DESIGNING WEBWORK PROBLEMS FOR APPLIED STATISTICS II

Interactive Qualifying Project Report completed in partial fulfillment

of the Bachelor of Science degree at

Worcester Polytechnic Institute, Worcester, MA

Submitted to:

Professor Joseph Petruccelli (advisor)

Minh Le _____

Vorayos Roungrojkarnranan _____

04/28/2011

_____

Advisor Signature

Table of Contents

Abstract 4

1. Introduction 5

2. Background 9

2.1 Online homework 9

2.1.1 Advantages of online homework 9

2.1.2 Student perceptions of online homework 10

2.1.3 Difficulties in using online homework for classes 12

2.2 Statistics courses 13

2.2.1 The subject statistics 13

2.2.2 Statistics courses 13

2.3 WeBWorK 14

2.3.1 Special features of WeBWorK 14

2.3.2 Effectiveness of WeBWorK 16

2.3.3 Use of WeBWorK at Worcester Polytechnic Institute 17

2.4 Types of homework questions 18

2.4.1 Multiple choice questions 19

2.4.2 Short answer questions 23

2.4.3 Essay questions 25

2.4.4 Combinations of different types of questions 27

3. Methodology 29

3.1 Develop questions for simple and multiple linear regression 30

3.1.1 Contents of the questions 31

3.1.2 Types of questions 31

3.1.3 Question set up 32

3.1.4 List of topics 33

3.1.5 Designing the questions 34

3.1.6 Consultation 34

3.2 Programming and uploading the problems 35

3.3 Test the database 37

3.4 Improvements 38

4. Results and Discussion 39

4.1 Results 39
4.2 Simple Linear Regression 39
4.3 Multiple Linear Regression 41
4.4 Results 43
4.5 Discussion of the testing 44
4.6 Other observations 49
5. Conclusions and Recommendations 50
Bibliography 53
Appendix 61
Appendix A.1 : WebWork Problems for Simple Linear Regression 61
Appendix A.2 : WebWork Problems for Multiple Linear Regression 67
Appendix A.3: Pretest and posttest for testing simple linear regression 70
Pretest 70
Posttest 70
Appendix A.4: Pretest and Posttest for testing multiple linear regression 72
Pretest 72
Posttest 72
Appendix A.5: Simple linear regression WebWorK problems that were used in control group 74
Appendix A.6: Multiple linear regression WebWorK problems that were used in control group 76

Abstract

This project's goal was designing effective WeBWorK problems for simple and multiple linear regression topics covered in the course Applied Statistics II at WPI. In this project, current literature concerning online homework was reviewed to determine the criteria for effective online homework problems. The WeBWorK problems were designed according to these criteria. The problems designed in this project were also tested against existing WeBWorK problems on the same topics for effectiveness and recommendations were made based on the results.

1. Introduction

Among various educational methods aimed at improving students' understanding, homework is important and currently being employed by most teachers and instructors. With the advancement of technology, especially information technology, students have been assigned online homework in addition to traditional paper assignments. With the assistance of various technological tools such as media effects or online interactions, instructors have more options for designing effective homework. However, online homework can only be useful if it is made suitable and effective for students and currently there is a debate about the efficacy of online homework as opposed to traditional paper homework (Bonham, Beichner and Deardoff, 2001).

To create an effective online homework set, an instructor has to face many decisions and tradeoffs. One tradeoff is the difficulty level of the homework. A homework set with high level of difficulty may encourage the best students in the class, but may hamper the rest of the students in understanding the material. In contrast, a homework set with low level of difficulty can give most of the students an incentive to finish the homework, but may not promote any further investigation on the materials from the students (Vatterott, 2008). Instructors who do not have experience with online homework also have difficulty deciding the number and the types of questions for online homework. Since students interact with online homework in a different way than they do with paper homework, the inexperienced instructors have to select the number and the types of questions carefully so the homework stills remains effective. All those decisions and tradeoffs have made creating effective online homework assignments a challenge for any instructor who wants to utilize online homework assignment for his class.

The application of online systems to college courses has been extensively studied through a variety of previous work. Vatterott presented criteria that characterize an effective homework assignment and guidelines on how to make such homework assignments (Vatterott, 2002). These criteria and guidelines can be applied to both traditional and online homework. Doorn and O'Brien (2005) not only showed that online homework is preferred by students to traditional homework but also pointed out some important criteria of a good online homework assignment such as the existence of grading systems. Stirling in a paper on English Language Garden Website surveyed various types of questions that can be used for homework and showed both advantages and disadvantages of those types of questions. Although this article was aimed mainly for English classes, the information from this article could be useful for any class (Stirling, 2005).

One existing system for online homework assignments is WeBWorK, an online homework system developed at the University of Rochester (Weibel and Hirssch, 2002). WeBWorK has many advanced features such as automatic grading and grade recording, the ability to recognize students' answers in various forms, including complex algebraic expressions, direct communication between students and instructors and flexibility for instructors in designing problems and homework structures (Gage and Pizer, 2010). Moreover, according to a number of studies, many instructors and students prefer the WeBWorK system to traditional paper homework. In a survey given to 2387 students during 2002-2004 at all levels of Calculus, Differential Equations, Discrete Mathematics and Linear Algebra, most students prefered to use WeBWorK (Bressoud, 2010). Hodge, Richardson and York (2005) found that more students in a college algebra course were motivated to complete homework using WeBWorK than using traditional methods, and most students would take future courses using WeBWorK. There has

also been some research specifically on how to use WeBWorK effectively as a homework tool. Lucas (2010) pointed out advantages and disadvantages of WeBWorK in helping students to learn.

WeBWorK has been used increasingly frequently in colleges across the United States and in particular in many mathematical courses at Worcester Polytechnic Institute, including calculus at all levels, differential equations, linear algebra, statistics and some actuarial mathematics courses such as Theory of Interest. However, as with other online homework systems, instructors using WeBWorK face many challenges such as determining the amount and length of homework and suitable problems to make an effective homework set. This problem is particularly more important and difficult for statistics courses, as statistics employs more interpretation and applications questions and less computation questions than other basic mathematics courses.

However, every online homework framework has unique features and presents different problems. Moreover, every subject requires different approaches to homework. Thus, despite a variety of research having been done on creating effective online homework, there are still places for additional research on how to create an effective WeBWorK online homework database for statistics students. A complete WeBWorK database for statistics students needs to be built. This database needs to not only satisfy the need of an online homework database for statistics courses at Worcester Polytechnic Institute but also serves as an effective tool for students to get better understandings of the materials and instructors to have good evaluations of students' performances.

With these goals in mind, it was our project's mission to research methods for creating effective WeBWorK homework problems for simple and multiple linear regression and to create a set of

such problems. We tested these problems in the statistics course MA 2612 taught by Professor Joseph Petruccelli in D term, 2011. Thus, we focused on the following goals:

- Identify the methods to build an effective WeBWorK homework database for simple and multiple linear regression
- Build a WebWorK homework database for simple and multiple linear regression
- Test the effectiveness of the database in improving students' performance in the MA 2612 course and make suggestions for further improvement.

In order to accomplish these goals, we worked closely with the instructor and students of the MA 2612 course. We also consulted other faculty members of the Mathematical Science department of Worcester Polytechnic Institute.

2. Background

2.1 Online homework

Online homework systems provide a new way for instructors to assign homework and for students to do homework. In contrast to traditional paper homework, online homework systems require instructors to input homework assignments to an online network instead of supplying handouts or assigning problems from textbooks. Students access these online homework assignments by logging into the online homework network using their own accounts. Students submit the assignments electronically through their online homework system rather than on paper. These differences create both advantages and difficulties for instructors who use online homework systems for their classes.

2.1.1 Advantages of online homework

Online homework has some special features that give it an advantage over traditional paper homework:

- Automatic grading. Online homework allows students to receive immediate feedback on their work. It allows students to realize their weaknesses faster and have more time to study to improve. This is especially helpful when students need to study for an exam. (Smolira, 2008)

- Interactive tools. Since online homework employs software technology, many interactive tools can be added to online homework to enhance students' study. Some online homework systems allow students to get assistance such as suggested hints when they get the wrong answers for their problems. This feature is almost impossible for traditional homework. Some online homework networks have multimedia features such as

animations or sound effects. These features enhance students' study as some students are visual learners, who learn better through animations and demonstrations. These multimedia effects also keep students interested in doing their homework. (Heffernan, 2009)

- Storage of completed assignments. Most online homework systems allow students to access their past assignments. This is particularly useful because it allows students to learn from their mistakes and review for their exams. This could be done with traditional paper homework, but it requires students to keep all the past papers on file. The storage feature of online homework reduces this burden. (Burnham, 2008)

- Access to the materials covered by the questions. Some online homework systems, such as WileyPLUS, created by the Wiley publisher, have an online version of the textbook included in the system. This feature allows a student to jump directly into the section of the textbook covered in the question the student is working on. This feature allows the student to review the material while doing questions related to that material, enabling the student to understand and remember the material better. With traditional paper homework, the student has to find the materials related to the questions in the textbook by himself, causing him to spend more time on homework. This feature saves time for students and makes them focus more on reviewing related materials and figuring out solutions. (information based on the WileyPlus homepage, www.wileyplus.com)

2.1.2 Student perceptions of online homework

A number of studies have found that students are generally satisfied with online homework.

Dillard, Wooten and Coker reported on a survey of 233 students in an accounting course that asked about their perceptions of and degree of satisfaction with online homework. .For 149 of the students, online homework was a required part of the course. For the rest, online homework problems were identified and only recommended for exam preparation. Fifty-three percent of all students thought that online homework resulted in a higher quality of study time than other alternative methods, fifty-five percent of all students thought that online homework resulted in a higher understanding than other alternative methods, forty-nine percent of students thought that online homework was better with respect to learning than "pencil and paper", and only thirty-one percent thought that it was worse compared to the "pencil and paper" (Dillard, Wooten and Coker, 2008)

Doorn and O'Brien did a study of student opinion about online homework, graded homework and the students' motivation to study. Students in seven economics courses were surveyed in 2008. Six hundred eighty-seven students participated. Each student was using online homework in the course. The surveys include questions attitudes about homework, perceptions of benefits of online homework, views of online homework compared to traditional homework, motivation to study, etc. Over 55% of the students preferred online homework to traditional homework and only 8.9% preferred traditional homework. (Doorn and O'Brien, 2010)

(2008) also conducted a study of the effectiveness of online homework. He specialized his study on the effectiveness of online homework on finance courses. Fifty undergraduate and 30 MBA students were asked to take a survey about how online homework helped them in studying in finance courses. From the survey, most of the students indicated that online homework did improve their understanding of the materials covered in classes. In addition, since online

homework, with automatic grading, gave the faster feedbacks to the students than traditional paper homework did, the students who had been given online homework usually had more time to review their homework for exams.

2.1.3 Difficulties in using online homework for classes

Although online homework systems have many useful features to help instructors and students, the instructors who use online homework systems still face many problems.

To benefit from the automatic grading feature of many online homework systems, instructors have to restrict the types of questions they can ask - essay questions and questions that require human judgment to grade are not suitable. This automatic grading feature can only grade the types of questions in which there is a well-defined set of choices, such as multiple choice questions or some short answer questions like fill-in the blank. This limitation prevents instructors from using the benefits of essay questions, and also prevents online homework from being used in many advanced courses, where essay questions are much preferred. (Burnham, 2008)

Another difficulty for an instructor using online homework is choosing the amount of homework that should be assigned for each student. Choosing the right number of problems is very important when assigning homework. Online homework makes this problem more complicated; since the time a student spends presenting his work on paper homework may be different than the time he spends doing so on online homework, though the homework set is the same. Thus, an instructor should not just make an online homework set the same length as a paper homework set; instead, he has to make necessary adjustments to achieve suitable length. (Dillard-Eggers, Wooten, Childs and Coker 2008)

2.2 Statistics courses

2.2.1 The subject statistics

Although usually considered a subfield of mathematics, statistics is quite different from other mathematical subfields like algebra or analysis. Statistics is a science concerned with the collection, organization, analysis and interpretation of data. (definition from Merriam-Webster Dictionary) The problems designed in this project emphasized analysis and interpretation.

2.2.2 Statistics courses

Since statistics has its own focuses that are different from those of other mathematical branches, the teaching of statistics requires a suitable approach. Some methods of teaching suitable for a statistics courses are (Gelman and Nolan 2002):

- Use of practical examples: Since statistics is a science dealing with data in real life, it is very important for statistics students to get some real experiences in their courses. With practical examples, students can see how statistics is applied in real life so they can use statistics well in the future. Practical examples usually used in statistics courses include data obtained from different fields, such as medicine or sociology.
- More focus on concepts than on basic calculations: In statistics, theoretical concepts are very important as different situations use different concepts and methods. Thus, a good statistics course needs to have a strong emphasis on theoretical concepts.
- Use of questions asking for interpretation: Since one important component of statistics is interpreting the results of data analysis, a statistics student also needs to be taught how to

interpret the results of a statistical study. Thus, a statistics course needs to incorporate interpretations of statistical results.

- Use of statistical software, if applicable: Since data in real life usually are very complex, analysis of those data is often complicated and requires a good amount of time to carry out by hand. Thus statistical software is essential and knowledge of these software applications is important. Therefore, a statistical course should prepare students with knowledge and experience in using statistical software..

Those special aspects of a statistics course mentioned above were focused on during the process of selecting statistical questions for the database in this project.

2.3 WeBWorK

WeBWorK is an online homework system developed at the University of Rochester. Its purpose is to provide an effective online homework system for courses in many different mathematical branches, from calculus to statistics. This system has also been used for many science courses in various subjects, including physics and chemistry. As do other online homework systems, WeBWorK provides a means for instructors to input the homework problems online and for students to log in using their own accounts and complete their assignments online. In addition, WeBWorK has some special features that enhance students' study. (Weibel and Hirsch, 2002).

2.3.1 Special features of WeBWorK

WeBWorK has many useful features that make it a good candidate for an online homework system (Gaze and Pizer 2010)

- Automatic grading and grade recording: WeBWorK is able to give automatic feedback to students right after they enter their answers. This automatic grading system also frees instructors from the grading task. WeBWorK also stores students' grades on the system

so the instructors do not need to keep their own grade books, reducing the time instructors need to spend on grading and administration. The student's grades are accessible anytime by the student and instructor, making it possible to keep track of the student's progress.

- Allowing multiple trials and partial credit: WeBWorK has an option that allows students to have multiple trials on any question, depending on the instructor's discretion. The default setting is unlimited number of trials, but the instructor can set it to the number of trials he wants. If this option is utilized, a student will have a number of trials set by the instructors to get a question right. This feature is very rare and difficult to carry out for traditional paper homework, since it requires the student to submit his homework and the instructor to grade and return to the student many times, consuming a lot of time. WeBWorK solves this problem, by giving automatic results on those parts of the question the student got wrong and allowing the student to try again immediately after that. The multiple-trial feature is very useful as it allows the student to learn from his mistakes and figure out the solutions all by himself, which enhances the student's understanding of the materials. Moreover, WeBWorK allows partial credit proportional to how much of the question the student got correct. This feature creates an incentive for the student to keep working on the question and employ all the trials he/she can get. Without partial credit, a student may quit working on the question without using all the trials if he believes he cannot get the question completely correct.
- Recognizing various answer forms: WeBWorK is capable of recognizing different types of answer forms, including complex algebraic expressions, such as ones including multiple pairs of parentheses or trigonometric functions. WeBWorK does this by

automatically calculating the results of the answers given by the students and comparing them to the one given by the instructor. This feature reduces the problem of losing points due to a difference in answer forms between the answers given by the students and the answer given by the instructor and also removes the worry about answer forms from the students so they will focus more on how to solve the problems.

- Allowing multiple question types: WeBWorK allows instructors to input various types of questions depending on their intentions, from multiple choice questions to short answer questions. Thus, instructors can choose the types of questions that they think are most suitable to their classes. By combining different types of questions, an instructor can accommodate different learning styles.
- Direct communication between students and instructors: WeBWorK also enhances learning by supporting direct communication between students and instructors. Whenever a student has troubles with a question, he/she can ask WeBWorK to generate an email to the instructor that contains a link to the problem and the student's questions regarding the problem, which allow him to diagnose the difficulty. From that point, the instructor and the student can communicate via email about the problem and WeBWorK will serve as an intermediate server to deliver the messages.

2.3.2 Effectiveness of WeBWorK

WeBWorK has received many positive reviews from both students and instructors. Bressoud conducted a survey of 2387 students asking their opinions about WeBWorK. These students were selected from many classes that used WeBWorK at all levels of calculus, differential equations, discrete mathematics and linear algebra from 2002 to 2004. Based on the

survey, Bressoud concluded that most students prefer to WeBWorK to paper homework. (Bressoud, 2010)

Professor Lucas at the University of California also conducted a study of the effectiveness of WeBWorK by doing an experiment with students in his mathematics courses. Those students were required to use WeBWorK during the first halves of their courses. For the second halves of the courses, students did not use WeBWorK. Then the performances of students were recorded and compared between the time they used WeBWorK and the time they did not. The result showed that performances with WeBWorK were significantly better (Lucas, 2010)

Another study of the effectiveness of WeBWorK on student performance was done by Weibel and Hirsch in calculus courses at Rutgers University. They performed statistical testing on students' grades to measure the performances of students with and without WeBWorK. They also sent out surveys asking about students' experiences with WeBWorK. They used data obtained from those surveys and statistical methods to conclude that WeBWorK had positive effects on students performance. They also measured some factors affecting the results such as students' consistency in doing WeBWorK problems. The results also showed positive feedbacks on WeBWorK. (Weibel and Hirsch, 2002)

2.3.3 Use of WeBWorK at Worcester Polytechnic Institute

WeBWorK has been used in many mathematics courses at Worcester Polytechnic Institute. Most of the courses are introductory courses in many mathematical fields, from calculus to actuarial mathematics. Some examples of those courses are given below:

Professor Tilley used WeBWorK for his Calculus 4 course in A term 2010. WeBWorK assignments were given once a week, each consisting of eight to ten problems. Most of the questions were given in short answer form.

Professor Abraham has used WeBWorK for his Theory of Interest course for about three years. WeBWorK assignments were given once every two weeks, each consisting of ten to twelve problems. The types of questions given are short answer type and multiple choice.

Professor Farr has used WeBWorK for many of his basic mathematics courses, including Linear Algebra I and Differential Equations. The assignments are usually given once every two weeks. He has used many types of questions for WeBWorK assignments: True/False, short answer and multiple choice.

WeBWorK has also been used in statistics courses. Professor Kim used WeBWork for his MA 2611 course two years ago. The assignments were usually given once a week and the types of questions used were multiple choice and short answer. Professor Petruccelli has also used WeBWorK for his MA 2611 course for two years and used it for his MA 2612 course once.

WeBWorK has also been used by other professors of the Mathematics department at Worcester Polytechnic Institute, especially the basic mathematics courses required by all majors. Thus, many students at Worcester Polytechnic Institute have been exposed to WeBWorK during their study at Worcester Polytechnic Institute.

2.4 Types of homework questions

As mentioned above, since students have different learning styles that are best addressed by different types of homework questions, selecting the right types of questions for homework assignments is a very important task for any instructor. There are many types of homework questions available for instructors to choose; each has its own advantages and disadvantages. Among those, the most popular types of questions are multiple choice, short answer, and essay questions.

2.4.1 Multiple choice questions

Multiple choice questions give a student a number of possible answers for each question and the student earns credit if he chooses the right answers among all the options given. The range for the number of options available for each multiple choice question is usually from two to five. Most questions of this type do not ask for explanations from students; they simply choose the options they think would be the right answers. However, some multiple choice questions ask students to show their work; usually the explanatory parts are graded separately from the multiple choice part. Multiple choice questions have been used intensively in most subjects, from natural sciences such as physics to social sciences such as economics or sociology.

2.4.1.1 Advantages of multiple choice questions

An important advantage of this type of question is that since the amount of time spent on each question is relatively short, more questions can be given on an assignment than would be possible with other types of homework questions. This would allow the instructor to cover more material on the homework assignment, thus increasing the breadth of the material covered by homework. This would benefit the students as they would understand the materials more fully while the likelihood that they would miss anything from the course would be decreased. To clarify this point, compare multiple choice questions with essay questions. A multiple choice question usually takes about 2 to 5 minutes to complete while an essay question typically requires about 20 to 40 minutes. Thus, for an intended 40-minute homework assignment, using the multiple choice questions, an instructor can assign 8 to 20 questions, which cover 8 to 20 different areas of the materials, comparing to only 1 to 2 essay questions We can see that

multiple choice questions allow the instructor to cover the materials more broadly. That also benefits the students as they can review more materials through homework. (Seaman 2003)

Another advantage of multiple choice questions is that these questions require students to have a solid understanding of the materials, since the instructor can make answer options that are seemingly accurate but contain some false information. The students need to understand the materials very well in order to distinguish the correct answer from those seemingly correct ones. Thus, using this technique, the instructors can test whether the students understand the materials really well or only superficially. (Trigwell 1992)

Another advantage of multiple choice questions is that these questions are very easy and quick to grade. For traditional paper homework, the instructor just needs to make a single answer key for the whole class and compare each student's work with the answer. This is relatively fast to carry out. For online homework, it is even easier and quicker to do as most online homework systems have automatic grading for multiple choice questions. Thus, the instructor just needs to access his account and record the grades of the students. The ease and quickness in grading multiple choice questions will save a lot of time for the instructors and remove the burden of grading from the instructors. (Ziemer 2010) In addition, automatic grading always guarantees 100% accuracy, thus reducing the errors in grading.

2.4.1.2 Disadvantages of multiple choice questions

One big disadvantage of multiple choice questions is the lack of opportunities for the students to practice exposition skills. As multiple choice questions only ask the students to select the right answer from a set of answer options, students do not have to show any of their work and explanations on how they get their answers. As a result, students, who are assigned multiple

choice questions, do not have the chance to learn and practice explaining their work and ideas. This can be a serious disadvantage as exposition skills are among problem-solving skills or team-work skills. Thus, the lack of opportunities for practicing exposition skills is an important factor that an instructor needs to take into consideration before assigning multiple choice questions. (Newble and Cannon, 1989)

Another disadvantage of multiple choice questions is that they create an incentive for students to be lazy by simply guessing the answer instead of spending time to review the materials to figure out the answers. This problem is even more dramatic when the students are having trouble understanding the material covered in class or when the homework is not a major component of the final grade as these scenarios create a greater incentive for the students to guess the answers. If the student simply guesses to finish his homework assignment, the whole purpose of the homework assignment, which is helping the student to review materials and practice, is lost, and the homework assignment will be meaningless for the student. Thus, how to prevent the problem of students guessing is something that an instructor needs to consider when making multiple choice questions. One solution is to provide each question with a significant number of answer options in conjunction with a sensible number of trials allowed, thus lowering the probability of guessing the right answers and discouraging students from guessing. (Newble and Cannon, 1989)

One more disadvantage of multiple choice questions is that they create an incentive to cheat. Since it is relatively quick to finish a multiple choice question – only selecting an answer option - a student will have incentive to cheat by copying the selections of someone else. The only thing he/she needs to do is to memorize the choices of other people and make the same answer selections. As it is relatively easy to cheat, a student will have an incentive to cheat on all

assignments instead of really spending time working on homework assignments. This problem is more dramatic in the case of the traditional paper homework or online homework systems that can keep a record of completed homework, since in those cases, students can access completed homework and share the results with each other. To prevent such a problem, it is important to encourage academic honesty amongst students. (Newble and Cannon, 1989)

2.4.1.3 Types of multiple choice questions

There are a number of types of multiple choices questions. Among those, the three most commonly used are the traditional multiple choice question, true/false question, and multiple choice question with short explanation. (Trigger 1992)

The traditional multiple choice question is the most commonly used type. It comprises a question and a set of answer options, usually ranging from four to six answer options. The number of correct answers can be one or more than one, depending on the intention of the question maker.

The true/false question is a special type of multiple choice question. Each true/false question comprises of a statement and two answer options, namely true and false. The student's task is to check whether the statement is true or false and indicate the corresponding answer choice. A disadvantage of the true/false question is the problem of student guessing, as each question has only two answer options, making the probability of getting the correct answer very high and encouraging students to guess.

To overcome the lack of opportunities for students to practice exposition skills, some instructors also require students to add some explanations besides selecting the answer options. This is a new form of multiple choice question, multiple choice questions with explanations.

Although partially overcoming the problem of lack of explanations, this type of multiple choice question consumes more time and effort of the students to complete one question. Sometimes, this type of multiple choice question can be considered a type of short answer question.

2.4.2 Short answer questions

In short answer questions students are asked to figure out and write down the solutions, usually in short forms. The type of answer required by short answer questions can be a number, an expression or a statement. Usually questions of this type do not ask for students' explanations; however some questions require students to briefly elaborate on their answers. Short answer questions have been used in many subjects, from natural sciences such as physics to social sciences such as economics.

2.4.2.1 Advantages of short answer questions

An advantage of short answer questions is that they avoid the problem of multiple choice questions, the problem of student guessing. Since the student has to enter his/her own answer, there is no way he/she can just guess the answer. Thus, short answer questions create an incentive for students to review the materials and solve the problems. This makes homework more helpful for the students. (Newble and Cannon, 1989)

One more advantage that short answer questions offer is the ease and quickness in grading for the instructors. For traditional paper homework, since responses for short answer questions are usually short and simple, instructors do not have to spend much time figuring out if the students get the right answer. Although grading short answer questions is not as quick as grading multiple choice questions, grading short answer questions will not consume much instructors'

time. Some, but not all, online homework systems do offer a feature that can recognize responses from the students for short answer questions, thus enabling automatic grading for this type of question. An example of such online homework system is WeBWorK. This automatic grading feature will certainly save a lot of time for the instructors as the only thing they need to do is to access their accounts and record the grades of the students. (Lucas, 2010)

2.4.2.2 Disadvantages of short answer questions

The first disadvantage of short answer questions is the same as that of multiple choice questions: lack of opportunities for students to present their work and practice exposition skills. Although short answer questions do ask students to enter their answers rather than simply selecting the answer from a set of answer options, the answers entered are short, simple and not the entirety of students' thoughts and ideas. Thus, the chance for students to present their ideas with short answer questions is extremely limited. As mentioned earlier in the discussion of multiple choice questions, this can be a serious disadvantage to the students. Instructors, therefore, need to take this disadvantage into consideration when assigning homework with short answer questions. (Newble and Cannon, 1989)

Another disadvantage of short answer questions is that, as do multiple choice questions, they create an incentive for students to cheat instead of honestly working on homework assignments. Since a short answer question only asks for brief answers such as a number or a short statement, it is relatively easy for a student to memorize answers from other people and copy those to his own homework. The best way, according to Trigwell), to prevent such problem is to promote academic honesty amongst students. (Trigwell, 1992) However, in the case of computational questions, an even better way is to randomize the inputs.

2.4.3 Essay questions

The third type of questions that is usually assigned to students is the essay question, in which students are asked to not only figure out the final answers but also to present their ideas and thoughts. It differs from the two other types of questions discussed above in that in this type of question, how to present the ideas is as important as getting the correct answers. Essay questions have been used by many instructors in many subjects, from mathematics (in the form of mathematical proofs) to history (in the form of discussion paper). Essay questions include all forms of questions in which students need to present their work, from a worked problem in mathematics to an essay in English.

2.4.3.1 Advantages of essay questions

The first advantage of essay questions is that they provide a very useful check on how much students understand, since students need to present all their thoughts and ideas. Without a good understanding of the materials, a student cannot present his work clearly and fluently. Thus, an instructor can use essay questions to check his/her students' understanding of important concepts and subjects and adjust his teaching approach to make the class more effective. (Newble and Cannon, 1989)

Another advantage of essay questions is that they create an incentive for students to review materials and work on the homework assignments. In other words, this type of question encourages students to spend time learning the materials and working on the homework. The reason lies in the fact that this type of question requires students to have good understanding of the materials to present their work and ideas well. If a student only has a superficial understanding, it would be very difficult for him/her to successfully finish the question. Thus,

being assigned essay questions, students will have strong incentive to learn the materials and complete the homework. This is an important advantage that an instructor should consider when assigning homework to his/her students. (Newble and Cannon, 1989)

Essay questions also have another advantage; that is, unlike the other two types of questions, essay questions make it difficult for students to cheat on homework. The reason is that essay questions require a student to present all the work, not just the final answer. Thus, it is not easy for a student to copy others' answers for his homework; even when he can remember some parts of others' work, it is not easy to replicate. Thus, essay questions are helpful in discouraging students from cheating and making them spending time working on the homework themselves. (Trigger 1992)

2.4.3.2 Disadvantages of essay questions

The first major disadvantage of essay questions is that they require a substantial amount of time from the students to complete. Even the shortest essay questions usually demand about ten minutes from the students, and some instructors even expect their students to spend hours for each essay question. This hampers instructors from assigning many essay questions on a homework assignment. The major consequence of this is that the number of questions on a homework assignment may not be enough to cover all the important aspects of the materials. This is a disadvantage to the students as they may not be able to review all the important aspects of the materials with homework. Therefore, this disadvantage needs to be considered by an instructor when assigning homework to students. (Newble and Cannon, 1989)

Another disadvantage of essay questions is that they require a considerable amount of time from the instructors for grading. Since for essay questions, the way of presenting the work

and ideas is as important as the final result, the instructors have to look through all the students' work, not just the final answer, thus spending a lot of time in grading. Moreover, as students have different ideas and ways to present their ideas, there is no unique answer key for essay questions; thus, the instructors have to look at each student's work to understand and evaluate carefully, instead of simply comparing students' answers with the answer key. Thus, essay questions say create a burden in grading for instructors. (Newble and Cannon, 1989)

In the matter of grading, in the case of online homework, essay questions create a much greater problem than the other two types of questions. The reason is that currently there is no online homework system that can evaluate students' responses to essay questions, as different students have different ways to present their ideas. In contrast, most online homework systems have available features to automatically grade multiple choice questions and many online homework systems, such as WeBWorK, can grade short answer questions. Thus, while the instructors do not have to spend time grading if using multiple choice questions or short answer questions, instructors have to spend a lot of time grading if using essay questions. This is another argument against the use of essay questions. (Zeimer 2010)

2.4.4 Combinations of different types of questions

From the discussion above, it can be seen that every type of question has its own strengths and weaknesses. Thus, a combination of different types of questions may be desired to combine the strengths and reduce the weaknesses, making homework assignments more helpful for both the students and instructors. Unfortunately, there is no definitely superior combination and the way to combine different types of questions very much depends on the intentions of the instructor.

One such combination is to assign alternatively between essay questions and a combination of multiple choice questions and short answer questions. Usually essay questions are assigned in the paper format while multiple choice questions and short answer questions are assigned online to utilize the automatic grading feature of many online homework systems. This kind of combining different types of questions has been used widely at Worcester Polytechnic Institute. An example is Professor Farr's Linear Algebra I class. In that class, Professor Farr assigned one paper homework assignment, which contained some essay questions, in one week and in the following week, he asked students to complete an assignment on WeBWorK, which contained multiple choice and short answer questions.

3. Methodology

The main goal of this project was to build an effective WeBWorK database of homework problems for simple and multiple linear regression, which can be used for the course Applied Statistics II offered at Worcester Polytechnic Institute, and other statistics courses which cover these topics. In this project, our team mostly developed our database of problems ourselves, based on relevant information and knowledge we had gained from our research. We also sought advice from some faculty members of the Mathematical Sciences Department at Worcester Polytechnic Institute. These professors had previously designed WeBWorK problems and implemented WeBWorK in their courses; thus, they were able to provide us with useful advice on how to design effective WeBWorK problems and what we needed to consider when designing our problems. In addition, as WeBWorK is a quite popular online homework system and has been used extensively by many educational institutions, we also consulted available documents, information and existing WeBWorK problems from those institutions in order to design our problems.

With this main goal in mind, our team had the following set of general objectives that we strived to achieve during our project:

- Research to develop useful and effective statistics questions that can be used for homework about simple and multiple linear regressions. The goal of these questions was to help students to acquire necessary skills and knowledge about these topics. To achieve this goal, we took information and knowledge obtained from our review of literature, advice given by faculty members and experience gained from existing problems developed by other educational institutions to improve the quality of our problems.

- Uploading our designed problems into WeBWorK system using pg programming language, the language that WeBWorK supports. When we uploaded our problems, care was taken with regard to programming techniques and designs; the goal was to ensure that the interface of the problems would be according to what we intended and would not affect the intended purposes of the problems. We also ensured that the display of the problems would not create any difficulty for students to understand the problems and input the answers.
- Test the effectiveness of the database on the students in the class Applied Statistics II offered in D term, 2011, which was taught by Professor Petruccelli, our IQP advisor. Students tried our problems during their lab sessions, and we tested if there would be any improvement of the students from using our problems.
- Based on the results of test, we made some adjustments to the database to make it more effective and suggested further developments.

3.1 Develop questions for simple and multiple linear regression

The first big step in this project we needed to take was to develop a set of useful and effective questions for simple and multiple linear regression. This step was extremely important, as without effective statistics problems and questions, our WeBWorK database would not be efficacious and could not benefit any student.

To develop such a set of useful and effective statistics questions, we first tried to identify the criteria and characteristics of effective homework questions, especially those for statistics courses. In order to achieve this goal, we relied on existing literature which discussed this issue.

3.1.1 Contents of the questions

Gelman and Nolan (2002) pointed out that a successful statistics course needs to incorporate statistical concepts and experiences with statistical software. Thus, when building the questions for our project, we spent a good amount of time to develop conceptual questions to make sure that students would get the most important concepts in those topics. The important issue was to ensure that every major topic would be covered in a reasonable portion of our database of problems. (Example questions: questions 4,5,18 in Appendix A.1; questions 1,2,3 and 15 in Appendix A.2)

Of course, computational questions were also included. The goal of these computational questions was to help students develop computational skills using statistical concepts they had learned in class. The problems we designed asked students to apply their computational skills using both basic and simple tools such as scientific calculators (examples: questions 6 and 14 in Appendix A.2) and sophisticated tools like statistical software applications (examples: questions 6 and 7 in Appendix A.1).

Another important group of questions we designed was interpretation questions. As noted in Gelman and Nolan (2002), a good statistics course needs to help students acquire the ability to interpret statistical results in real life contexts. Thus, we spent time designing questions specifically asking students for meaningful interpretations. (Examples: questions 14 and 17 in Appendix A.1; question 18 in Appendix A.2).

3.1.2 Types of questions

Newbel and Canon (1989) and Trigger (1992) discuss extensively various questions types. Based on their research, it appears clearly that multiple choice questions would be the most suitable question type for conceptual and interpretation questions, as this type of question has

some major advantages on checking students' understanding of the material compared to other types of questions. These advantages include the ability to test a wide variety of topics in a single homework set, the ability to make students realize the most important components of a single concept and the ability to utilize WeBWorK's automatic grading feature. Therefore, multiple choice questions were our choice for conceptual questions and also questions involving interpretations. (Examples: questions 1,2,8,9 in Appendix A.1; questions 1,2,3,4,5 in Appendix A.2)

In addition, based on their research, we realized that multiple choice questions, though effectively testing students' understanding of the concepts, would not be as useful in testing and helping students learn computational skills. The reason was that multiple choice questions already gave a student a set of answer options; thus, a student might guess or figure out the correct answer without going through computational steps. Therefore, we chose the short answer question type for computational problems, as this type of question asked the students to go through all the computational steps and figure out their own answers for the problems while still retaining the ability to apply the automatic grading feature of WeBWorK. (Examples of this type of question: questions 6,7 in Appendix A.1; questions 8 and 11 in Appendix A.2)

3.1.3 Question set up

Vatterott (2002) showed that it would be better to break down a question into multiple parts than to assign a set of questions that only ask for final answers. He noted that in this way, students would be more interested in finishing entire questions, as the students could use the previous parts they had already done as a hint for the next part. Moreover, when the problems were set up in this way, the material presented to the students would be more coherent and

correlated, as the students could see the relationship between different concepts and topics as they went from one part of the question to another. Thus, we also broke down some computational questions into multiple parts to take advantage of this finding. (Examples: questions 6 and 7 in Appendix A.1; questions 12 and 19 in Appendix A.2)

3.1.4 List of topics

After obtaining a list of characteristics of good homework questions, we started developing homework questions for the course. The first step was to review the materials and topics covered in the topics simple and multiple linear regression to identify key areas and knowledge that a student needed to acquire from those topics. This step was extremely important; if we missed any important material, the students would not have enough practice on that specific material, which might result in the lack of understanding on that specific material. Thus, to make our homework questions effective for the students, care was taken to make sure no material of those topics would be left out.

Through a careful process of reviewing the textbook and consulting our advisor, Professor Petruccelli, we came up with the following list of topics.

For simple linear regression, the key topics are: association and Pearson correlations, the simple linear regression model, least squares estimators, sum of squared errors, the coefficient of determination, estimation and inference from the simple linear regression model, and one-way and two-way tables.[1]

[1] One-way and two-way tables are usually not considered topics in simple linear regression in most textbooks. However, we put these topics into the simple linear regression since they concern with the relationship between two variables, which is also the concern for simple linear regression.

For multiple linear regression, the key topics are: the multiple linear regression model, interpreting the model, the principle of parsimony, the coefficient of multiple determination and adjusted coefficient of multiple determination, analysis of variance, the overall F test, the individual t test, and multicollinearity.

3.1.5 Designing the questions

After we had a completed list of materials we needed to cover for those topics, we started developing the homework questions. Our questions were written in such a way that they were carefully checked to meet all the characteristics of good questions we had found from our research. We built our questions in the order of topics covered in simple and multiple linear regression in the textbook; this means that we focused on building questions for one specific topic and then moving on to the next topic. In this manner, we believed we developed more effective questions while making sure we did not skip any important concept or topic.

3.1.6 Consultation

Since we were very new to developing homework questions, it was important to learn from experiences of others, who had developed questions for the topics covered in simple and linear regression. The first resource we consulted was an online library of WeBWorK questions called the National Problem Library (NPL). This library is a collection of many WeBWorK problems developed by professors at many higher educational institutions, including the University of Rochester and Arizona State University. This library contains questions and problems in many subjects, including statistics. To use this library, we looked at the portion of the library about statistics, downloading the questions related to the topics covered in simple and multiple linear

regression. Then we downloaded questions that met our criteria and used them as a reference when we wrote our own questions.

When developing our set of questions and problems for the course, we also consulted many textbooks that cover the topics offered in the course, especially the textbook used in the course. This was important because the problems introduced in the textbooks would be very close to the materials covered in the course, thus helping the students in reviewing the materials covered in the course.

Since our advisor, Professor Petruccelli, had used WeBWorK for this course before, he already had a collection of questions and problems designed specifically for this course. Thus, we also used his collection as an important reference resource and sought his advice when writing our own problems.

3.2 Programming and uploading the problems

In order to create questions in WeBWorK, we had to learn about the programming languages used in WeBWork. WeBWork uses a Problem Generation (PG) language which allows the inclusion of both Perl and LaTeX code. Therefore we had to fully understand how to program using those languages before creating any WeBWork homework sets.

LaTeX is used by WeBWorK to display equations in the problems. There were many resources online that gave information on how to program using LaTeX. However we only needed LaTeX for displaying mathematical expressions, so the research and study for the language was just to learn enough for inputting an equation so that the equation could be visible. We learned how to use LaTeX from the UCLA Academic Technology Services website.

The Perl language is used by WeBWorK to perform calculations and evaluate student answers in PG. Therefore, understanding this language was very important so no error in the calculation would be made and we could also increase the capability on what we could do on the questions. This information was learned from The Perl Programming Language website (www.perl.org).

After researching and studying these two base languages, we started writing our WeBWorK questions. We consulted a number of sources. The MAA (Mathematical Association of America) website (www.maa.org) provided a number of problem templates and sample techniques. We also looked at some of the techniques that Professor Petruccelli had used for his homework sets in the previous courses. When constructing our problems, we used a test facility called PGLabs. This facility allowed us to test the code before inputting it into the homework set. Once we finished testing with the code, we inputted it into one of the blank problems in the problem set.

Finally, we tested each problem to make sure that the answers were correct. For some problems we used randomly-generated data to give each student a unique data set. We tested these problems with several different random number seeds.

We encountered some difficulties in coding questions. For example, some questions with short multiple word answers did not work well because there were many ways a student can input an essentially correct answer. For instance, a student might accidentally press the space bar twice. This type of question was changed into drop box format, which provides students with a drop box containing the answer choices.

3.3 Test the database

After we finished building the database of problems, we tested the effectiveness of our problems on the students of the course Applied Statistics II, taught by Professor Petruccelli in D term 2011. Testing was done during a one hour lab period that accompanied the course. A total of 105 students were available in four lab periods in each of two successive weeks. The first week we tested our problems on simple linear regression, and the second week we tested the multiple linear regression problems. In each lab session, before the lab began, the students were randomly assigned to two groups: a treatment group and a control group.

The goal of the test was to compare the effectiveness of our problems against the existing WeBWorK problems. Thus, for each topic, simple linear regression or multiple linear regression, we formed two sets of WeBWorK problems: one comprising eight problems from our designed problems (the treatment problems) and the other consisting of eight problems we obtained from the National Problem Library (NPL) (the control problems). The topics and concepts covered in the two sets were almost identical to avoid bias. The students, who had already been randomly assigned to one of the two groups, were asked to take one of the two sets during the lab. One group would take the set of our problems, while the other group would take the other set. The students were informed that their performance on those problems would not be counted toward their grades, but they were encouraged to do their best.

At the beginning of each lab session, all the students were given the same paper-based pre-test, which consisted of a single problem with multiple parts. The pre-test was made in a way such that its parts covered most of the important material covered in the topic we were testing our problems on. The students were given ten minutes to complete the pre-test. During the pre-

test, the students were allowed to use supporting material such as calculators or software applications as some parts of the problem required computation.

After that, the students worked on the WeBWorK problem set of the group they were randomly assigned to. This served as practice for students, like homework, so students could have access to any support, including help from the teaching assistant. The students were given about 25 minutes to practice but they did not have to finish all the problems.

At the end of the lab session, the students were asked to take the post-test, which was very similar to the pre-test. The goal of the post-test was to determine to what extent student performance improved after working on the practice WeBWorK problems.

The students' performances on the pre-test and post-test were recorded and separated according to the problem sets they had worked on. Then we calculated the means and the standard deviations of the differences between the pre-test scores and the post-test scores for each problems set. After that, we conducted hypothesis testing (using t-test for comparing two independent populations) to see if our problems significantly improved the students' performances better comparing to the other set of problems.

3.4 Improvements

From the results of the testing, we drew conclusions about the effectiveness of our problems on simple linear regression and on multiple linear regression. If our questions were not effective, we tried to figure out the reasons and propose further adjustments to make them more effective. This task was done by reviewing the literature again to search for ways for improvement, and consulting our advisor, Professor Petruccelli.

4. Results and Discussion

4.1 Results

As stated in the methodology section, we successfully designed two WeBWorK sets, one having 24 problems for the topic simple linear regression and the other having 22 questions for the topic multiple linear regression. Screen shots of these questions are provided in Appendices A.1 (simple linear regression) and A.2 (multiple regression). The pg code for these questions is included in a supplementary file archived with this report.

After we finished designing these problems, we tested our problems on the students in the course Applied Statistics II, offered in D term, 2011. The problems selected to test for our problems were 1, 2, 3, 10, 13, 14, 15, and 17 for simple linear regression and 1, 3, 5, 8, 11, 12(parts a, b, c), 17, and 18 for multiple linear regression. The procedure for the test was discussed in the methodology section. The screenshots of problems for the control set for simple linear regression are provided in Appendix A5 and for multiple linear regression in Appendix A6. The results of the test are provided below.

4.2 Simple Linear Regression

After recording the scores for all the students on both the pretest and the posttest, we first separated them according to which set of WeBWorK problems they took during the lab, either the treatment set or the control set. After that, we proceeded by finding the difference between the pretest score and the posttest score for each student. Note that this difference measures the improvement in score between the pre and posttest. When doing so, we discarded the data from the students who had not completed either the pretest or the posttest or both. For simple linear regression, 49 students in the treatment group and 51 students in the control group actually participated in the test. From those, we obtained 24 complete values for the treatment set and 29

complete values for the control set. We further discarded data for 2 students in the treatment group and 4 students in the control group who did not do the WeBWorK. The detailed result for the difference between posttest scores and pretest scores for the two sets is presented below:

Treatment group		6	6	1	0	2	5	4	3	6	1
1	5	4	1	1	8	1	3	4	1	0	3
Control group		0	6	0	5	4	1	1	0	4	3
1	0	6	2	8	0	1	0	-2	6	1	-5
2	0	-2									

Table 4-1 Difference in scores for simple linear regression broken down by WeBWorK problem sets

From that information, we proceeded with finding the mean and standard deviation of these score differences for each set. The summary of our finding is presented below:

	Treatment set	Control set
Total of sample	65.00	43.57
Count of sample	33	32
Mean of sample	1.9698	1.3616
Standard deviation	3.0280	1.8795

Table 4-2 Summary for data for each problem set for simple linear regression

From that, we proceeded with our testing. We used the test of two means of two independent populations. Our null hypothesis was that the mean of score improvement of students in the treatment group is the same as the mean of score improvement of those in the control group. Since we expected that our set would be more effective, we used the alternative hypothesis being the mean of score improvement of the students taking our set is greater than the mean of score improvement of the students taking the control set; and we conducted the right-sided test. We chose α, the value of significance to be 0.05. The summary of our test is presented below:

t test statistics	1.7129
degrees of freedom	45
p-value	0.0468

Table 4-3 Summary of test for simple linear regression

Since the p-value 0.0468 is less than 0.05, we reject the null hypothesis and conclude that the mean of score improvement of the students taking our set is more than the mean of score improvement of the students taking the control set.

4.3 Multiple Linear Regression

Similar to the procedure for simple linear regression, we also found the difference in score between the pretest and the posttest for each student and separated the results according to the WeBWorK set they took during the lab session. We also discarded the results from the students who had not completed either the pretest or the posttest or both, as these students would not

provide the complete data. For multiple linear regression, 51 students in the treatment group and 49 students in the control group came to the lab for the test. After discarding incomplete values, we obtained 36 complete values for the treatment set and 33 complete values for the control set. Furthermore, based on the students' scores on WeBWorK, we discarded 3 values from the treatment set and 1 value from the control set; they are the values from the students who did not do WeBWorK before taking the posttest. The results are displayed below:

Treatment set		4.14	6.14	2.29	4	1.14	1.14	1	1	5	0
2	0.71	2.86	0	0.86	5	2.86	2	-0.86	2	-1	-1
5	2.29	4.71	2.43	2	1	3	2.57	1.86	1.14	-2.29	
Control set		1	5.86	-1	-1	3.29	-1	1.43	0.86	3.29	0
1	3.86	3.71	0.14	-0.14	2.71	-1	-1	1	1.29	1.86	4.71
0.29	0.29	3.71	0.71	-2	2.57	1	1.86	2	2.29		

Table 4-4 Difference in scores for multiple linear regression broken down by problem sets

From that information, we proceeded with finding the mean and standard deviation of these score differences for each set. The summary of our finding is presented below:

	Treatment set	Control set
sum of the sample	65.00	43.57
count of the sample	33	32
mean of the sample	1.9698	1.3616
standard deviation of the sample	3.0280	1.8795

Table 4-5 Summary for data for each problem set for multiple linear regression

From that, we proceeded with our testing. We used the test of two means of two independent populations. Our null hypothesis was that the mean of score improvement of students in the treatment group is the same as the mean of score improvement of those in the control group. Since we expected that our set would be more effective, we used the alternative hypothesis being the mean of score improvement of the students taking our set is greater than the mean of score improvement of the students taking the control set; and we conducted the right-sided test. We chose α, the value of significance to be 0.05. The summary of our test is presented below:

degrees of freedom	63
t test statistic	0.9761
p-value	0.1664

Table 4-6 Summary of test for multiple linear regression

Since the p-value is 0.1664, which is greater than 0.05, we do not reject the null hypothesis and conclude that the data provide insufficient evidence that the mean of score improvement of the students taking our set is more than the mean of score improvement of the students taking the control set.

4.4 Results

Based on the result of the testing for both simple linear regression and multiple linear regression, it was seen that our simple linear regression problem set was significantly more

effective than the control set in improving students' scores while the multiple linear regression set was not significantly more effective than the control set.

4.5 Discussion of the testing

Since our tests were only conducted on students taking the course Applied Statistics II offered in D term, 2011, care must be taken when extending the results to other groups of students. For example, students at Worcester Polytechnic Institute usually possess a good mathematical and computational background, suggesting that the results might be different for other groups of students who do not possess the same level of background.

Moreover, since the control set was chosen by us from the National Problem Library, bias might have arisen although we had tried our best to choose the problems that were closely matched our problems in term of level of difficulty and topics covered. To avoid such bias, we had spent time to choose the most appropriate problems, and spent time working on those problems to make sure these problems would match our problems well. However, bias still could arise. For example, some of the students tested in the simple linear regression experiment told us that the control problems for simple linear regression seemed to require more computational efforts than did the treatment problems, making it more difficult for the students to go through the whole problem set. To estimate the significance of this bias, we looked at the scores of the students on the WeBWorK problems given during the experiments. Below is the summary of the WeBWorK scores:

Treatment Set:	7.8	7.8	7	6.2	6.6	7	2.25	0	3.4	4	0.2
	5	5	4	2.5	5	3.5	7	4	1	0.33	7.2
Control Set:	5.9	1.3	2.3	3	4.5	5	7.8	7.2	7	7.8	6
	7	7.6	7.8	7.8	7.4	6.4	7	7.8	7.8	6	5	6.4
	5	7.8									

Table 4-7: Summary of WeBWorK scores for simple linear regression

From that, similar to the above analysis, we conducted the t-test of two independent populations. The null hypothesis is that there is no difference in the WeBWorK scores between two groups. We conducted a two-sided test with $\alpha = 0.05$. Here is a summary of our test:

	Treatment Set	Control Set
Total	96.78	154.6
Count	22	25
Mean	4.3991	6.184
Standard deviation	2.5453	1.8388

Table 4-8: Summary of WeBWorK scores for simple linear regression

t	-2.7228
degree of freedom	45
p-value	0.0092

Table 4-9: Summary of test on WeBWorK scores for simple linear regression

Since the p-value is much less than 0.05, we conclude that the difference in WeBWorK scores between the two groups is significant for simple linear regression, indicating a significant bias.

However, this result seems to contradict the feedback we mentioned earlier, which is that the problems in the control group were longer than the problems in the treatment group, as the mean WeBWorK score of students taking the control set was significantly higher than the mean WeBWorK score of students taking the treatment set. We figured out some possible explanations for this. Firstly, many of the students who complained about the length of the problems of the control set had not actually tried the problems before complaining. It turned out that many of them were able to figure out these problems. In addition, most of the problems in the control set are computational problems, and the fact that the students could use SAS when working on these problems may explain the higher WeBWorK scores of students taking the control set. When working on these problems of the control set, many students just input the data into SAS and took out the result, which did not take much time, without having to recall the formula or the knowledge they had obtained from class; while, at the same time, students taking the treatment set had to recall materials from class to answer the questions since the treatment questions do not have many computational parts. Thus, students taking the control set were able to spend less time on each problem and score higher. Also, the availability of the teaching assistant, who had previously taught the students about SAS, to assist students with SAS helped raise the WeBWorK scores of students taking the control set.

To see if bias arose for multiple linear regression, we also conducted test on the WeBWorK scores for multiple linear regression. Below is the summary of the WeBWorK scores:

Treatment set		8	6	4	3	3.4	3.83	3	5.33	6	4.23
5.33	5	8	2.23	3.7	3	8	8	1.33	8	8	5.63
7	5	8	7.5	4.53	8	7.67	5.67	6.17	4.9	6.87	
Control set		1	3	2	4	3	0	3.33	3	4.73	4
5	5	5.33	0.71	6.33	5.33	3	2.4	2.4	5	5	5
1	3	7.33	3.73	5.33	3.33	4.33	6	3	5.33		

Table 4-10: Summary of WeBWorK scores for multiple linear regression

From that, similar to the above analysis, we conducted the t-test of two independent populations. The null hypothesis is that there is no difference in the WeBWorK scores between the two groups. We conducted the two-sided test with $\alpha = 0.05$. Here is a summary of our test:

	Treatment group	Control group
Sum	184.32	120.94
Count	33	32
Mean	5.5855	3.7794
Standard deviation	1.9889	1.7283

Table 4-11: Summary of WeBWorK scores for multiple linear regression

degrees of freedom	63
T	3.9114
p-value	0.0002

Table 4-12: Summary of test on WeBWorK scores for multiple linear regression

From our analysis, we see that the p-value was much less than 0.05. Thus, we conclude that the difference in WeBWorK scores between two groups is significant in this case. Therefore, bias might have arisen from our selection of the control group.

The result above is the reverse of the result of the simple linear regression case. In this case, the mean WeBWorK score of students taking the treatment set is significantly higher than the mean WeBWorK scores of students taking the control set. There are some possible explanations for this result. Firstly, most of the WeBWorK questions in both sets do not require or only require minimal computation; thus the students did not use SAS at all. Therefore, the problem from the assistance of SAS that had occurred in the simple linear regression case did not occur here. In addition, some questions in the control set contain many parts, thus requiring students taking the control set to spend more time than the students taking the treatment set.

From our discussion above, it is clear that the WeBWorK problems in the treatment set and the control set are not similar in term of length, difficulty, and type of question. This is a bias that might have significant effects on our results. Thus, when our results are used, it is strongly recommended that care needs to be taken to make sure such bias is addressed.

Another problem with the test occurred in the test for simple linear regression. We received feedback from the students that both the pretest and posttest were too long for many of them so they could only get to some parts of those. It was a problem since it means the students could not get to all the topics we wanted to test. Therefore, when testing for multiple linear regression, we designed more plausible pretest and posttest; as a result, most students went through all parts of our pretest and posttest.

4.6 Other observations

When conducting our tests, we also spent time observing how students worked on our problems and received feedback from the students. One feedback was that the tolerance for accuracy we set up made some difficulty for the students, especially when they tried to input answers obtained from statistical software applications like SAS. Thus, we had to go back and adjusted the tolerance for accuracy for some computational problems.

Another feedback we received was that the wording seemed confusing for some students. However, since this only occurred for a small number of students, we did not change the wording.

5. Conclusions and Recommendations

Throughout this project, we have carried out necessary steps to achieve our goal, building an effective set of WeBWorK problems for simple and multiple linear regression. The first step of our project was to review the literature related to the project to set up criteria for effective WeBWorK problems. These criteria concern mostly with the type of questions and the setup of questions. After obtaining the set of criteria, we proceeded with obtaining a list of topics we needed to cover for these two subjects while, at the same time, got used to the programming techniques used to program problems in WeBWorK. Then we proceeded by designing our problems for simple and multiple linear regression based on the criteria we have found and also on the suggestions we got from our advisor, Professor Petruccelli.

The result of our design process is a set of 24 WeBWorK problems for simple linear regression and another set of 22 WeBWorK problems for multiple linear regression. The screenshots of these problems are presented in Appendices A1 and A2. To measure the effectiveness of our problems, we tested our problems with the students in the class MA2612 taught by our advisor Professor Petruccelli, offered in D term 2011. We tested our problems against a set of existing WeBWork problems on the same topics developed by other institutions. The goal of the test was to measure which WeBWorK set improved students' performance better. The result of the test showed that our set of WeBWorK problems for simple linear regression was significantly more effective than the set of existing WeBWorK problems; while for multiple linear regression, there was no significant difference between our set and the set of existing problems.

However, bias occurred in our test that might affect these results. It turned out from our analysis that the existing WeBWorK problems we selected to be our control were not completely similar to our problems in term of difficulty, length and type of question. Moreover, when testing our problems for simple linear regression, the pretest and posttest, which were used to measure students' performance before and after taking WeBWorK problems, were too long for many students to go through all the topics tested, potentially biasing the results of the test.

Another problem was that we only tested our problems on students in the course MA 2612 at WPI, which is a very limited group. The results might be different if the test of our problems was conducted on other groups of students. Thus, care needs to be taken when extending the results to other groups of students.

Although the statistical tests on our problems contain bias and are not enough to support the effectiveness of our WeBWorK problems, we still recommend the use of our problems for courses at Worcester Polytechnic Institute that cover the topics of simple and multiple linear regression. There are some reasons for this recommendation. Firstly, we went through a lot of literature that provides useful criteria for effective online homework problems and we have built our problems based on these criteria. Secondly, we believe that we have covered most of the important topics of simple and multiple linear regression; thus our problems will provide a complete practice for students in any course covering simple and multiple linear regression. In addition, we are also encouraged by the positive feedback from the students on our problems, as during the test most students taking our problems liked our problems and said they learned something from them. However, since the effectiveness of our problems could not be determined completely from the test as the test contains bias, care should be taken when our problems are used. We encourage applying any actions that may make our problems more effective.

Since our problems cover the most popular topics in simple and multiple linear regression, we also recommend the use of our WeBWorK problems in classes covering these topics outside Worcester Polytechnic Institute. However, since we only tested our problems on the students at Worcester Polytechnic Institute, we recommend instructors to be cautious regarding the difficulty level and the materials covered in each problem to make sure that the problems are suitable and will benefit the students.

Since the tests of the effectiveness of our problems may contain some bias, the results obtained from the tests may not be completely valid. Thus, to better measure of the effectiveness of our problems, we recommend more tests on our problems. We recommend the same procedures we carried out for our test, but with a more diversified group of students and a better selection of the control set such that the problems tested and the problems in the control set are equivalent. However, if possible, we recommend a test in which students' performance could be measured through a real exam environment and students take our WeBWorK problems and the control problems in the form of homework. We believe this testing procedure result will accurately show the effectiveness of our problems as homework problems.

Bibliography

Advantages And Disadvantages Of Homework | Tutorvista.com. (n.d.). *Tutorvista.com - Online Tutoring, Homework Help for Math, Science, English from Best Online Tutor*. Retrieved November 16, 2010, from http://www.tutorvista.com/physics/advantages-and-disadvantages-of-homework

Bonham, S., Beichner, R., & Deardorff, D. (2001). Online Homework: Does it make a Difference?. *The Physics Teacher, 39*, 293-296. Retrieved November 3, 2010, from http://www.ncsu.edu/per/Articles/OnlineHomeworkArticle.pdf

Brand, M. (2008, September 11). Too Much Homework? : NPR. *NPR : National Public Radio : News & Analysis, World, US, Music & Arts : NPR*. Retrieved November 5, 2010, from http://www.npr.org/templates/transcript/transcript.php?storyId=94509873

Bressoud, D. M. (n.d.). WeBWorK. *Mathematical Association of America*. Retrieved November 8, 2010, from http://www.maa.org/columns/launchings/launchings_04_09.html

Burnham, N. (2008, February 6). hWPI Teaching wit Technology Collaboratory - How Online Homework Reduces the Grading Load and Improves Instructor Feedback. *Worcester Polytechnic Institute (WPI)*. Retrieved November 16, 2010, from http://www.wpi.edu/Academics/ATC/Collaboratory/Stories/burnham.html

Cooper, H. (1994). Homework Research and Policy: A Review of the Literature. *Research/Practice, 2*(2). Retrieved November 16, 2010, from http://www.cehd.umn.edu/carei/reports/Rpractice/Summer94/homework.html

Dedic, H., Rosenfield, S., & Ivanov, I. Just Computer Aided Instruction Is Not Enough: Combining WeBWorK with In-Class Interactive Sessions Increases Achievement and Perseverance of Social Science Calculus Students. Retrieved November 8, 2010, from http://sun4.vaniercollege.qc.ca/PA-2005-008/Pedagogie_Collegiale_Article_Dedic_Rosenfield_Ivanov.pdf

Denny, J., & Yackel, C. (2005). Implementing and Teaching with WebWork at Mercer University. *ASCUE Conference,, 1*, 85-93.

Dillard-Eggers, J., Wooten, T., Childs, B., & Coker, J. (2008). Evidence On The Effectiveness. *College Teaching Methods & Styles Journal, 4*(5), 9-16. Retrieved November 4, 2010, from http://www.cluteinstitute-onlinejournals.com/PDFs/903.pdf

Doorn, D., Janssen, S., & O'Brien, M. (2010). Student Attitudes and Approaches to Online Homework. *International Journal for the Scholarship of Teaching and Learning, 4*(1), 1-19. Retrieved November 3, 2010, from http://academics.georgiasouthern.edu/ijsotl/v4n1/articles/PDFs/Article_DoornJanssenOBrien.pdf

Fynewever, H. A Comparison of the Effectiveness of Web-based and Paper-based Homework for General Chemistry. 1-15. Retrieved November 9, 2010, from http://homepages.wmich.edu/~hfynewever/T0610114Dec13Revised.pdf

Gage, M. E., & Pizer, A. K. (n.d.). WeBWorK -- Math Homework on the Web. *Mathematics Archives WWW Server*. Retrieved November 8, 2010, from http://archives.math.utk.edu/ICTCM/VOL12/P003/paper.html

Graham, D. (2007, October 19). WeBWorK versus Brownstone EDU and MapleTA. *Home | Duke University*. Retrieved November 8, 2010, from http://www.duke.edu/~dgraham/webwork/WeBWorK-vs-Brownstone.html

Hauk, S., & Safer, A. (2004). Impact of the web-based homework program WeBWorK on student performance in moderate enrollment college algebra courses. *1, 1*. Retrieved November 6, 2010, from http://hopper.unco.edu/faculty/personal/hauk/segalla/WBWquan.pdf

Heffernan, N. T., Razzaq, L., & Mendicino, M. (2009, March 22). A comparison of traditional homework to computer-supported homework.(Report) | HighBeam Business: Arrive Prepared. *Business information, news, and reports | HighBeam Business: Arrive Prepared*. Retrieved November 8, 2010, from http://business.highbeam.com/619/article-1G1-197722644/comparison-traditional-homework-computersupported-homework

Hodge, A., Richardson, J. C., & York, C. S. (2009). The Impact of a Web-based Homework Tool in University Algebra Courses on Student Learning and Strategies. *MERLOT Journal of Online Learning and Teaching* , *5*(4). Retrieved November 7, 2010, from http://jolt.merlot.org/vol5no4/hodge_1209.pdf

How much do college students really study? – InfoRefuge.com. Info Refuge. http://www.inforefuge.com/how-much-do-college-students-really-study (accessed December 14, 2010).

Linsin, M. (2010, July 31). A Simple, Effective Homework Plan For Teachers: Part 1 — Smart Classroom Management. *Smart Classroom Management*. Retrieved November 5, 2010, from http://www.smartclassroommanagement.com/2010/07/31/effective-homework-plan-for-teachers-part-1/

Lucas, A. R. (2010). Using WeBWorK, a Web-Based Homework Delivery and Grading System, to Help Prepare Students for Peer Instruction. *1*, *1*. Retrieved November 6, 2010, from http://www.dillgroup.ucsf.edu/~alucas/webworks-PRIMUS.pdf

McMullen, Steven. "The Impact of Homework Time on Academic Achievement." *The University of North Carolina* (2007): 1-38.

Jacobsen, M. Multiple Choice Item Construction. *Online Presentation*. Lecture conducted from University of Calgary, 45-46.

Newble, D. I., Baxter, A., & Elmslie, R. G. (1979). A comparison of multiple-choice tests and free-response tests in examinations of clinical competence. *Medical Education* (pp. 263-268). Oxford: Blackwell.

Noyes, S. B. (n.d.). The Most Effective Homework: Insight and Ideas from an Expert. *Make it Better*. Retrieved November 4, 2010, from www.makeitbetter.net/family/education/24-the-most-effective-homework

Oak, M. (n.d.). Benefits of Homework. *Buzzle Web Portal: Intelligent Life on the Web*. Retrieved November 16, 2010, from http://www.buzzle.com/articles/benefits-of-homework.html

Quilici, J. L., & Mayer, R. E. (1996). Role of Examples in How Students Learn to Categorize Statistics Word Problems. *Journal of Educational Psychology, 88*(1), 144-161.

Shrestha, P., Maharjan, A., Wei, X., Razzaq, L., Heffernan, N. T., & Heffernan, C. Are Worked Examples an Effective Feedback Mechanism During Problem Solving? 1876-1881.

Smolira, J. (2008, November 1). Student perceptions of online homework in introductory finance courses | Education & Training > Academic Standards & Testing from AllBusiness.com. *Small*

Business Advice and Resources from AllBusiness.com. Retrieved November 5, 2010, from http://www.allbusiness.com/education-training/academic-standards-testing/12597592-1.html

Stirling, J. (n.d.). English Language Garden Homework Article. *English Language Garden Homepage*. Retrieved November 5, 2010, from http://www.elgweb.net/hwk_article.html#types

Stronge, J. H. (2007). Monitoring Student Progress and Potential. *Qualities of Effective Teachers* (2 ed., pp. 86-88). Alexandria, VA: Association for Supervision and Curriculum Development.

Vatterott, C. (2008). what Is Effective Homework . Retrieved November 4, 2010, from http://www.sanjuan.edu/webpages/godabashian/files/What%20Is%20Effective%20Homework.pdf

WebWork, the Math Problem Homework Internet Solution . (2008, September 4). *iBridge: Linking ideas & innovation*. Retrieved November 7, 2010, from www.ibridgenetwork.org/rochester/1-11060-699

Weibel, C. (n.d.). Effectiveness of Rutgers Calculus Formats. *Mathematics Department - Welcome*. Retrieved November 10, 2010, from http://www.math.rutgers.edu/~weibel/studies.html

Weibel, Churk and Lew Hirsch (2002). Webwork Effectiveness in Rutgers Calculus. From http://www.math.rutgers.edu/~weibel/webwork.html

Ziemer, W. K. (0). WeBWorK: An Open-Source Online Homework System. *Web-Enabled Learning Environment, 0*, 169-171. Retrieved November 10, 2010, from http://www.aaas.org/publications/books_reports/CCLI/PDFs/06_WLE_Ziemer.pdf

Advantages and Limitations of Multiple-Choice Items. (n.d.). *Techno World Inc - The Best Technical Encyclopedia Online!*. Retrieved December 15, 2010, from http://www.technoworldinc.com/placement-papers/advantages-and-limitations-of-multiplechoice-items-t3657.0.html;wap2=

RESTRICTED RESPONSE. (n.d.). *Nipissing University*. Retrieved December 15, 2010, from http://www.nipissingu.ca/faculty/peterc/Psyc3205/Essay.htm

Seaman, P. (n.d.). Multiple Choice Testing: Will It Work For Me?. *University of New Brunswick Libraries*. Retrieved December 15, 2010, from http://www.lib.unb.ca/Texts/Teaching/JAN03/seaman.htm

Gelman, A. & Nolan, D. A. (2002). *Teaching Statistics: A Bag of Tricks*. Oxford University Press.

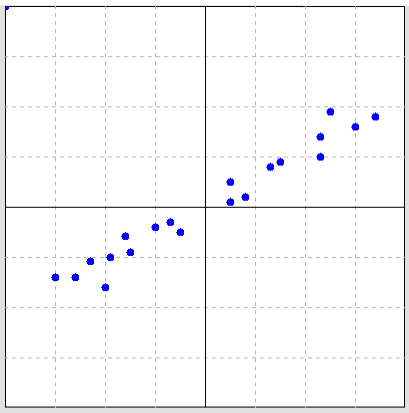
Newble, D. and Cannon, R. (1989). *A Handbook for Teachers in University and Colleges.* New York

Trigwell, K. (1992). Information for UTS staff on Assessment. Sydney

Appendix

Appendix A.1 : WebWork Problems for Simple Linear Regression

Problem 1:



What is the type of association for scatter plot above?

- **A.** Nonlinear
- **B.** Positive Linear
- **C.** Negative Linear
- **D.** Not enough Information

Problem 2:

If the Pearson correlation r of the plot is -1 , and the plot seems linear, what can you tell about its shape?

- **A.** Negative Linear
- **B.** Nonlinear
- **C.** Positive Linear
- **D.** Not enough Information

Problem 3:

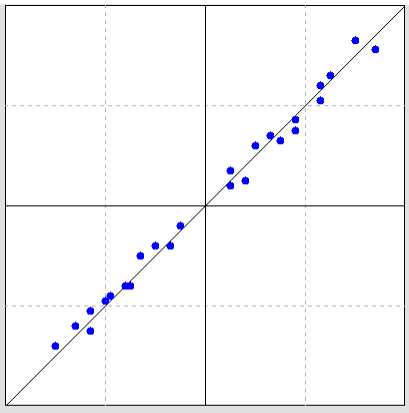
Linear regression model : FORCE = -5 + 16.656 * ACCELERATION + ε

i. Slope is
ii. Intercept is
iii. Regressor is
iv. Predictor is
v. Response is

Problem 4:

The best fitting line will be the line whose intercept and slope minimize SSE(b_0, b_1). These values are called the ? of intercept and slope

Problem 5:



What can you tell from the Studentized Residual Quantiled plot above?

- **A.** Left skew
- **B.** No skew
- **C.** Right skew
- **D.** Not enough Information

Problem 6:

The boiling point of water at different barometric pressures. There are 6 observations

Pressure	BPt
20.79	194.3
20.75	194.1
22.43	197.8
22.61	198.1
23.16	199.9
23.32	199.5

a.) Based on the data, calculate the Pearson Correlation Coefficient
b.) Using simple linear regression model, calculate the regression estimator
$\hat{\beta}_0 =$
$\hat{\beta}_1 =$
c.) Calculate the sum of squared error for the above model. $SSE =$
d.) Using the above model, calculate the boiling point of water when the pressure is 24. BPt is
e.) Calculate the sum of squared total. $SSTO =$
f.) Calculate the coefficient of determination. $R^2 =$
g.) The proportion of variation in the response explained by the regression is

Problem 7:

The data give the height and pulse rate of hospital patients. The researchers suspected that the pulse is dependent on the height.
There are two variables, height(cm) and pulse(beat per minute), measured for 6 patients.

Height	Pulse
158	67
165	79
164	85
174	79
188	81
165	79

a.) Based on the data, calculate the Pearson Correlation Coefficient
b.) Using simple linear regression model, calculate the regression estimator
$\hat{\beta}_0 =$
$\hat{\beta}_1 =$
c.) Calculate the sum of squared error for the above model. $SSE =$
d.) Calculate MSE. $MSE =$
e.) Calculate the estimated standard error of $\hat{\beta}_0$ and $\hat{\beta}_1$
$\hat{\sigma}(\hat{\beta}_0) =$
$\hat{\sigma}(\hat{\beta}_1) =$
f.) Determine the 90% confidence interval for $\hat{\beta}_1$
(,)

Problem 8:

If we found an association between X and Y, we can conclude:

- **A.** X causes Y
- **B.** Y causes X
- **C.** May not conclude anything if there is no careful, controlled and scientific experimentation to verify the association
- **D.** One of the variables X and Y is the cause and the other is the effect

Problem 9:

When calculating the Pearson correlation coefficient for a bivariate data set, if the standard deviation of one of the two variables equals 0, we assume r to be:

- **A.** 1
- **B.** -1
- **C.** 0
- **D.** Cannot be assumed

Problem 10:

If the coefficient of correlation is -1 for a simple linear regression model, what is the proportion of variation in response explained by the regression?

- **A.** 1.000
- **B.** 0.000
- **C.** -1.000
- **D.** 0.000

Problem 11:

Given the bivariate data set for salary of CEOs (in $1000s):

Age	Salary
50	144
40	620
34	264
43	202
48	367
57	422

a.) Based on the data, calculate the Pearson Correlation Coefficient

b.) Using simple linear regression model, calculate the regression estimates

$\hat{\beta}_0 =$

$\hat{\beta}_1 =$

c.) Calculate SSE

d.) Calculate MSE

f.) Calculate the estimated standard errors of $\hat{\beta}_0$ and $\hat{\beta}_1$

$\hat{\sigma}(\hat{\beta}_0) =$

$\hat{\sigma}(\hat{\beta}_1) =$

e.) Carry out the hypothesis test:

$H_0 : \beta_1 = 0$

$H_1 : \beta_1 \neq 0$

Test statistic =

P-value =

Using $\alpha = 0.05$, we:

- **A.** Do no reject the researcher's claim
- **B.** Reject the researcher's claim

Problem 12:

Pierce(1949) measured the frequency(the number of wing vibrations per second) of chirps made by a ground cricket, at various ground temperatures. Since crickets are ectotherms(cold-blooded), the rate of their physiology processes and their overall metabolism are influenced by temperature. Consequently, there is reason to believe that temperature would have a profound effect on aspects of their behavior, such as chirp frequency

Chirp Frequency	Temperature
19.8	88.4
15.9	71.5
19.8	93.9
18.1	84.2
17.7	80.7
15.9	75

a.) Based on the data, calculate the Pearson Correlation Coefficient

b.) Using simple linear regression model, calculate the regression estimates

$\hat{\beta}_0 =$

$\hat{\beta}_1 =$

c.) Calculate the sum of squared errors for the above model. $SSE =$

d.) Calculate MSE. $MSE =$

e.) Calculate the estimated standard error of $\hat{\beta}_0$ and $\hat{\beta}_1$

$\hat{\sigma}(\hat{\beta}_0) =$

$\hat{\sigma}(\hat{\beta}_1) =$

f.) Determine the 90% confidence interval for $\hat{\beta}_1$

(,)

Problem 13:

In the best fit SLR model, what is the meaning of the intercept being -3 ?

- **A.** The estimate of the mean response when the regressor equals 0 is -3
- **B.** The Pearson correlation coefficient is -3
- **C.** The change in the estimated mean response per unit change in the regressor is -3 times the change in the regressor
- **D.** No meaning

Problem 14:

In the best fit simple linear regression model, what is the meaning of the slope being -2 ?

- **A.** The change in the estimated mean response per unit change in the predictor is -2 times the change in the regressor per unit change in the predictor
- **B.** The Pearson correlation coefficient is -2
- **C.** The estimate of the mean response when the regressor equals 0 is -2
- **D.** No meaning

Problem 15:

The data give the amount spent by the Football Departments of Australian Football League clubs from 2003 to 2007, and their results

Clubs	Spent (million AUD)	Wins
Sydney	66	67
Collingwood	66.1	55
Brisbane	65.8	57
Westcoast	63.1	73
Essendon	60.9	48
Adelaide	58.9	65

a.) Based on the data, calculate the Pearson Correlation Coefficient

b.) Using simple linear regression model, calculate the regression estimates

$\hat{\beta}_0 =$

$\hat{\beta}_1 =$

c.) Calculate the sum of squared errors for the above model. $SSE =$

d.) Using the above model, given the amount spent is 62 million AUD.

Estimate number of wins. $\hat{Y} =$

Problem 16:

The residuals from a least square fit add up to

- **A.** 1
- **B.** r, the Pearson coefficient of correlation
- **C.** 0
- **D.** Cannot be determined from the given information

Problem 17:

Based on the study of income of 2000 father-son pairs, a researcher came up with the least squares fit $\widehat{SON} = 10000 + 0.2 * FATHER$. The researcher could claim that:

- **A.** If two fathers differ in income by \$160, the son of the one with higher income will earn \$800 more than the other son
- **B.** If two fathers differ in income by \$800, the model predicts that the son of the one with higher income will earn \$160 more than the other son
- **C.** If two fathers differ in income by \$160, the model predicts that the son of the one with higher income will earn \$800 more than the other son
- **D.** If two fathers differ in income by \$800, the son of the one with higher income will earn \$160 more than the other son

Problem 18:

If we need to test for independence in a two-way table, what kind of distribution will be used

- **A.** t distribution
- **B.** normal distribution
- **C.** chi-squared distribution
- **D.** gamma distribution

Problem 19:

A researcher suspects that the number of right-handed people in a region in Nepal is the same as the number of left-handed people there. To validate this claim, he conducted a study of 5000 random people in that region. The result is summed up in the following table:

	Number
Right-handed	2530
Left-handed	2470

a.) Fill in the table of expected values if the researcher is right:

	Number
Right-handed	
Left-handed	

b.) Select the correct statement for Null Hypothesis for this problem: (p_1 being the proportion of right-handed people and p_2 being the proportion of left-handed people)

- **A.** $p_1 = 0.25$, $p_2 = 0.75$
- **B.** $p_1 = 0.50$, $p_2 = 0.50$
- **C.** $p_1 = 0.00$, $p_2 = 0.00$
- **D.** $p_1 = 0.75$, $p_2 = 0.25$

c.) Compute the test statistic =

d.) P-value =

e.) Using $\alpha = 0.05$, we:

- **A.** Do no reject the researcher's claim
- **B.** Reject the researcher's claim

Problem 20:

A researcher suspects that older people have better chance to win a lottery. In particular, he claims that people above 50 years of age represent 40% of lottery winners while those in each of the other age groups shown in the table represent only 15%. A sample of 2000 lottery winners gave the following results:

Age group	Number
Less than 20	255
20 to 30	301
30 to 40	332
40 to 50	312
Above 50	800

a.) Fill in the table of expected values if the researcher is right:

Age group	Number
Less than 20	
20 to 30	
30 to 40	
40 to 50	
Above 50	

b.) Select the correct statement for Null Hypothesis for this problem: (p_1, p_2, p_3, p_4, and p_5 being the proportion of people less than 20, 20-30, 30-40, 40-50, and above 50, respectively)

- **A.** $p_1 = 0.15,\ p_2 = 0.15,\ p_3 = 0.15,\ p_4 = 0.15,\ p_5 = 0.40$
- **B.** $p_1 = 0.40,\ p_2 = 0.15,\ p_3 = 0.15,\ p_4 = 0.15,\ p_5 = 0.15$
- **C.** $p_1 = 0.20,\ p_2 = 0.20,\ p_3 = 0.20,\ p_4 = 0.20,\ p_5 = 0.20$
- **D.** $p_1 = 0.25,\ p_2 = 0.15,\ p_3 = 0.15,\ p_4 = 0.25,\ p_5 = 0.20$

c.) Compute the test statistics =

d.) P-value =

e.) Using $\alpha = 0.05$, we:

- **A.** Do no reject the researcher's claim
- **B.** Reject the researcher's claim

Problem 21:

A researcher studied the heights of 200 students to claim that heights and weights are independent. The result shows that

	Height			
Weight	Tall	Medium	Short	Total
Heavy	23	22	21	66
Medium	19	25	20	64
Light	23	9	38	70
Total	65	56	79	200

a.) Fill in the table of expected values if the researcher is right:

	Height			
Weight	Tall	Medium	Short	Total
Heavy				66
Medium				64
Light				70
Total	65	56	79	200

b.) Compute the test statistics for the following hypotheses:
H_0: Heights and Weights are independent
H_a: Heights and Weights are not independent

c.) P-value =

d.) Using $\alpha = 0.05$, we:

- **A.** Reject the researcher's claim
- **B.** Do no reject the researcher's claim

Problem 22:

A researcher studied 400 computers to investigate the independence between temperature of the computer and the mass of the computer. The result was summarized in the following table. The researcher claims that temperature and mass are independent.

	Temperature		
Mass	Low	High	Total
Light	130	142	272
Heavy	70	58	128
Total	200	200	400

a.) Fill in the table of expected values if the researcher is right:

	Temperature		
Mass	Low	High	Total
Light			272
Heavy			128
Total	200	200	400

b.) Compute the test statistics for the following hypotheses:
H_0: Mass and Temperature are independent
H_a: Mass and Temperature are not independent

c.) P-value =

d.) Using $\alpha = 0.05$, we:

- **A.** Do no reject the researcher's claim
- **B.** Reject the researcher's claim

Problem 23:

A researcher recorded the heights and weights of 200 students. The results are:

	Height			
Weight	Tall	Medium	Short	Total
Heavy	23	22	21	66
Medium	19	20	25	64
Light	23	9	38	70
Total	65	56	79	200

Compute the following:
a.) The chance of the person to be tall given the person is heavy.
b.) The chance of the person to be short
c.) The chance of the person to be medium given the person is light.

Problem 24:

A researcher studied 400 computers to investigate the independence between temperature of the computer and the mass of the computer. The result was summarized in the following table.

	Temperature		
Mass	Low	High	Total
Light	130	142	272
Heavy	70	58	128
Total	200	200	400

Compute the following probability:
a.) The chance of a computer to have low temperature given that the computer is light.
b.) The chance of a computer to be light.

Appendix A.2 : WebWork Problems for Multiple Linear Regression

Problem 1:

The regression model $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \epsilon$

- **A.** Is a full quadratic model
- **B.** Is an additive model
- **C.** Has two predictors and four regressors
- **D.** Is not a fitted multiple linear regression model
- **E.** Has four predictors and two regressors
- **F.** None of the above

Problem 2:

In the regression model $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \epsilon$, the regressors are:

- **A.** Z_1 and Z_2
- **B.** $\beta_0, \beta_1, \beta_2, \beta_3$ and β_4
- **C.** Z_1, Z_2, Z_1^2 and $Z_1 Z_2$
- **D.** Z_1, Z_2 and $Z_1 Z_2$
- **E.** None of the above

Problem 3:

Which of the following models is a full quadratic multiple linear regression model:

- **A.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1 Z_2 + \epsilon$
- **B.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \epsilon$
- **C.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \beta_5 Z_2^2 + \beta_6 Z_3 + \epsilon$
- **D.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_1 Z_2 Z_3 + \epsilon$
- **E.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \beta_5 Z_2^2 + \epsilon$
- **F.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \epsilon$

Problem 4:

The correlation coefficient between Y and $\hat{Y}$ in a multiple linear regression model is -1. What is the coefficient of multiple determinatio

- **A.** 1
- **B.** 1
- **C.** -1
- **D.** 2
- **E.** -1
- **F.** -2

Problem 5:

Given the fitted multiple linear regression model $\hat{Y} = -8 - 7Z_1 + 4Z_2 - 29Z_1^2 + 12Z_1 Z_2$, the change in $\hat{Y}$ per unit change in Z_2 is:

- **A.** 4+12Z_1
- **B.** 4
- **C.** -3
- **D.** 4+-29Z_1+12Z_2
- **E.** -4
- **F.** 16

Problem 6:

In a fitted multiple linear regression model that has 25 observations and 3 regressors, SSTO = 605 and SSE = 190. Calculate the value of the F statistic for testing the significance of this model.

F =

Problem 7:

Which of the following can **ALWAYS** be increased by adding one more regressor to the model?

- **A.** R^2
- **B.** SSE
- **C.** SSR
- **D.** R_a^2
- **E.** SSTO

Problem 8:

In a fitted multiple linear regression model that has 25 observations and 3 regressors, SSTO = 605 and SSE = 190. Calculate the adjusted coefficient of multiple determination.

R_a^2 =

Problem 9:

Given that the following models is perform equally well, which one should be chosen according to the principle of parsimony

- **A.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1 Z_2 + \epsilon$
- **B.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \beta_5 Z_2^2 + \epsilon$
- **C.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \beta_5 Z_2^2 + \beta_6 Z_3 + \epsilon$
- **D.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_1 Z_2 Z_3 + \epsilon$
- **E.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \epsilon$
- **F.** $Y = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_1^2 + \beta_4 Z_1 Z_2 + \epsilon$

Problem 10:

Which of the following may indicate a poor fit for a multiple linear regression model?

- **A.** A significantly large value of the F statistic
- **B.** A small value of the intercept
- **C.** A coefficient of multiple determination close to zero
- **D.** A small value of sum of squared errors
- **E.** A small value of SSTO
- **F.** All of the above statements are correct

Problem 11:

Complete the following ANOVA table for a multiple linear regression model

Analysis of Variance					
Source	DF	Sum of squares	Mean squares	F Stat	Prob > F
Model	4		201.1325		0.00000
Error	23	123.35			
C Total					

Problem 12:

Given the following portion of an ANOVA table for a multiple linear regression model:

Source	DF	Sum of squares
Model	4	103.06
Error	25	24.72
C Total	29	127.78

a.) Calculate the coefficient of multiple determination

b.) What is the null hypothesis for the overall F test for this model

- **A.** $\beta_1 = \beta_2 = \beta_3 = 1$
- **B.** $\beta_1 = 0$
- **C.** $\beta_1 = \beta_2 = \beta_3 = 0$
- **D.** $\beta_1 \neq 0, \beta_2 \neq 0, \beta_3 \neq 0$
- **E.** $\beta_1 = \beta_2 = \beta_3$

c.) Calculate the F test statistic

Problem 13:

For a multiple linear regression model with 4 regressors and 37 observations, calculate:

a.) The degrees of freedom for SSR:

b.) The degrees of freedom for SSE:

c.) The degrees of freedom associated with MSE:

d.) The degrees of freedom for SSTO:

Problem 14:

The correlation coefficient between Y and $\hat{Y}$ for a multiple linear regression model is -1. The proportion of the total variation in the response explained by the regression model is

Problem 15:

In a MLR problem, which distribution is used in testing for a significant relation between the response and the regressors?

- **A.** Normal distribution
- **B.** t distribution
- **C.** F distribution
- **D.** Chi-squared distribution

Problem 16:

For the model $\hat{Y} = -7 - 5Z_1 + 5Z_2 + 41Z_1^2 + 19Z_1Z_2$, if multicollinearity occurs, the best option would be:

- **A.** Center the predictors before taking the product
- **B.** Get rid of the product term
- **C.** Arbitrarily drop one regressor from the model
- **D.** Get rid of the term associated with Z_1

Problem 17:

A researcher built a multiple linear regression model for solubility of a material with 5 regressors: temperature, pressure, volume, mass and concentration. He suspected multicollinearity in his model. He tested multicollinearity by regressing the last regressor on the other 4 regressors and obtained a coefficient of multiple determination being 0.7

a.) Based on the above information, calculate the tolerance =

b.) Based on the value of tolerance calculated, we say that multicollinearity

- **A.** occurred
- **B.** did not occur

Problem 18:

Consider a fitted multiple linear regression model $\widehat{\text{Energy}} = 180 + 8 * \text{Velocity} + 156 * \text{Time}$ to model the amount of energy consumed by a machine.

a.) When Velocity and Time both take value 0, the predicted energy consumed by the machine is

b.) When Velocity is increased by 10 units, holding Time constant, the predicted value of energy consumed by the machine is ? by units.

c.) When Time is decreased by 5 units, holding Velocity constant, the predicted value of energy consumed by the machine is ? by units.

Problem 19:

A fitted multiple linear regression model $\hat{Y} = 3 + 9X_1 + 5X_2 + 17X_3$ is fitted to a data set of 16 observations. Given SSE = 32.

a.) Calculate MSE =

b.) Given the estimated standard error of $\hat{Y}$ is 3.9.

Calculate the standard deviation of a new response at regressor values $X_1 = 2$, $X_2 = 7$, $X_3 = 2$.

$\hat{\sigma}(Y_{new} - \hat{Y}_{new}) =$

Calculate the 95% prediction interval for new observation at $X_1 = 2$, $X_2 = 7$, $X_3 = 2$

(,)

Problem 20:

Which distribution is used for testing individual regressors

- **A.** Normal distribution
- **B.** chi-squared distribution
- **C.** t distribution
- **D.** F distribution

Problem 21:

For the fitted multiple linear regression model $\widehat{\text{Energy}} = 180 + 8 * \text{Velocity} + 156 * \text{Time}$, which is used to model the amount of energy consumed by a machine, the following information was found:

Parameters	Estimate for β_i	$\hat{\sigma}(\hat{\beta}_i)$
Intercept	180	9.3
Velocity	8	5.8
Time	156	4.8

a.) Identify the null hypothesis for testing the significance of the individual regressor Velocity:

- **A.** $\beta_1 = \beta_0$
- **B.** $\beta_1 = 1$
- **C.** $\beta_1 = 0$
- **D.** $\beta_1 = \beta_2$

b.) Calculate the test statistic

c.) Find the p-value given there are 12 observations.

P-value =

d.) Using $\alpha = 0.05$, we:

- **A.** Reject the researcher's claim
- **B.** Do no reject the researcher's claim

e.) Determine the 90% confidence interval for β_1

(,)

Problem 22:

We will have to be concerned with multicollinearity when:

- **A.** Sum of Squared Errors exceeds 10
- **B.** Tolerance equals 1
- **C.** Variance inflation factor exceeds 10
- **D.** The coefficient of multiple determination is 1

Appendix A.3: Pretest and posttest for testing simple linear regression

Pretest

Data were taken to investigate the relation between the boiling point of water and barometric pressure.

BPt	Pressure
194.5	20.79
194.3	20.79
197.9	22.4
198.4	22.67
199.4	23.15
199.4	23.15

a) Based on the data, calculate the Pearson Correlation Coefficient
b) A scientist wants to use a linear regression model for this data. He calculated the regression estimate $\widehat{\beta_1} = 2.08$. Use it to find $\widehat{\beta_0}$ for his model.
c) Using the above model, estimate the boiling point of water when the pressure is 24.
d) Calculate the estimate of the response when the regressor equals 0.
e) Is the direction of association of the data positive or negative?
f) Calculate the sum of squared errors for the above model fit.
g) If two pressures differ by 10, how much higher does fitted model estimate the boiling point associated with the higher pressure is than the boiling point associated with the lower pressure?
h) Calculate the total sum of squares.
i) Calculate the coefficient of determination.
j) Calculate the proportion of variation in the response explained by the regression.

Posttest

The data give the height and pulse rate of hospital patients. The researchers suspected that the pulse is dependent on the height.

There are two variables, height (cm) and pulse (beat per minute), measured for 6 patients.

Height(X)	Pulse(Y)
160	68
167	74

164	73
175	80
185	87
162	69

a) Based on the data, calculate the Pearson Correlation Coefficient
b) A scientist wants to use a linear regression model for this data. He calculated the regression estimate $\widehat{\beta_1} = 2.08$. Use it to find $\widehat{\beta_0}$ for his model.
c) Using the above model, estimate the pulse when the height is 24.
d) Calculate the estimate of the response when the regressor equals 0.
e) Is the direction of association of the data positive or negative?
f) Calculate the sum of squared errors for the above model fit.
g) If two pressures differ by 10, how much higher does fitted model estimate pulse associated with the higher height is than the pulse associated with the lower height?
h) Calculate the total sum of squares.
i) Calculate the coefficient of determination.
j) Calculate the proportion of variation in the response explained by the regression.

Appendix A.4: Pretest and Posttest for testing multiple linear regression

Pretest

A scientist studied the relationship between the energy cost of a car with its velocity and mass. The scientist obtained 40 observations and came up with the following model:

$$\widehat{energy\ cost} = 15 + 8 * Velocity + 10 * mass + 10 * mass^2 + 5 * mass * Velocity$$

1. Which of the following statement is correct regarding the above model?

a) Is not a fitted multiple linear regression model
b) Has two predictors and four regressors
c) Has four predictors and two regressors
d) Is an additive model
e) Is a full quadratic model
f) None of the above statements is correct

2. Find and expression in term of Velocity and mass to describe the change in energy cost per unit change in mass predicted by the model.
3. Complete the following ANOVA table (Replace A,B,C,D,E,F,G with appropriate values)

Analysis of Variance				
Source	DF	Sum of squares	Mean square	F Stat
Model	A	804.03	E	G
Error	B	123.25	**F**	
C Total	C	D		

4. Calculate the proportion of the total variation in the response explained by the regression model based on the ANOVA table above.
5. Calculate the adjusted coefficient of multiple determination
6. The scientist suspected multicollinearity in his model. He tested multicollinearity by regressing the last regressor (mass*Velocity) on the other three regressors and obtained a coefficient of multiple determination being 0.85. Calculate the tolerance of the last regressor.
7. Based on the tolerance above, is multicollinearity a cause for concern?
8. When Velocity and mass both take value 0, what is the expected energy cost of the car?
9. When Velocity is increased by 5 units, at mass = 10 and velocity = 5, the predicted value of energy cost of the car is increased by how many units?

Posttest

A scientist studied the relationship between the income of a person with his years of experience (Experience) and years of education(Education). The scientist obtained 50 observations and came up with the following model:

$\widehat{income} = 200 + 8 * exprience + 10 * education + 10 * education^2 + 50 * experience^2 + 5 * experience * education$

1. Which of the following statement is correct regarding the above model?

a) Is not a fitted multiple linear regression model
b) Has two predictors and four regressors
c) Has four predictors and two regressors
d) Is an additive model
e) Is a full quadratic model
f) None of the above statements is correct

2. Find and expression in term of education and experience to describe the change in income per unit change in education predicted by the model.
3. Complete the following ANOVA table (Replace A,B,C,D,E,F,G with appropriate values)

Analysis of Variance				
Source	DF	Sum of squares	Mean square	F Stat
Model	A	804.03	E	G
Error	B	123.25	**F**	
C Total	C	D		

4. Calculate the proportion of the total variation in the response explained by the regression model based on the ANOVA table above.
5. Calculate the adjusted coefficient of multiple determination
6. The scientist suspected multicollinearity in his model. He tested multicollinearity by regressing the last regressor (experience*education) on the other four regressors and obtained a coefficient of multiple determination being 0.96. Calculate the tolerance of the last regressor.
7. Based on the tolerance above, is multicollinearity a cause for concern?
8. When education and experience both take value 0, what is the expected income?
9. When education is increased by 5 units, at experience = 10 and education = 8, the predicted value of income is increased by how many units?

Appendix A.5: Simple linear regression WebWorK problems that were used in control group

Problem 1:

Is the number of games won by a major league baseball team in a season related to the team batting average? The table below shows the number of games won and the batting average of 8 teams.

Team	Games Won	Batting Average
1	60	0.262
2	106	0.264
3	115	0.286
4	83	0.273
5	113	0.264
6	98	0.267
7	75	0.263
8	71	0.283

Using games won as the independent variable x, do the following:
(a) Compute the value of SST (Total Sum of Squares)
answer:

(b) Compute the value of SSR (Regression Sum of Squares)
answer:

(c) Compute the value of SSE (Error Sum of Squares)
answer:

(d) The coefficient of determination is
answer:

(e) What percent of variation in the observed values of the response variable is explained by the regression?
answer:

Problem 2:

The linear correlation coefficient of a set of data points is -0.975.

a) Is the slope of the regression line positive or negative?
answer:

b) Determine the coefficient of determination.
answer:

Problem 3:

The coefficient of determination of a set of data points is 0.75 and the slope of the regression line is -9.02. Determine the linear correlation coefficient of the data.
answer:

Problem 4:

Consider the following small data set.

Subject	x	y
1	3	16
2	14	18
3	16	30
4	8	23
5	16	18

Find the linear correlation coefficient.

$r =$

Problem 5:

The amounts of 6 restaurant bills and the corresponding amounts of the tips are given in the table below.

Bill	32.98	49.72	70.29	97.34	43.58	52.44
Tip	4.50	5.28	10.00	16.00	5.50	7.00

Find the following:

The regression equation is $\hat{y} =$ $+$ x.
If the amount of the bill is $\$65$, the best prediction for the amount of the tip is

Problem 6:

Consider the linear equation $y = b_0 + b_1 x$.

a. In the equation, b_0 is

- **A.** the slope
- **B.** the independent variable
- **C.** the y-intercept
- **D.** the dependent variable

b. In the equation, b_1 is

- **A.** the slope
- **B.** the dependent variable
- **C.** the y-intercept
- **D.** the independent variable

c. Give the geometric interpretation of b_0. It indicates

- **A.** the x-value where the straight-line graph of the linear equation intersects the x-axis
- **B.** the y-value where the straight-line graph of the linear equation intersects the y-axis
- **C.** how much the x-value on the straight line changes when the y-value increases by unit
- **D.** how much the y-value on the straight line changes when the x-value increases by unit

d. Give the geometric interpretation of b_1. It indicates

- **A.** how much the x-value on the straight line changes when the y-value increases by unit
- **B.** the x-value where the straight-line graph of the linear equation intersects the x-axis
- **C.** the y-value where the straight-line graph of the linear equation intersects the y-axis
- **D.** how much the y-value on the straight line changes when the x-value increases by unit

Problem 7:

For the equation $y = 1 + 2x$,

a. the y-intercept is _____, and the slope is _____.

b. the line

- **A.** is horizontal
- **B.** slopes upward
- **C.** slopes downward
- **D.** none of the above

Problem 8:

Use a scatterplot and the linear correlation coefficient r to determine whether there is a correlation between the two variables.

x	0.1	1.6	2.1	3.8	4.8	5.3	6.4	7.8	8.1	9.6	10.2	11.2	12.1	13.1	14.7
y	1.9	2.7	0.3	4.9	6.8	3.8	7.8	6	6.1	8.9	10.6	9.6	11.9	11.2	12.8

$r =$ _____

There is

- **A.** a perfect positive correlation between x and y
- **B.** a negative correlation between x and y
- **C.** a positive correlation between x and y
- **D.** no correlation between x and y
- **E.** a perfect negative correlation between x and y
- **F.** a nonlinear correlation between x and y

Appendix A.6: Multiple linear regression WebWorK problems that were used in control group

Problem 1:

Which of the following statements is not true?

- **A.** Multicollinearity does not affect the $F-$test of the analysis of variance
- **B.** Multicollinearity exists in virtually all multiple regression models
- **C.** Multicollinearity is also called collinearity and intercorrelation
- **D.** Multicollinearity is a condition that exists when the independent variables are highly correlated with the dependent variable

In a multiple regression analysis, if the model provides a poor fit, this indicates that:

- **A.** the multiple coefficient of determination will be close to zero
- **B.** the sum of squares for error will be large
- **C.** the standard error of estimate will be large
- **D.** all of the above answers are correct

Problem 2:

In multiple regression analysis involving 10 independent variables and 100 observations, the critical value t for testing individual coefficients in the model will have:

- **A.** 89 degrees of freedom
- **B.** 100 degrees of freedom
- **C.** 10 degrees of freedom
- **D.** 9 degrees of freedom

In a multiple regression analysis involving 40 observations and 5 independent variables, the total variation $SSTO = 350$ and $SSE = 50$. The multiple coefficient of determination is:

- **A.** 0.8571
- **B.** 0.8529
- **C.** 0.8408
- **D.** 0.8469

Problem 3:

Select True or False from each pull-down menu, depending on whether the corresponding statement is true or false.

? **1.** In order to test the significance of a multiple regression model involving 4 independent variables and 25 observations, the numerator and denominator degrees of freedom (respectively) for the critical value of F are 3 and 21.

? **2.** In a multiple regression problem involving 24 observations and three independent variables, the estimated regression equation is $\hat{y} = 72 + 3.2x_1 + 1.5x_2 - x_3$. For this model, $SSTO = 800$ and $SSE = 245$. The value of the F statistic for testing the significance of this model is 15.102.

? **3.** In a multiple regression problem, the regression equation is $\hat{y} = 60.6 - 5.2x_1 + 0.75x_2$. The estimated value for y when $x_1 = 3$ and $x_2 = 4$ is 48.

? **4.** In multiple regression, the descriptor "multiple" refers to more than one dependent variable.

Problem 4:

Select True or False from each pull-down menu, depending on whether the corresponding statement is true or false.

? **1.** In reference to the equation $\hat{y} = 1.86 - 0.51x_1 + 0.60x_2$, the value 0.60 is the change in y per unit change in x_2, regardless of the value of x_1.

? **2.** In testing the significance of a multiple regression model in which there are three independent variables, the null hypothesis is $H_0 : \beta_1 = \beta_2 = \beta_3$.

? **3.** A multiple regression model has the form $\hat{y} = b_0 + b_1x_1 + b_2x_2$. The coefficient b_1 is interpreted as the change in y per unit change in x_1.

? **4.** In a multiple regression analysis involving 50 observations and 5 independent variables, $SSTO = 475$ and $SSE = 71.25$. The multiple coefficient of determination is 0.85.

Problem 5:

Complete the ANOVA table for a completely randomized design below.

Source	df	SS	MS	F
Treatments	10	18.8		
Error				
Total	41	41.8		

Problem 6:

Select True or False from each pull-down menu, depending on whether the corresponding statement is true or false.

? **1.** In multiple regression, the problem of multicollinearity affects the t—tests of the individual coefficients as well as the F—test in the analysis of variance for regression, since the F—test combines these t—tests into a single test.

? **2.** In multiple regression, and because of a commonly occurring problem called multicollinearity, the t—tests of the individual coefficients may indicate that some independent variables are not linearly related to the dependent variable when in fact they are.

? **3.** Excel prints a second R^2 statistic, called the coefficient of determination adjusted for degrees of freedom, which has been adjusted to take into account the sample size and the number of independent variables.

? **4.** In regression analysis, the total variation in the dependent variable y measured by $\sum (y_i - \bar{y})^2$, can be decomposed into two parts: the explained variation, measured by SSR, and the unexplained variation, measured by SSE.

Problem 7:

Which of the following changes the analysis of variance results?

- ☐ **A.** the order of the samples is changed
- ☐ **B.** each value in one of the samples is multiplied by the same constant
- ☐ **C.** each of the sample values is multiplied by the same constant
- ☐ **D.** each of the sample values is converted to a different scale
- ☐ **E.** the same constant is added to each value in one of the samples
- ☐ **F.** the same constant is added to every one of the sample values

Problem 8:

Find the multiple regression equation for the data given below.

x_1	-3	-2	0	1	3
x_2	-3	1	-1	-1	2
y	-6	-17	3	8	4

The equation is $\hat{y} =$ ____ + ____ x_1 + ____ x_2.