semester General Chemistry Final Exam at the end of the course to evaluate their achievement.

Assumptions

This study makes a number of assumptions: First, the two groups are similar. While not truly random, there were no changes made to the requirements to enroll in the class, and the populations of the class were not appreciably different. The instructor was the same for both classes and the material for the course did not change between semesters.

The second assumption was that the students did not cheat on the online homework program. Since the students are not monitored while working on the homework it is difficult to control what they access. The online homework program has a feature to address this concern. Variables associated with many of the problems are randomized so that two students would receive the same basic problems, but with different numerical quantities and answers.

The third assumption is that the ACS First Semester General Chemistry Examination is a reliable and valid indicator of student performance and understanding of first semester general chemistry. The final exam is developed by the Examinations Institute of the ACS Division of Chemical Education, is widely accepted and used in college classes around the country. It has undergone extensive validation by the Exams Institute and is considered a highly reliable assessment of student achievement.

Design

As data for the two groups already exists, a casual-comparative design will be used for the study. Casual comparative designs seek to explain the causes for differences between two existing groups. Unlike other designs the researcher does not control the variables, rather seeks scores on similar measures and then divides the sample into two groups. The scores on these groups are then compared to determine if the differences for the groups caused the difference in scores. Scores can be analyzed by assessing the means for the two groups and then comparing them to determine if there is a significant difference between the two groups.

Location

The study used data from two separate classes of first semester general chemistry at the University of Missouri-St. Louis (UMSL). UMSL is a medium sized midwestern state university of about 16,000 students located northeast of downtown Saint Louis. The university is often referred to as a “commuter school” because the majority of students do not reside on campus, though on-campus housing is used by about 15% of them.

Both classes involved in this study met in a large lecture hall located in the ground floor of the science complex. Workshop sections of up to 22 students were held in smaller classrooms, as were the laboratories. Six to eight graduate student teaching assistants met the weekly workshops and laboratories.

Sample

The sample consisted of 195 students, a combination of two separate courses of 100 and 95 students. The first group, which did not use Mastering Chemistry, was enrolled in General Chemistry 1111 during the fall semester of 2005. The group that used Mastering Chemistry consisted of students enrolled in General Chemistry 1111 in the fall semester of 2007. This researcher acted as the laboratory coordinator for the two groups, and was responsible for the managing of the laboratory and workshop sections.

The sample was selected through convenience sampling. The researcher was present at the site, had access to the relevant data, and was familiar with the similarities and differences that occurred between the two classes.

The students varied in age from what would be considered traditional freshmen (18-19 yrs old) to older, non-traditional students (+25 yrs). The course is designed for science majors and engineers, but was not limited exclusively to those majors. Before enrolling, students are required to have completed both college algebra and trigonometry, although concurrent enrollment in trigonometry is allowed. The course is the first part of a two-course series in General Chemistry, and most students are required to take both courses.

Demographics between the two sample sets were similar. Both courses had roughly the same number of male and female students and no noticeable differences in ethnic or age distribution.

Institutional Research Board Approval

Since the data is archived with no identifiable relationship between subject and data, the study took place in a commonly accepted educational setting, made use of common educational tests, and does not fall under any of the standard exceptions, consent forms were not necessary.

IRB approval at the University of Missouri-Saint Louis was obtained as the study was found to be exempt under sections II.a, b and d as listed by University of Missouri - St. Louis Guidelines for Application for Exemption from Review by the Institutional Review Board

Course

General Chemistry 1111 is designed as the first in a sequence of two separate courses. While many students may take chemistry in high school, General Chemistry 1111 assumes that students enter the class without prior chemistry coursework.

For the two semesters that were involved in the study the textbook used was *Chemistry* by McMurray and Fay, published by Pearson-Prentice Hall. For the 2005 class the fourth edition was used, and the fifth edition was used for the 2007 sample. Differences between the two editions were minor, consisting largely of new graphics and pictures being included in the text. Even the questions at the end of the chapters remained almost the same, often just varying by their placement in relation to other problems.

The course covered the following chapters and topics:

1. Chemistry: Matter and Measurement
2. Atoms, Molecules, and Ions
3. Formulas, Equations, and Moles
4. Reactions in Aqueous Solutions
5. Periodicity and Atomic Structure
6. Ionic Bonds and Some Main-Group Chemistry
7. Covalent Bonds and Molecular Structure

8. Thermochemistry: Chemical Energy

9. Gases: Their Properties and Behavior

10. Liquids, Solids, and Phase Changes

11. Solutions and Their Properties

The course consisted of two, 75-minute lectures per week by the instructor. The instructor assigned the students a portion of the chapter to read before they arrived in class. The instructor used largely Powerpoint presentations in his lectures, which were posted for later viewing by students. Four classroom examinations, written by the instructor, were given during the semester. The final exam was held at the end of the semester during a two-hour period.

In addition to the lecture, the students were assigned peer-led workshop sections of 18-20 students. These sections were led by teaching assistants and were scheduled for seventy five minutes. One hour of this was devoted to students working together on assigned materials in groups of about three or four. The role of the teaching assistant was to circulate throughout the room and assist the students when difficulties arose. At the end of most periods a short quiz was given that covered relevant material.

Each student was also enrolled in a laboratory section of 18-20 students that met once a week. These sections were led by a teaching assistant and lasted for up to three hours. The labs were written by the instructor and the laboratory coordinator and were designed to focus more on inquiry than laboratory skill development. The laboratory reports were due at the end of the hour, and students were required to participate to receive a grade for the activities.

Instruments

American Chemical Society Final Exam

The American Chemical Society (ACS) First Term General Chemistry Final Examination is a multiple choice test designed to assess student understanding of basic principles that are covered in general chemistry courses. The test was developed as a tool for collegiate chemistry instructors to assess their students' knowledge and skills with respect to what the ACS deems important. Results from universities around the country are available and allow instructors to compare their students' achievement to others taking the same exam.

The final consists of 70 multiple choice items with four possible answers. Two versions of the test were used, with the only difference between them being the order of the questions.

The test itself covers a wide range of topics that are covered in general chemistry. These topics include:

- Molecular formulas
- Stoichiometry/Unit conversions
- Balancing chemical equations
- Definitions and descriptions of chemical phenomena
- Balancing oxidation reduction reactions
- Solubility
- Thermochemistry
- Radiochemistry
- Absorption-Emission
- Periodic trends
- Molecular structure
- Polarity
- Laboratory procedures and skills
- Atomic configuration

The questions vary in their structure and form, but all of them are multiple-choice. Some require students to manipulate equations, some to determine chemical formulas from names, and others show an illustration and then have students select the correct description of what is shown in the picture.

To develop the test, a group of experienced chemistry faculty was assembled by the American Chemical Society Division of Chemical Education. These volunteers were college chemistry instructors from various institutions and backgrounds. The committee met and agreed on the topics that would be covered on the exam and the questions that would address those topics. With committee members varying in specialty, background, and content preferences a diverse range of topics was assured (Holme, 2003; Fornoff, 1978). Statistics on each item are available, including difficulty index, discriminatory index, and the distribution of incorrect responses.

Mastering Chemistry

Mastering Chemistry is an online homework program provided by Pearson/Prentice Hall for use with its textbooks. The program was tied to the textbook, and students were required to purchase a copy for the course, and accounted for about 10% of their total grade. Each user was required to have an individual password to access the quizzes, and item responses and scores are saved by Pearson on their server. This information is then transmitted to the instructor, and automatically entered into an electronic grade book that was accessible to students.

Most of the questions are taken from the textbook with some variables (weights, molecules, atoms, etc.) changed to keep students from looking up answers in a Solutions Manual or from another student's work. The number, type, and difficulty of questions, were determined by the instructor. In the Mastering Chemistry group the students were assigned about ten problems per assignment. The length of time the students were allowed for each assignment is at the discretion of the instructor, and can range from a few hours to an entire semester. For this group the students were given one week to submit their answers. This time was independent of when the student first opened the quiz, but rather was assigned by the instructor as an absolute date. This means that a student could open the quiz, look at the problems, and leave it open on their computer as long as they wanted; the answers just needed to be submitted by the assigned date. For this reason, one of the statistics provided in Mastering Chemistry, the time spent on a problem, was of limited utility.

Mastering Chemistry also includes a hint function for some problems that allows students to receive assistance when they need it. This is available on most problems, and can be used multiple times per problem, though usually only one or two hints are available per problem. This feature was made available for the Mastering Chemistry group, but with a caveat; if the students answered a problem without using the hint function they would receive a small bonus (10%) on the problem. If the students used the hint function, and gave the correct response they would still receive the full one point for the problem.

Comparison of Groups

There is an advantage in studying these two groups; there is a significant amount of similarity between the two groups that is difficult to obtain with studies across campuses or with different instructors. Both groups were enrolled in the same course, Chemistry 1111, at the same university. There were no significant changes in the university during the time interval between the two groups, and there is no reason to suspect that there were radical differences between the two groups of students. The classroom where the course was taught was the same for both as well as discussion and lab periods.

The instructor for the course was also the same for the two groups, and the class was taught in the same manner. The instructor has taught at the university for more than 30 years, and has taught Chemistry 1111 multiple times. For the two groups under study, the same material was presented, and much of the same materials (Powerpoint, demonstrations, laboratories, etc) were used. There were some differences in the teaching assistants for the two courses, but they were under the direction of the same laboratory coordinator, and were given the same instructions on how to teach and what to do in class.

Both groups were given the ACS General Chemistry Final Exam at the end of the semester. For both groups the final counted for about 16% of the total course grade, and was administered in the same manner in line with proscribed methods.

Data Collection

The data on final scores for both groups from the ACS Final Exam was archived and accessible to the researcher. Each student's answer to every question on the exam is available and need only be converted into a file format compatible with statistics software to be analyzed.

For the Mastering Chemistry group, the total scores as well as scores on each individual assignment on Mastering Chemistry were archived as part of the normal course information, and were easily accessed.

Data Treatment

SPSS 19 was used in all analysis. (SPSS, 2012)

An independent samples t-test was used to compare differences in achievement on the ACS Final exam. This treatment was selected as the study utilizes two separate groups of subjects. Levene's test for equity of variance was used to determine if the internal variance for each group was comparable.

To assess potential correlations between performance on Mastering Chemistry and the ACS Final exam for the 2007 group, two separate analyses were used. First, a simple linear regression analysis comparing overall totals on both Mastering Chemistry and the ACS Final was used to determine the degree of correlation. Then a more complex linear regression model was developed to incorporate student performance on individual assignments and their correlation with student performance on the final. Residual analysis was conducted to check the assumptions of normality and increase confidence in the model.

For the analysis of students at separate achievement levels; the median and the mean Final Exam scores were calculated. Students were then separated into groups depending on where their scores fell relative to these points. Final exam scores were then analyzed and students were then separated into thirds based on their level of performance. Student scores for these groups on Mastering Chemistry and the ACS Final were then compared using an ANOVA linear regression analysis.

Chapter Four

Data Analysis and Results

Introduction

This study was undertaken to investigate the potential effect of the online homework program "Mastering Chemistry" on students enrolled in first semester general chemistry. Scores on the standardized ACS Final Exam were used as the benchmark of understanding and used to judge achievement. Data from two different groups was used, a 2007 group who used the Mastering Chemistry program and a 2005 group who did not use the program. As described in the methods section, both groups used the 2005 ACS Final Exam which allows for a direct comparison to be made.

Results

A preliminary assessment of the data shows that both groups performed similarly on the ACS Final Exam. The minimum score, maximum score, and means for both groups nearly the same. The standard deviations for the two groups were also similar, suggesting little difference between the performances of the two groups on the final examination (Figure 4.1)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
ACSScore2007	95	15	64	32.37	10.850
ACSScore2005	100	17	64	33.00	10.128
MasChemTotal	95	.00	125.66	82.7763	31.48036
Valid N (listwise)	95				

Figure 4.1: Descriptive Statistics of the ACS Scores and Mastering Chemistry Totals

For the 2007 group, all subjects were left in the data set, no matter how poorly they performed on Mastering Chemistry. This included a number of students who skipped assignments and one student who received no points on any assignment. Since the hypothesis is that there is an impact on student performance from using Mastering Chemistry, if a student did not use Mastering Chemistry often or haphazardly then this should have an impact on their ACS Exam performance. Conversely, if a student did not perform well on Mastering Chemistry, but did perform well on the ACS Final exam then this would suggest that there is no potential relationship.

An independent-samples T-Test was used to compare the means of the two groups. Levene's Test for Equality of Variances yielded a $p = 0.474$ (Figure 4.2), which is greater than 0.05. This suggests that the internal variances between the two groups are similar and equity of variance can be assumed.

The means for the two groups differed slightly, with a lower mean score for the group that used the Mastering Chemistry program. The results from the independent t-test gave a significance of 0.675 (Figure 4.2), higher than the standard $\alpha<0.05$ required to assume a significant difference between the two groups. While the means for the 2007 group are slightly lower than that of the 2005 group, the difference is not statistically significant.

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
ACS_Score	MCUser	95	32.3684	10.85009	1.11320
	NonMC	100	33.0000	10.12847	1.01285

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ACS_Score Equal variances assumed	.514	.474	-.420	193	.675	-.63158	1.50235	-3.59471	2.33155
Equal variances not assumed			-.420	190.254	.675	-.63158	1.50501	-3.60023	2.33708

Figure 4.2: Results from the Independent Samples T-Test**.**

Second, a linear regression analysis was performed on the data from the 2007 group to determine if there was correlation between performance on the homework program and the scores on the ACS Final Exam. The analysis gave a significance of 0.002 (Figure 4.3), which fulfills the $\alpha<0.05$, and suggests that there is a significant correlation between the performance on Mastering Chemistry and total scores on the ACS final exam.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.312[a]	.098	.088	10.47680

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1104.429	1	1104.429	10.062	.002[a]
	Residual	10207.992	93	109.763		
	Total	11312.421	94			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	23.250	3.038		7.653	.000
	MCTOTAL	.109	.034	.312	3.172	.002

a. Dependent Variable: ACSTOTAL

Figure 4.3: Results from the Linear Regression Analysis of the 2007 Group Mastering Chemistry and ACS Final Exam Scores

A histogram of the residuals gave a relatively mound-shaped distribution, which suggests that we can assume the normality of the data. (Figure 4.4)

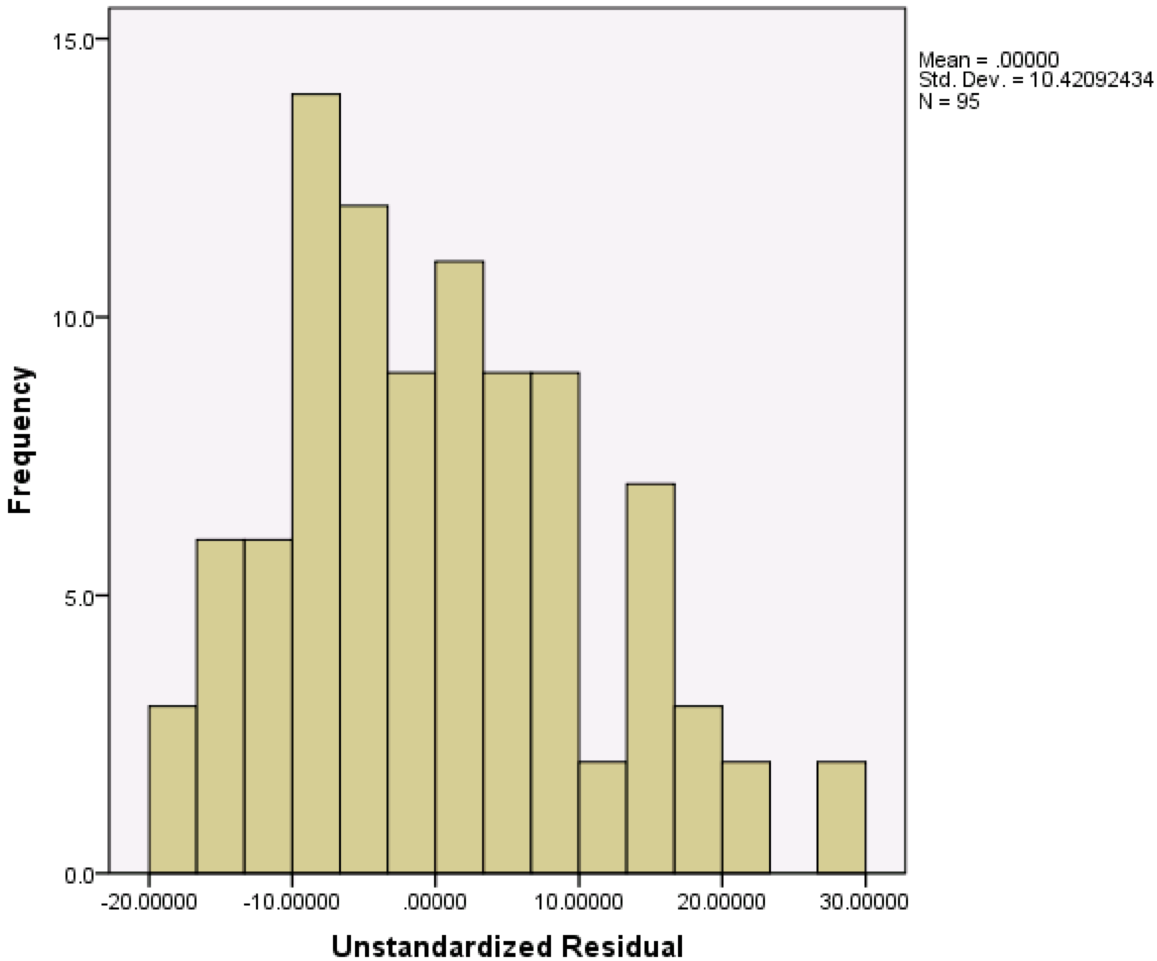

Figure 4.4: Histogram of the Residuals from the Linear Regression Analysis of the 2007 Group Mastering Chemistry Totals and ACS Final Exam Scores

A plot of the residuals verses the total scores on Mastering Chemistry gave an apparently random distribution. This suggests that the linear regression method used for this analysis was appropriate. (Figure 4.5)

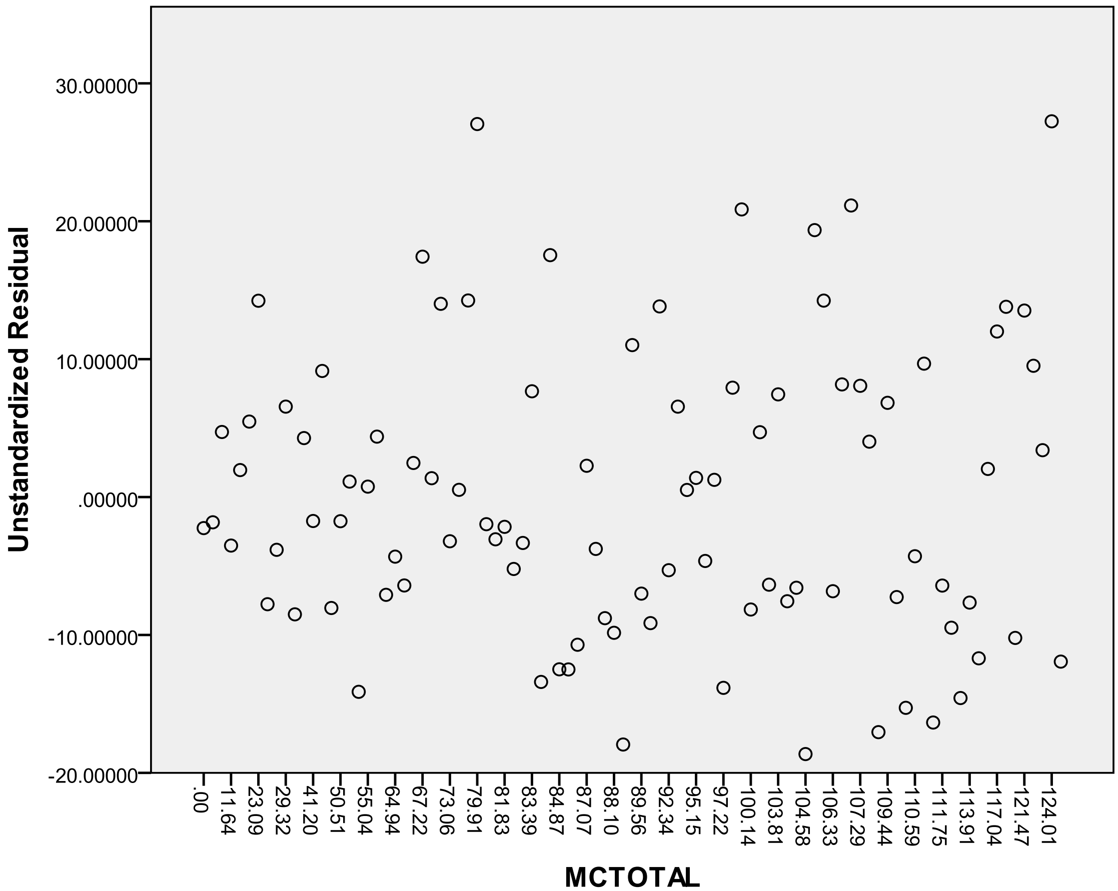

Figure 4.5: Plot of Residuals Versus Total Scores on Mastering Chemistry for the 2007 Group

The third analysis attempted to build a more complex model to assess potential correlation between performance on Mastering Chemistry and performance on the ACS final exam. Each Mastering Chemistry assignment was assumed to have had an equal potential effect, and a first order model with each assignment taken indivdually. The resulting first order model gave an over all significance of 0.004, which meets $\alpha<0.05$ to reject the null. (Figure 4.6) This first order linear regression model also suggests that correlation between performance on Mastering Chemistry and the score on the ACS Final Exam is significant. Looking at the significance for each of the variables it appears that only two of the assignments had a significance below 0.05, which would suggest multicollinearity of variables. (Figure 4.6)

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.535[a]	.286	.182	9.92227

a. Predictors: (Constant), MCA13, MCA3, MCA6, MCA2, MCA4, MCA12, MCA9, MCA5, MCA10, MCA11, MCA7, MCA8

b. Dependent Variable: ACSTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3239.400	12	269.950	2.742	.004[a]
	Residual	8073.021	82	98.451		
	Total	11312.421	94			

a. Predictors: (Constant), MCA13, MCA3, MCA6, MCA2, MCA4, MCA12, MCA9, MCA5, MCA10, MCA11, MCA7, MCA8

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	23.542	3.836		6.137	.000
	MCA2	.159	.531	.042	.300	.765
	MCA3	.086	.377	.032	.229	.819
	MCA4	.186	.422	.061	.440	.661
	MCA5	2.097	.592	.551	3.541	.001
	MCA6	-.743	.565	-.207	-1.315	.192
	MCA7	-.360	.616	-.101	-.585	.560
	MCA8	-1.491	.579	-.462	-2.578	.012
	MCA9	.221	.577	.059	.383	.703
	MCA10	.202	.500	.067	.403	.688
	MCA11	.591	.546	.178	1.081	.283
	MCA12	.219	.422	.082	.519	.605
	MCA13	.323	.427	.122	.756	.452

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3239.400	12	269.950	2.742	.004[a]
	Residual	8073.021	82	98.451		
	Total	11312.421	94			

a. Predictors: (Constant), MCA13, MCA3, MCA6, MCA2, MCA4, MCA12, MCA9, MCA5, MCA10, MCA11, MCA7, MCA8

a. Dependent Variable: ACSTOTAL

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	14.1281	45.5840	32.2632	5.87041	95
Residual	-20.73536	19.12191	.00000	9.26732	95
Std. Predicted Value	-3.089	2.269	.000	1.000	95
Std. Residual	-2.090	1.927	.000	.934	95

a. Dependent Variable: ACSTOTAL

Figure 4.6: Results of Linear Regression Analysis for First Order Model of Mastering Chemistry Assignments and ACS Final Exam Scores.

A histogram of the residuals gave a reasonably symmetric shape, and would suggest that the data is normally distributed. (Figure 4.7)

This model is admittedly simplistic, and real world relationships are often more complex and require complex models. (Mendenhall & Sincich, 2003) Numerous second order models were attempted, but none proved to yield a statistically significant result.

Since both comparison of scores and an expanded multiple linear model suggest that there is a statistically significant correlation between the scores on the final and Mastering Chemistry, an analysis to determine which assignments, if any, had an impact on student performance on the final, was performed. A simple linear regression analysis was conducted comparing each assignment to the scores on the final exam. Results suggest that no single Mastering Chemistry assignment has a statistically significant correlation to performance on the ACS Final Exam, as all failed to meet the $\alpha<0.05$ required to reject the null hypothesis. (Figure 4.8)

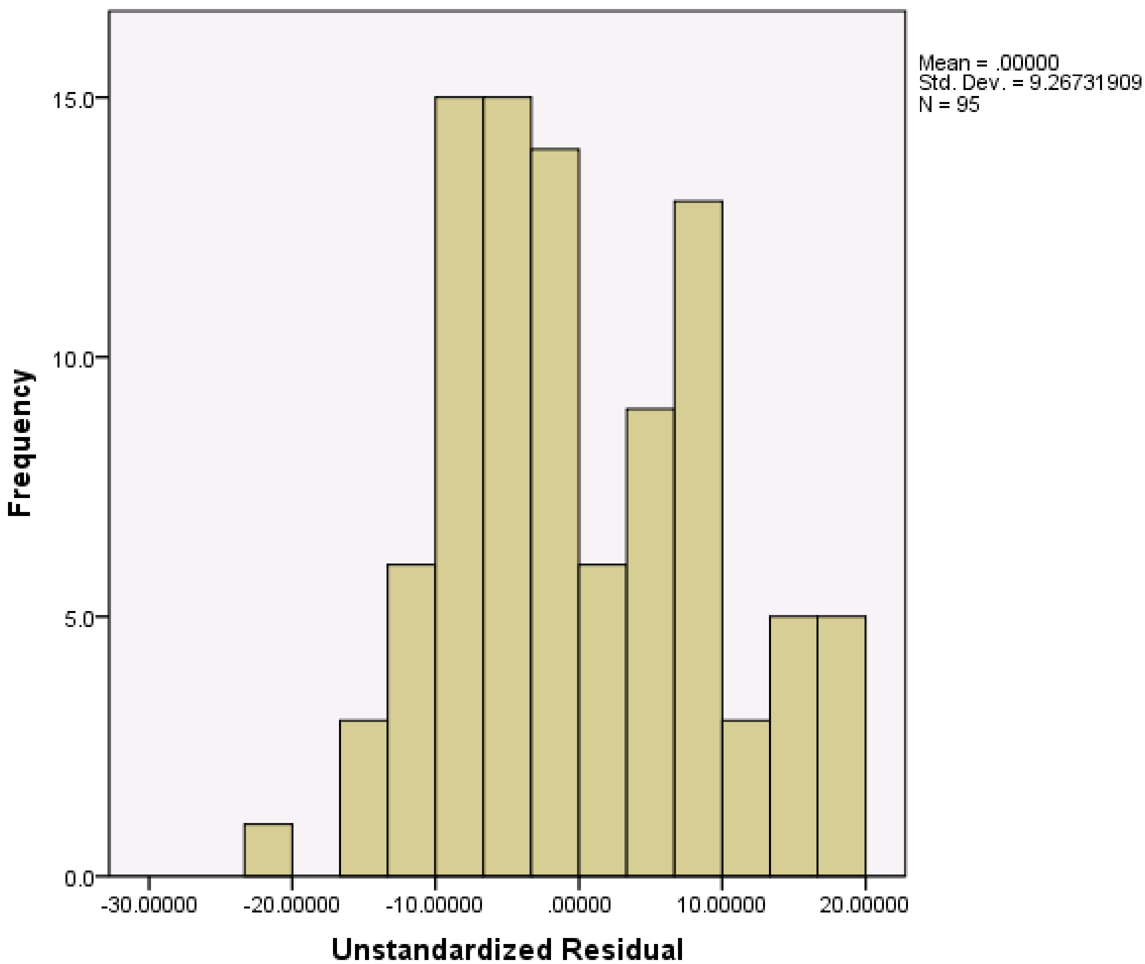

Figure 4.7: Histogram for Residuals of First Order Linear Regression Model for Mastering Chemistry Assignments and ACS Final Exam Scores.

Mastering Chemistry Assignment	α
Assignment 2	0.498
Assignment 3	0.389
Assignment 4	0.506
Assignment 5	0.3
Assignment 6	0.725
Assignment 7	0.52
Assignment 8	0.75
Assignment 9	0.669
Assignment 10	0.417
Assignment 11	0.385
Assignment 12	0.415
Assignment 13	0.282

Figure 4.8: Results from Linear Regression Analysis of Each Mastering Chemistry Assignment and ACS Final Exam Score

To determine if Mastering Chemistry had a more significant impact on students who performed at different levels on the ACS final exam, the 2007 group was broken down three ways for three separate analyses. The first was to assess potential differences between those students who scored above the mean and those who scored below. The mean for the Mastering Chemistry group on the ACS Final was 32.36, with 58 students scoring at thirty two or below and with 37 students above 32. A simple linear regression analysis was run on the two groups comparing total scores on the ACS Final and Mastering Chemistry total scores.

For those students who scored below the mean there was a significance level of 0.713, which is far above the 0.05 needed to suggest a statistically significant relationship. This would suggest no relationship between performance on Mastering Chemistry and scores on the ACS Final. (Figure 4.9)

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.049[a]	.002	-.015	4.621

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.913	1	2.913	.136	.713[a]
	Residual	1195.656	56	21.351		
	Total	1198.569	57			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24.401	1.515		16.109	.000
	MCTOTAL	.007	.018	.049	.369	.713

a. Dependent Variable: ACSTOTAL

Figure 4.9: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Scored Below the ACS Final Exam Mean

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.390[a]	.152	.128	7.082

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	314.717	1	314.717	6.274	.017[a]
	Residual	1755.554	35	50.159		
	Total	2070.270	36			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	32.772	4.548		7.206	.000
	MCTOTAL	.119	.047	.390	2.505	.017

a. Dependent Variable: ACSTOTAL

Figure 4.10: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Scored Below the ACS Final Exam Mean

For students who scored above the mean (33 and above) there was a significance of 0.017, which would suggest that there is a statistically significant relationship between performance on the ACS Final exam and Mastering Chemistry performance. (Figure 4.10) The magnitude of this relationship, r=0.390, is small and can account for only 15.2% (R^2=0.152) of the variation in the sample. This suggests that if Mastering Chemistry did have an effect on the performance of those students who scored above the mean, it was very weak. (Figure 4.10)

The second analysis was for those students who fell on either side of the median score of 29 on the ACS Final. Since multiple students scored 29, the division was not completely perfect and this resulted in the numbers being slightly skewed with 49 students below the median and 46 above.

For those students who scored below the median score there was not a statistically significant relationship between performance on the ACS Final and scores on Mastering Chemistry, with the significance being 0.304. (Figure 4.11)

For those students who scored 30 and above on the ACS Final there was a significant relationship, with α=0.00. This relationship was, again, fairly weak, r=0.505, but could account for over 25% of the variance in the sample (R^2=0.255). (Figure 4.12)

Since the previous two analyses suggested that there was a potential relationship for those students who scored above the mean and median on the ACS Final the group was then broken down, roughly, into thirds. Since multiple students could have the same score this distribution was approximate.

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.152[a]	.023	.002	3.983

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	17.178	1	17.178	1.083	.304[a]
	Residual	729.801	46	15.865		
	Total	746.979	47			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	22.639	1.447		15.642	.000
	MCTOTAL	.017	.017	.152	1.041	.304

a. Dependent Variable: ACSTOTAL

Figure 4.11: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Scored Below the ACS Final Exam Median

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.505[a]	.255	.238	7.477

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	840.603	1	840.603	15.037	.000[a]
	Residual	2459.766	44	55.904		
	Total	3300.370	45			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	27.620	3.681		7.503	.000
	MCTOTAL	.156	.040	.505	3.878	.000

a. Dependent Variable: ACSTOTAL

Figure 4.12: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Scored Above the ACS Final Exam Median

There were thirty two students who scored a 26 or below on the ACS Final, and a linear regression of their scores in comparison to those on Mastering Chemistry did not yield a statistically significant relationship (α=0.387) (Figure 4.13)

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.158[a]	.025	-.007	3.323

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.514	1	8.514	.771	.387[a]
	Residual	331.361	30	11.045		
	Total	339.875	31			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.465	1.381		14.814	.000
	MCTOTAL	.014	.016	.158	.878	.387

a. Dependent Variable: ACSTOTAL

Figure 4.13: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Had the Bottom Third of ACS Final Exam Scores

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.082[a]	.007	-.025	2.566

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.385	1	1.385	.210	.650[a]
	Residual	204.131	31	6.585		
	Total	205.515	32			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	30.663	1.262		24.292	.000
	MCTOTAL	-.007	.015	-.082	-.459	.650

a. Dependent Variable: ACSTOTAL

Figure 4.14: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Had the Middle Third of ACS Final Exam Scores

Thirty three students scored between 27 and 36 on the ACS Final and a linear regression of their performance on this measure in comparison to their Mastering

Chemistry total did not give a statistically significant relationship (α=0.650). (Figure 4.14)

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCTOTAL[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.242[a]	.059	.025	6.516

a. Predictors: (Constant), MCTOTAL

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	74.085	1	74.085	1.745	.197[a]
	Residual	1188.881	28	42.460		
	Total	1262.967	29			

a. Predictors: (Constant), MCTOTAL

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	39.421	5.146		7.661	.000
	MCTOTAL	.068	.052	.242	1.321	.197

a. Dependent Variable: ACSTOTAL

Figure 4.15: Results from Analysis of Mastering Chemistry Totals and Scores on the ACS Final Exam Students Who Had the Top Third of ACS Final Exam Scores

For the remaining thirty students who scored 36 or above the analysis did not give a statistically significant relationship between the ACS Final scores and the Mastering Chemistry totals, with $\alpha=0.197$. (Figure 4.15)

Chapter Five

Discussion and Conclusions

Introduction

This study was undertaken to assess the potential effect of the online homework program Mastering Chemistry on student performance in first semester general chemistry. A review of the literature found that there is no consensus on whether or not computer based homework programs have an impact on student performance. Two separate groups of students enrolled in first semester general chemistry at the University of Missouri Saint Louis were identified; one which used the online homework program Mastering Chemistry and one which did not. Both groups used the ACS First Semester Final Exam and their scores on this assessment were used as a benchmark for understanding of the material.

Answers to Research Questions

Research Question 1: Does the use of an online homework program have an effect on student's understanding of the material?

From Figure 4.2 we can see that the "between groups" analysis shows that there is no statistically significant difference between the group that used Mastering Chemistry and the group did not. This may even have been a positive result, as the mean on the ACS final exam was slightly lower for the group that used the Mastering Chemistry program. This would suggest that the use of the online homework program, despite its potential benefits, did not have a meaningful impact on the students who used it.

At best it could be said that there is no significant impact on student learning from using the online homework program MasteringChemistry.

Research Question 2: Are there specific areas of the material where the program has a greater impact on students understanding?

The first order linear regression analysis and comparison of totals both suggest that there is a statistically significant correlation ($\alpha = 0.002$ and 0.004 respectively) between Mastering Chemistry and performance on the ACS Final Exam. To determine if any of the assignments had a significant impact on student performance on the final a linear regression analysis for each Mastering Chemistry assignment in comparison to the ACS final total was performed. No single Mastering Chemistry assignment had a statistically significant relationship.

From this analysis it is not possible to determine if there is a specific area where Mastering Chemistry had a more significant impact on student understanding.

Research Question 3: Did use of Mastering Chemistry have an impact on lower performing students versus higher performing students?

For the Mastering Chemistry group there was a statistically significant relationship between performance on the program and scores on the final exam. We were then interested in determining if there was a stronger relationship for students who performed at a particular level on the ACS final exam. The analysis suggests that there was a significant relationship for those students who scored above the mean and those who scored above the median score on the ACS final exam. No such relationship existed for those who scored below the mean and median. The students were then divided into thirds and the analysis run again. No statistically significant relationship for any group was displayed. This suggests that there may be a relationship for higher performing students opposed to lower performing ones.

General Discussion

Despite the theoretical advantages that the online homework program Mastering Chemistry could offer, there was no apparent difference on ACS Final Exam scores for students who used the program and the group that used a much simpler online quizzing system. This result is consistent with other work on online homework programs as discussed in the literature review. El-Labban's dissertation came to a similar conclusion, with no statistically significant improvement on the ACS final exam between a group of students who had used the OWL online homework program and a group that had not. (El-Labban, 2003)

When assessing the results of this study it is important to remember that this was not a comparison between groups that did and did not have homework assigned. Both had assigned work that was to be completed for points using computer based assessments, the difference was primarily the depth and complexity of the program that was used, the availability of tutorial-type questions, and "hints". The 2005 group had used a relatively simplistic program that gave students (usually) ten questions and allowed for only multiple choice responses. Mastering Chemistry, which was used by the 2007 group, had numerous features; allowing for multiple part questions with the possibility of open ended responses, and a hint function that allowed students to elicit help while working on the problem. The results suggest that this added complexity had no significant impact on students. This correlates with Bellend's study comparing student performance using different computer based homework programs in a chemistry course. No difference was noted between the overall course performance of students using four different programs, each with different features. (Bellend, 2009)

It is worth noting that this study used student performance on the ACS final exam as the benchmark for student learning. It is possible that this measure is not the most effective method of determining student understanding of chemistry. While the ACS examination is written by experts in the field and undergoes a strenuous editing process, it is not a perfect measure. The responses are limited to a multiple choice format, and it is not possible to receive credit for partially correct answers or correct work. Thus if a student completed the overwhelming majority of a given problem correctly, but made a math error, an incorrect response would be recorded. This is the same number of points (zero) for that problem as someone who had no understanding of the material and guessed at the correct answer. In addition, they would receive fewer points than someone who had no idea as to the correct answer, and simply beat the odds and guessed correctly. It is almost impossible to determine what the student was thinking as he/she made choices.

For the 2007 group there did appear to be a relationship between performance on Mastering Chemistry and performance on the ACS Final Exam. In light of the results from the comparison between groups it would be incorrect to attribute this to an increase in learning. Rather, this could suggest that students who perform well on homework also perform well on the final, and students who perform poorly on the homework also then perform poorly on the final. This is similar to what Charlesworth and Vician noted in their analysis of online WebCT. (Charlesworth & Vician, 2003)

This assumption is not completely substantiated by further analysis of the 2007 data. The group was divided it into halves and thirds to determine if higher or lower performing students may have benefited more. In the first two cases those above the median and mean scores on the ACS final exam had a statistically significant relationship between their performance on the homework and on the final. Though it is worth noting that these effects were potentially small (accounting for less than 25% of the variance). This lends credence to the suggestion that students who perform well on the homework also will do well on the final. If this was true then there should have been a significant relationship for those students who performed below the mean and medians. But the analysis showed no such significance for the lower performing students. This could be attributed to numerous factors, such as students with a weaker grasp performing better when time is not a factor, a manifestation of test anxiety, and potential cheating.

This last possible factor, cheating, is often used as to counter arguments for online homework programs that are assigned for points. In light of recent research (Baird, 2006; Vician et al, 2006) on cheating in college courses it would be foolish to assert that it does not, or will not, occur. Though what counts as "cheating" is depends on the guidelines specified by the instructor. For the 2007 group in this study, students were encouraged to collaborate, discuss, and seek help from tutors and teaching assistants if they encountered difficulty with homework. While encouraged to work together, there was the potential that some students may have simply printed off the homework, had other individuals complete the homework, and then submit the answers as their own. The significance between the 2007 group's performance on the homework and on the final would suggest that this was not a significant problem. Those students who performed well on the homework also performed well on the final. If students did consistently cheat on the homework and accumulated numerous points, then they were either able to perform well on the final or cheat.

By dividing the group into thirds by scores on the comprehensive final exam, it was hoped that an increase in distinction between groups would allow for potential effects to be better identified. This would have allowed us to further assess potential effects at different performance levels. Instead, no significance was noted between performance on the homework program and that on the final exam for the bottom, middle, or top third of students. This could be because the sample size for this study was not large to begin with, with 95 students in the 2007 group, and dividing students even further could have reduced the effectiveness of the analysis. Another possibility is that the significance that was noted for the students above the mean and median was an anomaly and not potentially relevant.

The results of the individual analysis for Mastering Chemistry assignment in comparison to the scores on the final also work against the suggestion that the correlation is simply indicative of students performing consistently at their level. If it were a matter of stronger students performing well on homework and also on the final, and the opposite for weaker students, then we would expect to see a correlation on each assignment with the scores on the final exam. This phenomenon did not manifest, as there was no statistically significant correlation between performance on any of the Mastering Chemistry assignments and on the final. This could be because each assignment is slightly different, adding more and different content, and different students may have difficulties with certain portions of the course. This would have been averaged out over the course of the semester, and would explain why a correlation exists between the Mastering Chemistry totals and first order model with the ACS final totals. Since the final exam covers the entire course, those areas where certain students struggled would be diluted with material covering other areas.

Conclusions

This study was undertaken to determine if the online homework program Mastering Chemistry, with its advances over more simplistic programs, would have a positive impact on student understanding of Chemistry. Results suggest that there is little or no benefit derived from these “bells and whistles”. Students who used a bare-bones program that offered no feedback performed just as well on the final exam as those students who used Mastering Chemistry.

This does not mean that these programs may not be without value, or an eternal condemnation. Homework programs may be an effective way to assess student performance and understanding of material that is not possible with other methods. If homework is desired to allow students to earn points and demonstrate knowledge outside a testing situation Mastering Chemistry may be a more effective tool, as it allows for in-depth questions, ease of use for instructor, and student feedback. Those instructors who decide to use the program should not expect to see a significant impact on their students understanding or performance in the class. Further, there is now at least one assessment/tutorial system that uses artificial intelligence to create an automated learning experience that is individualized for each student (ALEKS). One might hope that it would be able to provide more effective learning than do homework management systems in the Mastering Chemistry class.

There is also the issue of cost. As Mastering Chemistry is not a free program, the students in the 2007 group were required to purchase it, the potential benefits must be weighed against forcing students to incur an additional cost for a product that may have a limited impact on their learning. With the rising costs of a college education a serious concern, free programs that result in similar student performance may be a better choice.

Suggestions for Future Research

This is an area that is rich for future research. A study involving a larger sample size of students may provide a larger picture of how the program affects student performance. This would present other problems though, as a larger sample size may make it more difficult to control for differences between groups, something this study was able to do by minimizing, to a large extent, those differences.

Online homework programs have found use in a variety of different disciplines and courses. It could be that the homework programs are effective in some areas, mathematics for example, but less so in others.

A study that involves interviews with students may also prove to be enlightening. By speaking with users, researchers may be able to probe how students use the program, what problems they encountered, and what suggestions they may have for improvement.

Studies that analyze student understanding of Chemistry using additional measures could prove beneficial. It could be that Mastering Chemistry has a positive impact on student performance, in some way that was not assessed by the ACS Final Exam.

Mastering Chemistry is but one of numerous programs that are available for use. It could be that other programs prove more effective and have an impact on student performance. Also, these programs are constantly being updated with new features and more complex additions. It could be that improved systems may have a positive impact on students, a negative impact, or no effect at all.

References

Allain, R., and Williams, T., (2006) The Effectiveness of Online Homework in an Introductory Science Class. *Journal of College Science Teaching*, *35*(6), 28-30

American Teacher (2009) Research on Homework Remains a Mixed Bag, *American Teacher,* 93(5), 7

Baird, J. (2006) Current Trends in College Cheating, *Psychology in the Schools, 17*(4), 515-522

Belland, J. (2009) Comparison of Homework Systems (Four Web-based) Used in First Semester General Chemsitry (Thesis) Available from University of North Texas Digital Library (UNTCAT: b3795806)

Burch, K., & Kuo, J.K, (2010) Traditional vs. Online Homework in College Algebra. *Mathamatics and Computer Education Journal*, *44*(1), 53-63

Bonham, S.W., Deardorff, D.L., & Beichner, R.J., (2001) Online Homework: Does it Make a Difference? *The Physics Teacher, 39*, 293-296

Bonham, S.W., Deardorff, D.L., & Beichner, R.J., (2003) A Comparison of Student Performance Using Web and Paper-based Homework in College-level Physics. *Journal of Research in Science Teaching, 40*(10), 1050-1071

Charlesworth, P. & Vician, C., (2003) Leveraging Technology for Chemical Sciences Education: An Early Assessment of WebCT Usage in First-Year Chemistry Courses. *Journal of Chemical Education, 80*(11) 1333-1337

Chamala, R.R., Ciochina, R., Grossman, R.B., Finkel, R.A., Kannan, S., and Ramachandran, P., (2006) EPOCH: An Organic Chemistry Homework Program That Offers Response Specific Feedback to Students. *Journal of Chemical Education, 83*(1), 164-169

Cambre, M., & Hawkes, M. (2004) *Toys, tools & teachers.* Lanham:ScarecrowEducation.

Clark, K., Dwyer, F., (1998) Effect of Different Types of Computer-Assisted Feedback Strategies on Achievement and Response Confidence. *International Journal of Instructional Media, 25*(1), 55-63

Cole, R.S., & Todd, J.B., (2003) Effects of Web-Based Multimedia Homework with Immediate Rich Feedback on Student Learning in General Chemistry. *Journal of Chemical Education, 80(11), 1338-1343*

Connolly, J.W., (1972) Automated Homework Grading for Large General Chemistry Classes. *Journal of Chemical Education, 49*(4), 262

Cooper, H. (1989). *Homework*. White Plains, NY: Longman

Cooper, H. (1989) Synthesis of Research on Homework. *Educational Leadership, 47*, 85-92

Cooper, H., Valentine, J.C., Nye, B., & Lindsay, J.J., (1999) Relationships Between Five After-School Activities and Academic Achievement. *Journal of Educational Psychology*, 72, 278-292

Cooper, H., & Valentine, J.C., (2001) Using Research to Answer Practical Questions About Homework. *Educational Psychologist, 36*(3), 143-153

Cooper, H., Robinson, J.C., and Patall, E.A., (2006) *Does Homework Improve Academic Achievement? A Synthesis of Research 1987-2003*. Review of Educational Research, 76(1), 1-62

Cuban, L. (2001) *Oversold and Underused: Computers in the Classroom* Harvard University Press

Cuadros, J., Yaron, D., and Leinhardt, G., (2007) “One Firm Spot”: The Role of Homework as Lever in Acquiring Conceptual and Performance Competence in College Chemistry. Journal *of Chemical Education, 84*(6), 1047-1052

Deeter, C.L. (2008*) The Effect of Online Quizzes on Student Achievement in High School Chemistry*. (Dissertation) Available from Dissertations and Theses Database

Donovan, W. & Nakhleh, M. (2001) Students' Use of Web-Based Tutorial Materials and Their Understanding of Chemistry Concepts. *Journal of Chemical Education, 78*(7), 975-980

Donovan, W. & Nakhleh, M (2007) Student Use of Web-based Tutorial Materials and Understanding of Chemistry Concepts. *Journal of Computers in Mathematics and Science Teaching, 26*(4), 291-327

Demirci, N., (2007) University Students' Perceptions of Web-based vs. Paper-based Homework in a General Physics Course. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(1), 29-34

Dillard-Eggers, J., Wooten, T., Childs, B., and Coker, J, (2008) Evidence on The Effectiveness of On-Line Homework. *College Teaching Methods & Style Journal, 4*(5), 9-16

El-Labban, W. (2003) *Assessment of the Effect of Online Homework on the Achievement of Students in Chemistry.* (Dissertation) Available from Dissertations and Theses Database

Fornoff, F. (1978) *Review of ACS General Chemistry Exam* The Eighth Mental Measurements Yearbook, Lincoln: Univeristy of Nebraska Press

Freasier, B., Collins, G., and Newitt, P., (2003) A Web-based Interactive Homework Quiz and Tutorial Package to Motivate Undergraduate Chemistry Students and Improve Learning. *Journal of Chemical Education, 80*(11), 1344-1347

French, C.B., (2009) Comparison of Features, Electronic Homework Management Systems. *Journal of Chemical Education, 86*(6), 693

Fynewever, H., (2008) A Comparison of the Effectiveness of Web-based and Paper-based Homework for General Chemistry. *The Chemical Educator, 13*(4), 264-269 doi: 10.1333/s00897082142a

Grimstad, K., & Grabe, M. (2004). Are online study questions beneficial?

Teaching of Psychology, 31, 143-146

Hagerty, G., & Smith, S. (2005). Using the Web-Based Interactive Software ALEKS to Enhance College Algebra. *Mathematics and Computer Education*, *39*(3), 183-194

Hall, R.W., Butler, L.G., Kestner, N.R., and Limbach, P.A., (1999) Combining Feedback and Assessment via Web-Based Homework. *Campus-Wide Information Systems. 16*(1), 24

Hall, R.W., Butler, L.G., McGuire, S.Y., McGlynn, S.P., Lyon, G.L., Reese, R.L., and Limbach, P.A., (2001) Automated, Web-Based, Second-Chance Homework. *Journal of Chemical Education, 78*(12), 1704-1708

Harris, H. (2009) Electronic Homework Management Systems: Reviews of Popular Systems. *Journal of Chemical Education, 86*(6), 691

Harter, C., & Harter, J. (2004) Teaching with technology: Does access to computer technology increase student achievement? *Eastern Economic Journal, 30*, 507-514

Harwell, D., Brown, K., Caldwell, A., Frazier, W., & McGee, T., (2009) Science Homework and Parental Involvement: Factors Influencing Behaviors and Attitudes. *Academic Leadership, 7*(3). Retrieved from http://www.academicleadership.org/authors/Dana_Rolison_Harwell.shtml

Holme, T. (2003) Assessment and Quality Control in Chemistry Education. *Journal of Chemical Education*, *80*(5), 594

JCE Staff (2009) Comparison of Features, Electronic Homework Management Systems. *Journal of Chemical Education, 86*(6), 693

Jungic, V., Kent, D., Menz, P. (2012) On Online Assignments in a Calculus Class. *Journal Oof University Teaching & Learning Practice* 9, 1-13

Kitsantas, A., Zimmerman, B.J., (2009) College Students' Homework and Academic Achievement: The Mediating Role of Self-Regulatory Beliefs. *Metacognition Learning*, 4, 97-110

Kohn, A., (2006) Abusing Research: The Study of Homework and Other Examples. *The Phi Delta Kappan*, 88(1), 8-22

Kohn, A., (2006) *The Homework Myth: Why Our Kids Get Too Much of a Bad Thing.* Cambridge, MA: Da Capo,

Kralovec, E., & Buell, J. (2000) *The End of Homework: How Homework Disrupts Families, Overburdens Children, and Limits Learning.* Boston, MA: Beacon Press

MasteringChemistry [Online Software] (2007), Upper Saddle River, NJ: Pearson Prentice Hall Retrieved from www.masteringchemistry.com

McMurry, J., Fay, R.C. (2007) *Chemistry* Upper Saddle River, NJ: Prentice Hall

Mendenhall, W., & Sincich, T. (2003) A *Second Course in Statistics Regression Analysis.* Pearson Education: Upper Saddle River, New Jersey

Mory, E. (1992) The Use of Informational Feedback in Instruction: Implications for Future *Research. Educational Technology Research and Development, 40*(3), 5

Nwaogu, E. (2012) *The Effects of ALEKS on Students' Mathematics Acheivement in an Online Learning Environment and the Cognitive Complexity of the Initial and Final Assessments* (Dissertation)

Oppenheimer, T. (2003) *The Flickering Mind*. New York: Random House.

Pearson Education (2007) Mastering Chemistry [computer software]. Pearson Prentice Hall; Upper Saddle River, NJ

Peck, M.L., (1998) ChemSkill Builder, Version 5.1, *Journal of Chemical Education*, 75(7), 831

Peng, J.C., (2009). Using an Online Homework System to Submit Accounting Homework: Role of Cognitive Need, Computer Efficancy, and Perception. *Journal of Education for Business, 84*(5), 263-268

Penn, J.H., Nedeff, V.M., (2000) Organic Chemistry and the Internet: A Web-Based Approach to Homework and Testing Using the WE_LEARN System. *Journal of Chemical Eduation, 77*(2), 227-231

Radhakrishnan, P., Lam, D., & Ho, G., (2009). Giving University Students Incentives to do Homework Improves their Performance. *Journal of Instructional Psychology, 33* (3), 219-224

Richards-Babb, M., Jackson, J. (2011) Gendered Responses to Online Homework Use in General Chemistry. *Chemistry Education Research and Practice, 12*, 409-412

Richards-Babb, M., Drelick, J., Henry, Z., Robertson-Honecker, J. (2011) Online Homework, Help or Hinderance? What Students Think And How They Perform. *Journal of College Science Teaching. 40*(4), 81-93

Roth, V., Ivanchenko, V., Record, N., (2008) Evaluating Student Response to WeBWorK, a Web-Based Homework Delivery and Grading System

Robinson, W.R. & Nash, J.J. (n.d.) *Visulaization and Problem Solving for General Chemistry*. Retrieved January 15, 2010, from http://www.chem.purdue.edu/gchelp/

Shepherd, T.D. (2009) Mastering Chemistry *Journal of Chemical Education*, *86*, 694

Shimazu, Y. (2005) Language course taught with online supplement material: Is it effective? *Education, 126*, 26-36

Spain, J.D., (1996) Electronic Homework: Computer-Interactive Problem Sets for General Chemistry. *Journal of Chemical Education, 73*(3), 221-225

Taylor, J. M. (2008). The effect of computerized-algebra program on mathematics achievement of college and university freshmen enrolled in a developmental math course. *Journal of College Reading and Learning*, *39*(1), 36-37.

Trautwein, U., Schnyder, I., Niggli, A., Neumann, M., Ludtke, O., (2009). Chameleon Effects in Homework Research: The Homework-Achievement Association Depends on the Measures Used and the Level of Analysis Chosen. *Contemporary Educational Psychology*, *34,* 77-88

Trautwein, U. and Koller, O., (2003) The Relationship Between Homework and Achievement-Still Much of a Mystery. *Educational Psychology Reivew*, 15(2), 115-145

Walberg, H. J., Paschal, R. A., & Weinstein T., (1985). Homework's powerful effects on learning. *Educational Leadership*, *42*, 76-79.

Vatterott, C. (2007). *Becoming a middle level teacher: Student focused teaching of early adolescents.* New York, NY: McGraw-Hill

Vatterott, C. (2009). *Rethinking homework: Best practices that support diverse needs.* Alexandria, VA: ASCD

Vician, C., Charlesworth, D., & Charlesworth, P. (2006) Students' Perspectives of the Influence of Web-Enhanced Coursework on Incidences of Cheating. *Journal of Chemical Education, 83*(9), 1368

Zerr, R. (2007) A quantitative and qualitative analysis of the effectiveness of online homework in first semester calculus. *The Journal of Computers in Mathematics and Science Teaching, 26*, 55-73

Appendix I - Institutional Research Board Exempt Letter

University of Missouri St. Louis

OFFICE OF RESEARCH ADMINISTRATION

Interdepartmental Correspondence

Name: Brian Huesgen

Title: Determination of Effectiveness of the Online Homework Program Mastering Chemistry

The chairperson of the Human Subjects Committee for UM-St. Louis has reviewed the above mentioned protocol for research involving human subjects and determined that the project qualifies for exemption from full committee review under Title 45 Code of Federal Regulations Part 46.101b. The time period for this approval expires one year from the date listed below. You must notify the Human Subjects Committee in advance of any proposed major changes in your approved protocol, e.g., addition of research sites or research instruments.

You must file an annual report with the committee. This report must indicate the starting date of the project and the number of subjects to date from start of project, or since last annual report, whichever is more recent.

Any consent or assent forms must be signed in duplicate and a copy provided to the subject. The principal investigator must retain the other copy of the signed consent form for at least three years following the completion of the research activity and they must be available for inspection if there is an official review of the UM-St. Louis human subjects research proceedings by the U.S. Department of Health and Human Services Office for Protection from Research Risks.

This action is officially recorded in the minutes of the committee.

Protocol Number	Date	Signature - Chair
100217H	2/18/10	Carl J Davis

Appendix II - SPSS Output for Comparison of Each Mastering Chemistry Assignment with ACS Final Scores

```
ONEWAY ACSTOTAL BY MCASS2
  /MISSING ANALYSIS.


REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS2.
```

Regression

Notes

Output Created		04-Jun-2012 20:00:57
Comments		
Input	Data	K:\mastchemresearch\2007data2012.sav
	Active Dataset	DataSet2
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	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS2.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000

	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS2[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.070[a]	.005	-.006	10.943

a. Predictors: (Constant), MCASS2

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	55.322	1	55.322	.462	.498[a]
	Residual	11257.210	94	119.758		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS2

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.737	1.356		23.403	.000
	MCASS2	.070	.102	.070	.680	.498

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS2[a]	.	Enter

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS3.
```

Regression

Notes

Output Created		04-Jun-2012 20:02:50
Comments		
Input	Data	K:\mastchemresearch\2007data2012.sav
	Active Dataset	DataSet2
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	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS3.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000

	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

[DataSet2] K:\mastchemresearch\2007data2012.sav

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS3[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.089[a]	.008	-.003	10.927

a. Predictors: (Constant), MCASS3

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	89.299	1	89.299	.748	.389[a]
	Residual	11223.234	94	119.396		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS3

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.

		B	Std. Error	Beta		
1	(Constant)	31.419	1.479		21.243	.000
	MCASS3	.089	.103	.089	.865	.389

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS4.
```

Regression

Notes

Output Created		04-Jun-2012 20:03:41
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	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS4.
Resources	Processor Time	00 00:00:00.032
	Elapsed Time	00 00:00:00.031

Memory Required	5840 bytes
Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS4[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.069[a]	.005	-.006	10.944

a. Predictors: (Constant), MCASS4

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53.405	1	53.405	.446	.506[a]
	Residual	11259.128	94	119.778		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS4

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.847	1.277		24.948	.000
	MCASS4	.060	.090	.069	.668	.506

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS5.
```

Regression

Notes

Output Created		04-Jun-2012 20:04:01
Comments		
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	Filter	<none>
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	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS5.

Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

[DataSet2] K:\mastchemresearch\2007data2012.sav

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS5[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.107[a]	.011	.001	10.908

a. Predictors: (Constant), MCASS5

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	128.957	1	128.957	1.084	.300[a]
	Residual	11183.576	94	118.974		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS5

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		

1	(Constant)	31.413	1.379		22.783	.000
	MCASS5	.111	.106	.107	1.041	.300

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS6.
```

Regression

Notes

Output Created		04-Jun-2012 20:04:31
Comments		
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	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS6.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.017
	Memory Required	5840 bytes

Notes

Output Created		04-Jun-2012 20:04:31
Comments		
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	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS6.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.017
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS6[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.036[a]	.001	-.009	10.963

a. Predictors: (Constant), MCASS6

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.929	1	14.929	.124	.725[a]
	Residual	11297.604	94	120.187		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS6

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.982	1.369		23.370	.000
	MCASS6	.036	.102	.036	.352	.725

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS7.
```

Regression

Notes

Output Created		04-Jun-2012 20:04:53
Comments		
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	Active Dataset	DataSet2

	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS7.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.015
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS7[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.067[a]	.004	-.006	10.946

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.067[a]	.004	-.006	10.946

a. Predictors: (Constant), MCASS7

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	50.075	1	50.075	.418	.520[a]
	Residual	11262.458	94	119.813		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS7

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.704	1.410		22.492	.000
	MCASS7	.073	.112	.067	.646	.520

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS8.
```

Regression

Notes

Output Created	04-Jun-2012 20:05:36
Comments	

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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS8.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

[DataSet2] K:\mastchemresearch\2007data2012.sav

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS8[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.033[a]	.001	-.010	10.964

a. Predictors: (Constant), MCASS8

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.247	1	12.247	.102	.750[a]
	Residual	11300.286	94	120.216		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS8

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.971	1.439		22.224	.000
	MCASS8	.035	.109	.033	.319	.750

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS9.
```

Regression

Notes

Output Created		04-Jun-2012 20:05:59
Comments		
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	Active Dataset	DataSet2
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	Weight	<none>

	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS9.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS9[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.044[a]	.002	-.009	10.960

a. Predictors: (Constant), MCASS9

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.051	1	22.051	.184	.669[a]
	Residual	11290.481	94	120.112		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS9

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.733	1.662		19.094	.000
	MCASS9	.060	.141	.044	.428	.669

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS10.
```

Regression

Notes

Output Created		04-Jun-2012 20:06:31
Comments		
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	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.

	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS10.
Resources	Processor Time	00 00:00:00.031
	Elapsed Time	00 00:00:00.017
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

[DataSet2] K:\mastchemresearch\2007data2012.sav

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS10[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.084[a]	.007	-.004	10.932

a. Predictors: (Constant), MCASS10

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	79.556	1	79.556	.666	.417[a]
	Residual	11232.977	94	119.500		

	Total	11312.533	95			

a. Predictors: (Constant), MCASS10

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.574	1.397		22.599	.000
	MCASS10	.091	.112	.084	.816	.417

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS11.
```

Regression

Notes

Output Created		04-Jun-2012 20:06:55
Comments		
Input	Data	K:\mastchemresearch\2007data2012.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.

Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS11.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS11[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.090[a]	.008	-.002	10.926

a. Predictors: (Constant), MCASS11

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	91.127	1	91.127	.763	.385[a]
	Residual	11221.406	94	119.377		
	Total	11312.533	95			

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	91.127	1	91.127	.763	.385[a]
	Residual	11221.406	94	119.377		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS11

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.686	1.294		24.490	.000
	MCASS11	.093	.107	.090	.874	.385

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS12.
```

Regression

Notes

Output Created		04-Jun-2012 20:07:10
Comments		
Input	Data	K:\mastchemresearch\2007data2012.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.

	Cases Used	Statistics are based on cases with no missing values for any variable used.
Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS12.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.000
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS12[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.084[a]	.007	-.003	10.931

a. Predictors: (Constant), MCASS12

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	80.094	1	80.094	.670	.415[a]
	Residual	11232.439	94	119.494		

	Total	11312.533	95			

a. Predictors: (Constant), MCASS12

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.542	1.419		22.232	.000
	MCASS12	.078	.095	.084	.819	.415

a. Dependent Variable: ACSTOTAL

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT ACSTOTAL
  /METHOD=ENTER MCASS13.
```

Regression

Notes

Output Created		04-Jun-2012 20:07:41
Comments		
Input	Data	K:\mastchemresearch\2007data2012.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	96
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any variable used.

Syntax		REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT ACSTOTAL /METHOD=ENTER MCASS13.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.014
	Memory Required	5840 bytes
	Additional Memory Required for Residual Plots	0 bytes

```
[DataSet2] K:\mastchemresearch\2007data2012.sav
```

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	MCASS13[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: ACSTOTAL

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.111[a]	.012	.002	10.902

a. Predictors: (Constant), MCASS13

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	139.405	1	139.405	1.173	.282[a]
	Residual	11173.128	94	118.863		
	Total	11312.533	95			

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	139.405	1	139.405	1.173	.282[a]
	Residual	11173.128	94	118.863		
	Total	11312.533	95			

a. Predictors: (Constant), MCASS13

b. Dependent Variable: ACSTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.297	1.424		21.980	.000
	MCASS13	.116	.107	.111	1.083	.282

a. Dependent Variable: ACSTOTAL