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The Effectiveness of Computer-Based Tutorials in Learning Computer-Aided Design Methods for Tool Design Procedures

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THE EFFECTIVENESS OF COMPUTER-BASED TUTORIALS IN LEARNING COMPUTER-AIDED DESIGN METHODS FOR TOOL DESIGN PROCEDURES

by

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ABSTRACT

THE EFFECTIVENESS OF COMPUTER-BASED TUTORIALS IN

LEARNING COMPUTER-AIDED DESIGN METHODS

FOR TOOL DESIGN PROCEDURES

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Throughout the past twenty-five years the process of designing and manufacturing a product has been revolutionized by the integration of Computer Aided Design (CAD). Although three-dimensional solid modeling, or 3-D CAD, offers a better representation of the product in a virtual environment, it can be complicated and difficult to learn. Tutorials have been developed to assist manufacturing tool design student in the learning of 3-D CAD principles as they apply to tool design. This study seeks to test the effectiveness of those tutorials.

A BYU tool design class was divided into two groups according to their assigned laboratory time. The experimental group used the tutorials in their lab assignments. The other group acted as the control group for the study and did not use the tutorial in their lab assignments. Both groups took a pre-evaluation quiz and three short quizzes

throughout the semester to test how well they had learned the software. The short quizzes included ten written answers and a small design project. The answers to the quizzes were graded and the students recorded the time it took to complete the design project. This data was analyzed statistically using an ANCOVA model.

The student who used the tutorials performed better on the written answer section of the quizzes. This was proven to be statistically significant. There was no significance difference, however, in the time it took students to complete the design projects on each quiz.

It was concluded from this data that the tutorials were effective teaching 3-D CAD principles to tool design students.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Throughout the past twenty-five years the process of designing and manufacturing a product has been revolutionized by the integration of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). (Amirouche, 2004) CAD and CAM have incorporated three-dimensional solid modeling that allows the designer to better visualize a product being modeled. This software enables an engineer to accurately design products with increasingly complex geometry and features that would otherwise be impossible to design with a pencil and paper. (McDermott, 1995) In addition, this software allows the user to visualize a product's components as they interact with each other in an assembly.

Although three-dimensional solid modeling, or 3-D CAD, offers a better representation of the product in a virtual environment, it can be complicated and difficult to learn. As a result, companies that sell 3-D CAD software packages offer classes for the purpose of training future users. In addition, training manuals are available with the software to show all of its functions.

CAD and CAM are used in engineering education to train future engineers for industry. In the Manufacturing Engineering Technology (MET) program at Brigham Young University this software is taught to most students during their first or second years of college. It is typically not until the students' senior year that they take tool design, a class that heavily utilizes CAD software to teach the fundamentals of designing tools for manufacturing. By that time many students have either forgotten how to use this software or never developed skills in this area. The assignments in the tool design class are complex and in some cases require an exact methodology to complete using the 3-D CAD software.

In order to assist the students in the class, tutorials have been developed to teach the software as it is applied to their various laboratory assignments. These tutorials are designed to show the tool design students how to do each lab assignment in a simple, understandable manner, familiarizing each student with the 3-D CAD software as they move through them. They are also designed so that they can be updated easily as future versions of this software are released from year to year. The focus of this study is to determine how effective these tutorials are in teaching students how to use 3-D CAD software to complete their assignments in the tool design class.

1.2 STATEMENT OF PROBLEM

The use of 3-D CAD software in the tool design class typically occurs outside of class instruction in a computer laboratory environment. There, the students receive hands-on instruction by means of a lab instructor, or teaching assistant. Typically the teaching assistant is a student who has taken the class previously and knows the software well enough to help the students when they have questions.

The laboratory assignments serve not to only familiarize the students with the 3-D CAD software; they are also designed to give students an idea of how to use it when designing manufacturing tools such as jigs and fixtures. The teaching assistant helps the students by answering their questions and instructing them on how to do the assignments with the CAD software. Occasionally, when most of the students in a lab section have problems understanding a certain concept, the teaching assistant can present a demonstration to the whole lab on a projector screen.

In the past, the lab assignments for the tool design class were done on CAD software that was 2-D based. This software was less complex than the 3-D solid modeling CAD software. Students, in many cases, were able to easily complete these assignments without problems due to the simplicity of the software.

With the introduction of 3-D CAD software, these lab assignments have become increasingly more difficult for the students. The teaching assistant has to be well educated in the software to be able to help the students complete the assignments. Even if the teaching assistant is educated in the software, they still have to know the methodology of each lab assignment to be effective.

The tutorials developed for this class offer a complete, step-by-step methodology of how to do each assignment from start to finish. They also teach students the basic concepts of the 3-D CAD software needed for today's tooling engineer.

This study tested how effective these tutorials are in teaching 3-D CAD software. This was based on the students' ability to understand 3-D CAD concepts taught by using the tutorials in the labs.

1.3 THESIS STATEMENT

Stated in the form of a null hypothesis, the thesis for this study states that there is no significant difference in the improvement of learning for tool design students who used a tutorial as opposed to students who did not use the tutorial to complete their laboratory assignments. More specifically the following hypotheses are tested in the study:

(a) There is no significant difference in the quiz scores (which tests the learning of basic 3-D CAD principles as they applied to the lab assignments) between the students who used a tutorial and those who did not.

(b) There is no significant difference in the amount of time taken by each student to complete a given design assignment that utilizes the skills gained from the lab assignments.

1.4 JUSTIFICATION

This thesis will demonstrate the effectiveness of computer-based tutorials on the learning process of 3-D CAD software for tool design students. These tutorials add greatly to the learning resources students have for completing the lab assignments and learning the 3-D CAD software. With these tutorials, students will be able to learn the principles of the software as it applies to tool design. The tutorials will also enable them to learn, starting at their current level of knowledge of the software, without the use of a qualified teaching assistant, which is not always available from semester to semester.

3-D CAD software is upgraded frequently. When a new version of the software is released there can be changes in the way the software looks (Graphical user interface).

There will be a considerable amount of effort required to update the tutorials so that they will be current to the upgraded software. This study will show that by using these tutorials, the students will learn the 3-D CAD software more effectively, justifying the costs associated with updating the tutorials.

1.5 METHODOLOGY

The MFG 431 tool design class was divided into two groups of students. This was done according to lab sections. There were five lab sections for this class. Three labs had the tutorials available to them over the Internet via Blackboard™ while the other two lab sections did not. The three lab sections that had the tutorials were the experimental group, or the treatment group. The two lab sections that did not use the tutorials were the control group of the study. Both groups of students had access to a teaching assistant who was well versed in the use of the software.

At the beginning of the semester the students took a pretest to determine their knowledge of CAD software. At three separate times throughout the semester subsequent quizzes were administered to the students. These quizzes had two sections to them:

(a) Ten questions that require an explanation of a concept learned from the lab assignments.

(b) A short design project that incorporates the skills learned by doing the lab assignments.

For the first section of the quizzes, the teaching assistant graded each of the ten questions on a scale of one to five. If the students demonstrated that they had excellent knowledge of the concept being asked then five points were awarded to that question.

One point was awarded if the students answered the questions wrongly or didn't have any idea how to answer the question. The same teaching assistant graded all of the quizzes using these same criteria.

For the second section of the quizzes, the students were asked to record the time it took them to complete the small design project.

Both the scores from the written answer section and the design project times were analyzed statistically using an analysis of variance model with the pretest score as a covariate (ANCOVA) to determine if there was any level of statistical significance in the final quiz scores between the group that had access to the tutorials and the group that didn't.

1.6 DELIMITATIONS

The students that were used for this study were enrolled in the MFG 431 Tool Design class that was taught fall semester of 2003. There were 18 students in the group to be tested and 16 in the control group.

The tutorials used were developed in Microsoft PowerPoint™ and were developed for use with SolidWorks™ 3-D design software. The version used in this study was SolidWorks™ 2003 Educational Edition. The tutorials gave a detailed explanation of the steps needed to complete each assignment. A picture showing the students where to go to complete the steps of the assignment followed each explanation.

This study dealt only with how well students learn by using the tutorials as opposed to not using them, it did not deal with the students' attitudes or opinions concerning the tutorials or how effective they thought the tutorials were. In addition, this study did not test the difference in the actual grades of the students in the tool design class. Nor did it test the effectiveness of the tutorials on the final grades of the individual laboratory assignments.

1.7 DEFINITION OF TERMS

2-D CAD Software — Computer-Aided Design software that only utilizes two-dimensional entities to define a particular drawing, i.e. lines, arcs etc.

3-D Solid Modeling — Computer-Aided Design software that utilizes 3-D graphics to represent a design project on a computer screen.

ANCOVA — Analysis of variance with the use of a covariate . . .

Assembly — A combination of two or more parts, called components, within a CAD software document.

BlackBoard™ — An online course delivery software used by many universities and educational organizations to instruct students over the Internet.

CAD Education — Education in the field of Computer-Aided Design.

CAD File — A computer file associated with CAD software.

Computer — A machine that computes and performs high-speed mathematical operations or assembles, stores, or processes information.

Computer-Aided Design (CAD) — The use of computer programs to design detailed two- or three-dimensional models of physical objects.

Computer Aided Instruction (CAI) —

Computer Aided Manufacturing (CAM) — The use of computer programs to manufacture parts that are designed by the use of CAD software.

Control Group — A group that represents a standard of comparison verifying the results of an experiment.

Drawing — A 2-dimensional representation of a part depicted by orthogonal views within a CAD software document.

Graphical User Interface — An interface in computer software for interacting with a computer utilizing a mouse that is used to manipulates the graphical images on a monitor.

Internet — A system of networks that connects computers around the world.

Mechanical Drawing — A 2-dimensional representation of a part depicted by orthogonal views that shows the dimensions of the part.

Network — A group of computers interconnected to each other through a series of telephone wires or radio signals.

Parts — A 3-dimension representation of an object within a CAD software document.

PowerPoint — Slideshow presentation software produced by Microsoft.

Software — A combination of programs, routines and languages that control computer hardware.

SolidWorks™ — Commercial 3-dimensional modeling and mechanical design software.

Treatment Group — A group upon which an experimental condition is placed to determine the effects that that experimental condition will bring.

Tutorial — A book or program that provides special instruction on how to complete a task in a software program.

Tutorial-based Learning — Learning that is based on using tutorials to teach concepts about a specific task.

Web-based Instruction — Instruction from a class that is based primarily on the Internet. The student receives all instruction over the Internet

Web-based Tutorials — Tutorials that are made accessible to the students over the Internet.

WebCT™ — An online course delivery software used by many universities and educational organizations to instruct students over the Internet.

Windows-based — Software that utilizes the Windows operating system.

World Wide Web — The complete set of documents on all Internet servers that use the HTTP protocol.

CHAPTER 2

BACKGROUND AND REVIEW OF LITERATURE

2.1 INTRODUCTION

This study deals with the effectiveness of computer-based tutorials in a tool design class. More specifically, it deals with the use of these tutorials to guide students through lab assignments using CAD software. There are many relevant topics that apply to the background and literature review of this study. The review of literature consisted of a search of such topics as "the effectiveness of tutorial-based learning", "CAD education" and "computer-based instruction." Also, since the tutorials were made available to the students over the Internet via Blackboard, an extensive search on the topic of "web-based instruction" and its effectiveness was conducted.

Collecting background information on these subjects included a search of holdings in the Harold B. Lee Library at Brigham Young University, the ERIC (WebSPIRS) and Web of Science (ISI) databases, and a search of Internet sources.

Since very little resulted from searching these subjects combined, they were searched separately. A more in depth search was conducted in the area of web-based learning. These searches supplied several important reference sources including a variety of research done in the area of web-based and computer-based learning.

The information gathered from the review of literature is organized into two sections. The first section is an overview of computer-aided design, CAD education and training, using the Internet to administer CAD training, and CAD in the Tool Design class. The second section is devoted to computer-based instruction (CBI) and web-based instruction (WBI). This section examines the methods of administering CBI and WBI, the effectiveness of CBI and WBI as an educational tool, the uses of CBI and WBI in the training of CAD, and how this can be applied specifically to the tool design class. These topics will help create a better understanding of the background and previous research in this field.

2.2 OVERVIEW OF COMPUTER-AIDED DESIGN (CAD)

Computer-aided design (CAD) is the use of computer software developed for the "creation and manipulation of pictures (design prototypes) on a computer to assist the engineer in the design process." (Amirouche, 2004. p 10) Computer-aided manufacturing (CAM) also utilizes computer software to control manufacturing equipment and tools. CAM software typically takes the "pictures," or computer files, from the CAD software and implements it into itself. In today's world, both CAD and CAM are used together in product development and manufacturing.

In the past CAD has stood for "computer-aided drafting" because in the early days it replaced the old flat drafting tables, pencils, erasers, T-squares, triangles, compasses and circular templates etc. by allowing users to draw a representation of the arcs or line that would normally be in a mechanical drawing on the screen of a computer. Now CAD means "computer aided design" because the computer can graphically represent the product in an accurate 3-D environment and allow the user to change features on the part to match the desired geometry. Figure 2.1 shows some examples of CAD models and CAD drawings.

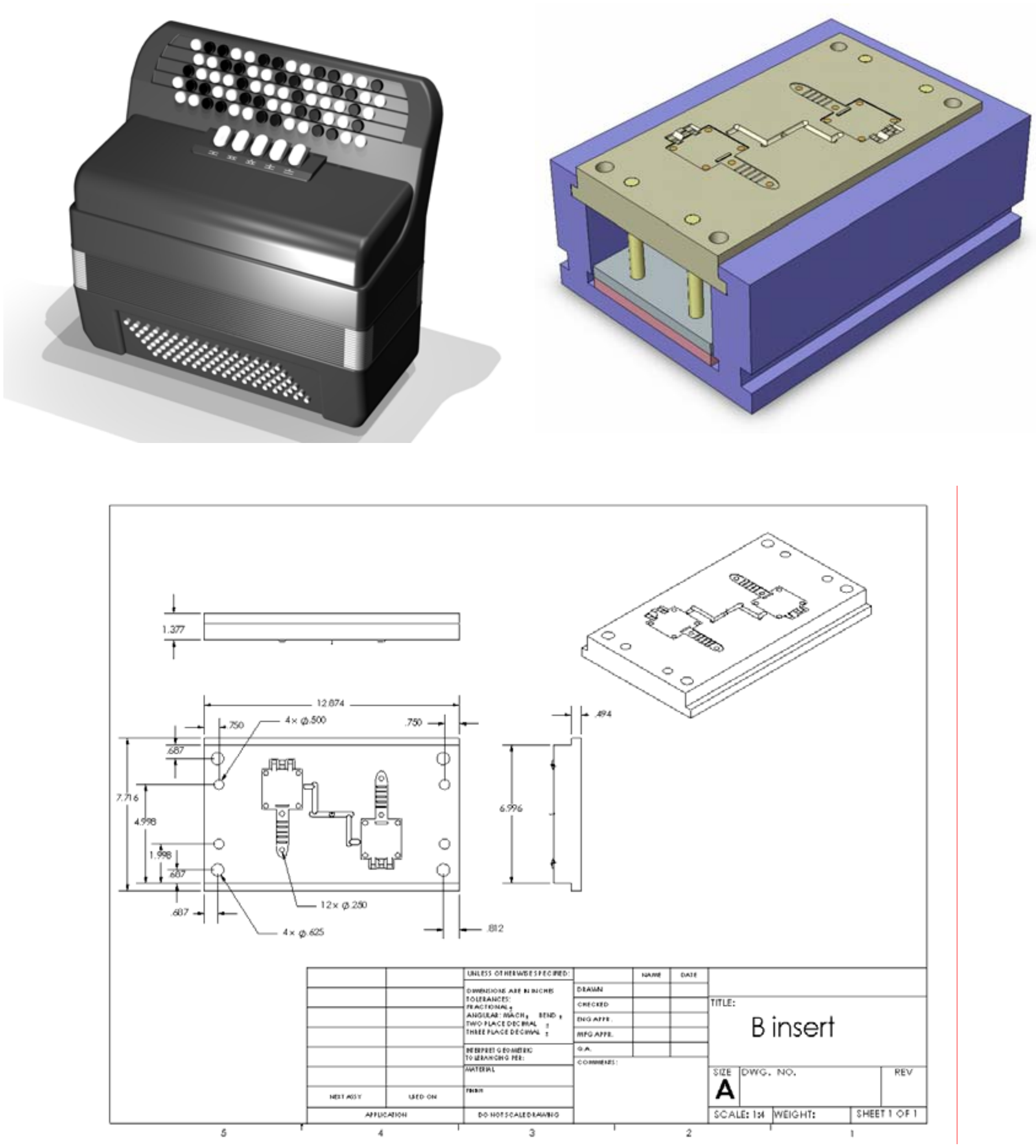


Figure 2.1 Some examples of CAD models and drawings

When computers were invented about the middle of the 1940s, they served as the first machines invented by humankind that could perform complicated mathematical calculations efficiently. (Amirouche, 2004) This meant that computers could now serve as an effective tool for design and engineering.

The first graphical representation on a computer was in the mid 1950s when the government used Semi-Automatic Ground Environment (SAGE) to convert radar data into computer-generated images. These images could be accessed and analyzed by the means of a light pen touching a Cathode Ray Tube (CRT) screen. (Amirouche, 2004)

The first software developed for engineering and manufacturing was in 1957 when Dr. Patrick Hanratty developed PRONTO. This was the first commercial CAM system. It interfaced with a machine tool allowing for the creation of simple shapes like rectangles and circles. (iMB, 2004)

In 1963 Ivan Sutherland developed SKETCHPAD, software that allowed a user to draw 2-D engineering drawings on a cathode ray tube (CRT) screen with the use of a light pen. This gave the user the ability to interact with the design on the computer. Before that time, all the design data was entered into the computer in the form of number, or code, making the process of design complicated.

In addition to being the first graphical representation of engineering drawings, SKETCHPAD introduced many ideas used in modern CAD systems, like the ability to zoom it and out an a drawing and saving a document on the computer’s memory. (SUN, 2004)

In the 1970s, CAD software became popularly used in industry as a replacement of manual drafters. Before that time it was primarily used and developed in research facilities in conjunction with large automobile and aerospace manufacturers. It was during this time that IBM and Lockheed developed CADAM. (CADAZZ, 2004)

During this decade the computer became more advanced in what it could do as processors and microchips allowed for the development of more affordable computers.

As a result, CAD software became more advanced. In 1977 Avion Marcel Dassault, a French company; enlisted its engineers to create a three dimensional interactive program called Computer-Aided Three-Dimensional Interactive Application or CATIA. This served as the first 3-D modeling CAD software. In 1981 this company became Dassault Systems. (iMB, 2004)

As computer systems and hardware have gotten more advanced and less expensive, CAD has moved into all areas of product development and manufacturing, from industrial designers to engineers to tool designers to machinists.

In the past thirty years, CAD has become a valuable resource for the design and manufacturing industries, especially 3-D solid modeling. This has allowed engineers and designers to better visualize a product long before it is released to manufacturing. With 3-D solid modeling, complex assemblies can be analyzed to determine how the separate components will fit together and interact with each other. In addition to this, a CAD file can be easily transferred into CAM software for manufacturing purposes.

Companies which develop and sell CAD software have made the software so that it is less complicated to learn and understand than it was five or ten years ago. This allows engineers, designers, and toolmakers to focus more on the design of the product or the manufacturing too rather than how to work the software.

2.3 CAD EDUCATION AND TRAINING

As companies have implemented CAD into their design processes, there has been a need for training and education of this software. In addition to training their own workers, companies have needed more graduating students who enter the workforce to be proficient in the use of 3-D CAD and other engineering software. (Briggs, 2001) Many students are not receiving the background in how to implement many of the modern technologies used in industry. (Newman, Whatley & Anderson 2003) This can be the same with 3-D CAD software. This section reviews training in 3-D CAD and some of the ideas about how it should be done in schools and industry.

Training in this software in industry is done in a number of ways. Many companies and organizations choose to use an informal training methodology to train their employees. The workers learn how to use the software through on-the-job training; either through their own experience or through being mentored and trained from a co-worker who already knows the software. Many companies also offer to their employees a formal training course that teaches the CAD software. Formal training means that the training occurs in a classroom at a set time and with learning materials separate from the manuals that typically accompany the software. There are advantages to both types of training. Informal training tends to bring about lower skills in the people being trained, but they are more satisfied with their training. Formal training brings about a higher level of skills in the workers but it can be expensive to pay for the extra training. (McDermott & Marucheck, 1995)

Many venders offer courses in their software that cover a whole range of abilities of the software from simple parts and drafting, to complex surfacing and manufacturing.

(Amirouche, 2004) The vendors of SolidWorks™, a 3D CAD software package, offer formal training courses to train the users of their software. The basic training course takes four days to complete. (SolidWorks, 2004) This class usually takes place at the vendors' facilities but they can also come out and train on-site if the customers demand is sufficient. Similarly, the vendors of CAMWorks™, a third party CAM software used with SolidWorks™, offers a one-day training course which cover all the basic functions of the software. UGS, another 3D CAD software package, offers one to four hour online courses. A qualified instructor teaches these courses over the Internet. The students can ask questions and receive answers, view demonstrations and practice what is learned by doing hands-on exercises. (UGS, 2004) These courses are taught out of training manuals that have been specifically developed to teach these courses. In addition to these classes and training manuals, additional tutorials are available with the software to train the user on their own.

In colleges and schools the training with regards to 3-D CAD in usually formal. There are set class times with an instructor. This serves better for the students because they can gain a better knowledge of the background of the software. Concepts in 2-D drafting like drawing lines and arcs, which can be examined in these classes, are helpful in the training of more complex 3-D CAD concepts. (Begler, 1998)

It is widely believed that the most effective way for a student to learn a technical skill is through interacting with the technology directly, or by actually using and doing it. (Sung & Ou, 2002) (Fletcher, 2001)(Wilkerson & Elkins, 2000) The same holds true for 3-D CAD design. This is why informal training is in many cases preferred to the formal training. Students and workers get to actually handle the software to get a better idea of how to use it.

In schools CAD can be learned informally. Students in manufacturing take classes that require them to design something and they have to find out on their own how to use the software. Informal training could be utilized in schools by means of tutorials that show the students how to work the 3-D CAD software. This enables the students to work on their own at their own pace. One study used side-by-side screen images of the software in a tutorial format, a tutorial that showed the written steps of how to use the software along with images, and a traditional learning method to determine which method is the most effective. Students using the first two tutorials didn't even use a computer or the software as they worked through the tutorial. The results show that while using the tutorials didn't show any significant improvement in the learning skills of the students, they did show that the students did learn the material faster and more efficiently. These kinds of tutorials provide a means through which students can learn CAD concepts faster to help them in a normal semester. It also can provide a means whereby companies can train employees cheaply and efficiently especially when the employees have opportunities to use that training daily in their work. (Martin-Michiellot & Mendelsohn, 2001)

2.3.1 THE INTERNET AND CAD TRAINING

In the past decade, the Internet has revolutionized the way training in technology can be done. It has been shown that an Internet-based tutorial can be successfully implemented in other technical areas in Manufacturing Engineering Technology. (Wu, 2002) Technical skills in manufacturing software like 3-D CAD can also be introduced over the Internet. In one instance, students from Canada and US participated in a CAD/CAM class that was offered online. The students were given all of the syllabi, lectures, and assignments along with an email link to the instructor all over the Internet. They responded to interviews and questionnaires concerning their learning. In addition to being convenient for the students, this class was shown to be effective in teaching the principles of the CAD/CAM software. Most of the students who took the class indicated that they would take the class again if the opportunity presented itself. (Wilkerson & Elkins, 2000)

Training over the Internet in CAD can be enhanced by the development of virtual reality (VR) models that can be made available over the Internet. These models can show students in a 3-D environment how to better interact with the software. The study confirmed that students benefited from the models because they gave the students opportunities to learn by actually doing the assignment. (Sung & Ou, 2002) These models provide an interactive method of teaching known as Intelligent Tutoring Systems or ITS. These systems will be examined in greater depth in a later section of this chapter.

2.3.2 CAD IN THE TOOL DESIGN CLASS

CAD software is utilized in many areas of a Manufacturing Engineering Technology student's studies. As a freshman, students take an introductory course in computer graphics and mechanical drawing. This class also teaches them a 3-D CAD system on a basic level. In the same year they learn from another class the fundamentals of CAM software and how to use is. Tool design is typically taught to students during their senior year after many students have forgotten how to use CAD software. During the past fifteen years, the tool design class has served as a way for senior students to review CAD software before they graduate and enter the workforce.

CAD is used in this class as part of a lab time aside from the usual coursework taught during the class time. These labs occur once a week in a computer laboratory where there is a hired teaching assistant present to help the students when they have questions. These labs last about two hours each allowing the students ample time to complete each lab assignment. If this isn’t enough time the students can come back at open lab times throughout the week.

Until about 15 years ago all the mechanical drawing associated with the tool design class was done on a drafting table with a pencil. In the 1990s the students started to use simple 2-D drafting software that allowed them to draw lines and arcs and print these drawing of on a plotter. Since this software was in a 2-D environment, after a brief orientation from the lab instructor most students were able to figure it out quite easily. Figure 2.2 shows an example of a typical 2D CAD drawing a tool design student would have dealt with at that time.

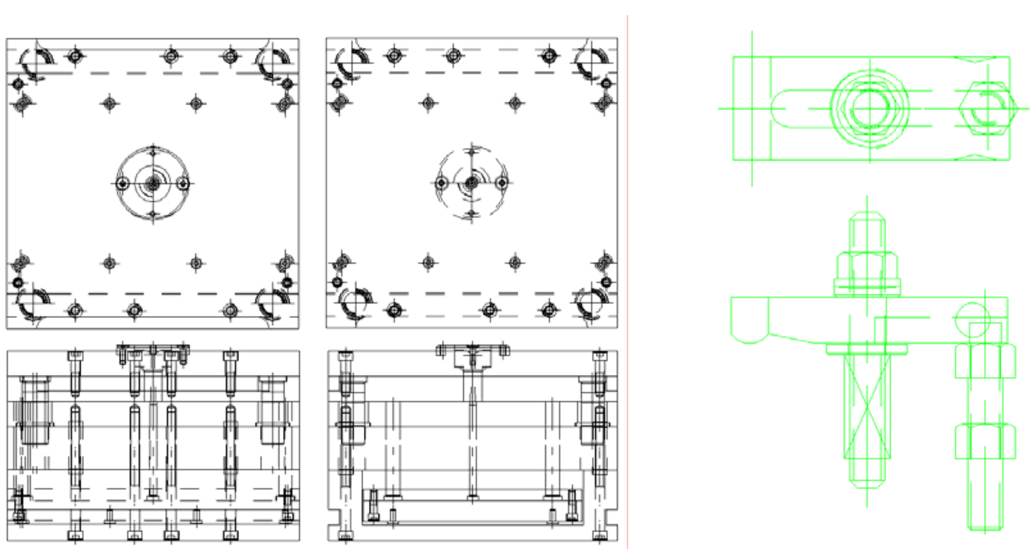


Figure 2.2 Examples of 2D CAD drawings

In recent years 3-D CAD software like SolidWorks™, ProEngineer™, SolidEdge™ and Unigraphics™ have been used to do all of the lab assignments. While the tool design students are not required to use a specific version of CAD software, it is now strongly recommended that they use 3-D CAD software so they can gain a better understanding of what is used in industry. This 3-D software tends to be more complicated than the 2-D lines and arcs of the simpler 2-D CAD software. Figure 2.3 shows examples of some 3D CAD models typically used in tool design. The teaching assistants are not always adequately trained to help the students understand how to run the software well enough to do the assignments. Also, even if the teaching assistant knows a certain 3-D CAD software package, it doesn't mean the other students in the labs will use it. Because of this, the students in these labs have needed more guidance on how to do these assignments.

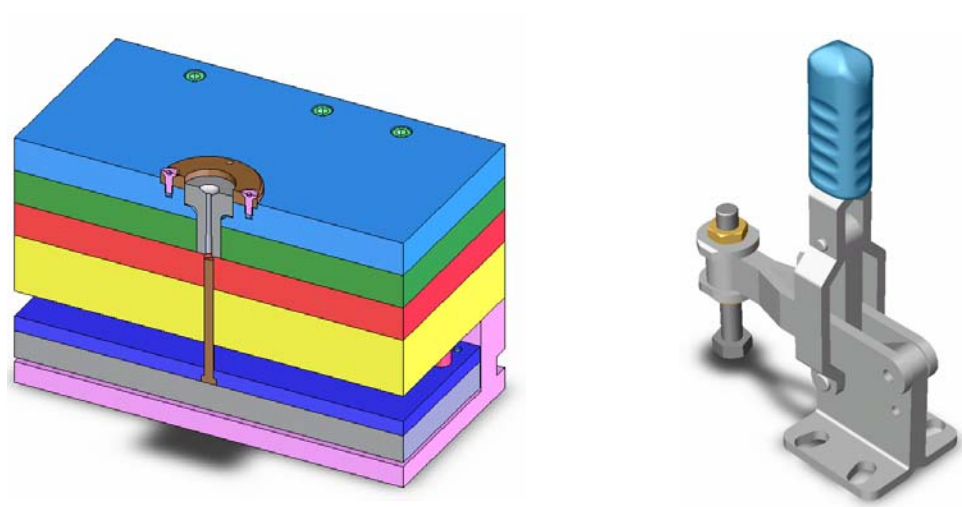


Figure 2.3 3D CAD models typically used in tool design

2.4 OVERVIEW OF WEB-BASED AND COMPUTER-BASED INSTRUCTION

This study examines the effectiveness of computer-based tutorials on the education of tool design students as they learn 3-D CAD software as it applies to their laboratory assignments. These tutorials were made available to students over the Internet through the use of a web-based instructional software called Blackboard. This section takes a closer look at the use of computer-based and web-based instruction and its effectiveness in advancing the learning of students.

In many cases, web-based instruction (WBI) and computer-based instruction (CBI) are considered to be the same thing. CBI deals with any kind of learning that is initiated by means of a computer. In today's world computers are so integrated with the Internet that implementing the CBI over the web is obvious. WBI occurs when the learning and instruction by means of a computer is done over the Internet. (Olson & Wisher, 2002) This next section gives a brief history of both.

Computers have played an important role in education. With the advent of the World Wide Web (WWW) in the past fifteen years computers can now assist in the actual delivery of information to students in addition to classroom instruction. In many cases, course delivery over the Internet can even replace the classroom experience altogether. In addition to that, the Internet can be used for communication and interaction with not only the instructor of the course, but also with other students taking the course.

Computers were first able to communicate with each other over a network as early as the 1960's. This was first done through sending a message or email on time-sharing computers that were hooked up to each other. In 1969 the United States government used ARPNET (Advanced Research Projects Agency Network) to link various researchers to remote computer centers throughout the world. These researchers wanted a way to send and receive messages to these centers as a way to monitor their progress on various projects. As a result, in the early 1970's an email function was added to the ARPNET system. In 1978 a Bulletin Board System (BBS) was added to the personal computer that allowed users to post messages on an online message board. (Harasim, Hiltz, Teles & Turoff, 1995) Later on, in 1986, the National Science Foundation Network (NSFNet) was set up linking five supercomputers throughout the country. This later became the backbone of today's Internet. (Harasim, Hiltz, Teles & Turoff, 1995) These advances in Internet and communication technology became the basis for using the World Wide Web as a resource in education.

Although computers have been used for instruction as early as 1957, (Olson & Wisher, 2002) delivering the instruction over a network didn't happen until the late 1960's with the development of Computer Aided Instruction (CAI) systems. In 1969 these systems were used over a network to teach lower income student math in Mississippi, Kentucky and California. (Harasim, Hiltz, Teles & Turoff, 1995)

During the next two decades as networking technology became more advanced so did the means of delivering instruction over these networks. In 1995, the computer science department of the University of British Columbia started to develop a learning management system (LMS) In 1996 the first beta release of the software occurred. This software was known as WebCT™. In February of 1997 University of Massachusetts began using it as a prototype and by September of that year there were the first courses offered using WebCT™. (UMass, 2004) In 1997 Blackboard LLC was founded " . . .with a vision to transform the Internet into a powerful environment for the educational experience." (Blackboard, 2004) Today WebCT ™ is used in more than 70 countries around the world with thousands of users. Blackboard also has expanded to many colleges and universities throughout the world. (WebCT ™, 2004) (Blackboard, 2004)

2.4.1 COMPUTER-BASED INSTRUCTION (CBI)

Computer-based instruction (CBI) uses computer software as the primary source of learning for a student. (Olson & Wisher, 2002) This software is usually in the form of tutorials that present the material by means of audio, video, illustrations and quizzes. Through these media instruction is demonstrated to the students. The tutorials and learning resources are typically accessible only on a computer in a fixed location as oppose to over a network where students can access the tutorials anywhere. CBI materials are usually in the form of a CD-ROM or other permanent file system that is unalterable. Updates to the course curriculum can take more effort because the instructor or tutorial designer has to go back and redesign the tutorial before another CD-ROM can be produced. There are typically three main formats that CBI tutorials and learning aids can be in:

- **Drill and Practice**. This deals with a series of computer-based exercises aimed at teaching the student by means of repeated practice.
- **Simulation**. Simulates complicates concepts so that the students can better understand certain process. One study implements this format to teach ecology students population growth. It was shown to be an effective alternative to a laboratory because students spent more time learning the concepts of population

growth rather than wasting time dealing with equipment. (Korfiatis, Papatheodorou & Stamou, 1999)

- **Tutorial**. This format deals with the training of students by means of explaining the concepts, showing the concepts, testing the concepts, and selecting the next step of the subject. (Inoue, 1999)

CBI can be a great instructional resource to teachers and students. If implemented correctly, CBI can reduce the cost of instruction by a third. Also, it can either reduce the time of instruction by a third or increase the quality of instruction by a third. This successful implementation of CBI is called "The Rule of Thirds". (Olson & Wisher, 2002) (Fletcher, 2001) This depends, however, on how well the CBI tutorials and learning aids are designed. If it takes a lot of time and effort to develop and maintain the tutorials it might not be worth the benefits. Also, many instructors who develop CBI are not familiar enough with instructional design to design it effectively for the students. (Burgess, 2003)

It has been documented that CBI can be effective in educating students. A 1991 paper evaluated 254 separate studies on the effectiveness of CBI in the classroom. These studies covered CBI in all grades of study from elementary school to college-aged students. These studies included an experimental group using the CBI and a control group that used classroom instruction. Examination scores were analyzed to determine the effectiveness of the CBI compared to classroom instruction. It was determined that CBI had a positive effect on the learning of all of these students. (Kulik & Kulik, 1991) This shows that instruction can be effectively implemented by means of a computer.

Intelligent Tutoring Systems

There is a fourth format the CBI materials can be in that interacts with the students to enable more effective learning. This format is known as an Intelligent Tutoring System or ITS. ITSs are designed so that they will dynamically adapt the instruction to a student. This in done by providing help and coaching that is relevant to the learner no matter what situation the learner is in. ITSs also have some form of error detection integrated into the system that indicates if the student is responding incorrectly and provides feedback to the student. (Orey, 1993) This is done through software that is programmed to accept input from the students concerning the material and processing it. The computer determines is the input is correct and provide the appropriate feedback.

ITSs have been shown to be effective in instances where they are implemented and tested against traditional classroom instruction. (Inoue, 1999) (Frith, Jaftha &Prince, 2004) (Orey, 93) (Olson & Wisher, 2002) The setback to this is that they can take a lot of time and resources to develop. It can require hundreds of hours of programming and testing to create one hour of instructions with ITS. (Orey, 1993)

2.3.2 WEB-BASED INSTRUCTION (WBI)

Web-based instruction (WBI) is similar to CBI only that it is distributed over the Internet. Its main advantage is that students can have access to the instruction at their own convenience. It virtually eliminates the need of scheduled class hours and a dedicated computer facility, if the course requires a computer to be used. (Chui & Wright, 1999) Compared to CBI, WBI is more flexible, more accessible, allows for easier access to other resource via the Internet, and allows for easier communication between the students and the instructors. (Olson & Wisher, 2002) The flexibility comes from the fact that Internet resources can be updated quicker and easier than a fixed CBI tutorial. If a course is updated, or new curriculum added, the instructor can easily go back and update the WBI tutorial. The tutorials and learning materials are more accessible to students in that they are able to access the instruction at anytime during the day or for any length of time they need. The WBI can have other resources associated with it like links to other websites or other readings for the students to read. Also, the instructors and other students can be easily contacted through email and instant messaging for a more personalized help.

WBI can be implemented in many ways. Galloway (1998) describes a three-level model for Internet usage in course delivery. The first level uses the Internet as a supplementary tool to provide supporting material for the class. It is also used as a tool to manage the class and the instruction of the class. Level two uses the Internet for actual delivery of instruction. Assignments are handed out and turned it by email. Level three is structured such that all interaction between the instructor and students is done through the Internet. This model describes the way the Internet is utilized in college education.

College courses are offering more resources online to aid the students in their learning. In addition to this, universities have moved to WBI courses as a means to attract students who are not able to attend traditional classes. (Burgess, 2003) Because of this software has been developed to ensure adequate delivery of this instruction over the Internet. This software not only makes the instruction material available to students in a secure, safe environment, but also allows the students and the instructor to communicate with each other during the course. This software allows the instructor to fully implement a web-based environment with the course materials without having to have the technical know-how of being able to write and program web pages. (Morss, 1999) This software is known as course delivery software. Some examples of this software are WebCT and Blackboard.

These course delivery software packages have been studied to determine their effectiveness in teaching students. For the most part they are successful. One study surveyed students taking a technical education class about their perceptions of WebCT. During that particular semester most students reported that they felt comfortable using WebCT even though it was their first time using it. Most of these students indicated that they would use it again if the opportunity permitted even if the only interaction the students had with the professor was through the Internet. (Burgess, 2003) Another study examined the benefits of using Blackboard to enhance a graduate-level course in school counseling. The study focused on whether Blackboard facilitated learning in students. This effectiveness was measured by examining student usage records from Blackboard and the evaluations of students and instructors. It was determined that there was no significant difference between the students using Blackboard and the ones that didn’t by means of the student evaluations. However, the instructor felt that student learning was enhanced by the fact that learning materials were made available to the students online outside of class time. (Klecker, 2002)

2.4.3 THE EFFECTIVENESS OF WBI, CBI

For the most part, it has been shown that students can learn skills just as well from online sources as in the classroom in a traditional setting. Davies and Mendenhall (1998) studied 112 students taking a physical education class. 37 of these students took theirs studies online. To measure how well they learned, test scores were taken and examined. It was determined from this that the students taking the course completely online had learned just as well as the students who took the class. Other studies strengthen this conclusion. In a study conducted at the State University of New York, 64 freshman English students learning library research skills were examined as to whether learning these skills was better facilitated by online means. Of the group, 24 students were taught in a classroom environment and the remaining 40 students used only online tutorials developed for this material. Pre and post-tests were administered to determine the level of learning. The conclusion from this study is that students learned just as well from online means as in the traditional classroom environment. (Nichols, Schaffer & Shockey, 2003)

Cherry, Yuan and Clinton (1994) tested the effectiveness of an online tutorial in teaching students how to use computer-based library search software. A control group and a treatment group were set up each having fifteen students in them. The treatment group used the tutorials while the control group did not. The students' performance was evaluated by a pretest an exercise in using the software and a post-evaluation. From the analysis of the data that was collected it was also determined that there was no significant difference between the two groups in terms of how well the performed on the performance evaluation. However, students believed that the tutorial helped them answer questions in an exercise. (Cherry, Yuan & Clinton 1994)

Olson and Wisher (2002) examined 47 different studies on whether WBI was effective at classroom instruction. The conclusion from this was similar to the previously stated hypothesis: that there is no significant difference in WBI compared to classroom instruction. In fact there appears to be even a slight advantage to WBI.

2.5 CONCLUSIONS

These studies show that the Internet and WBI can be implemented as an effective alternative to a classroom environment. Students can learn just as well from online instruction as well as in class. Students can also learn a technical topic such as Wire EDM controls by means of an internet-based tutorial. (Wu, 2002) What is unknown, however, is the effectiveness of how well students learn 3-D CAD principles as they apply to tool design with the aid of computer-based tutorials. This study seeks to determine this.

As the web-based learning technologies like Blackboard and WebCT spread across the campuses of universities, more and more classes will utilize it to give instruction to students. It is important to know the effect this has on how well students learn from it, as this will justify the costs of updating the software and the lessons. This is true for the tool design class at BYU as 3-D CAD software can be difficult and time consuming to both teach and learn. Using WBI might prove to be the best way to distribute instruction in this area to students. This is why the topics discussed in this review of literature show an appropriate background for this study.

CHAPTER 3

METHODS AND PROCEDURES

This chapter describes the methods and procedures of the study. It begins with a brief overview and is followed by three sections that describe in greater detail the procedures of this study. These sections include (a) description of the tutorials used in the study, (b) design of the study and (d) data collection and analysis.

This study used students in the fall 2003 semester class of MFG 431 tool design, taught at Brigham Young University. The software used in the study was SolidWorks™ 2003 Educational Edition, a mechanical 3-D CAD program that is Windows based. The tutorials developed for this study was developed using Microsoft PowerPoint™. They were made available online to the treatment group of the study. The control group in the study did not have access to the tutorials. Quizzes were passed out three times throughout the semester to the students in the labs as a means to test how well the students learned the 3-D CAD design concepts as they applied to the lab assignments.

3.1 TUTORIAL DESIGN AND DEVELOPMENT

The tutorials were designed to provide a step-by-step guide through each of the lab assignments. They were developed on Microsoft PowerPoint™ using a slideshow format. PowerPoint™ was chosen as the software to use for these tutorials because it is easy to create slides with, which is the format of these tutorials. It is also easy to show the steps the students need to follow by taking screen shots of the working SolidWorks™ software and pasting it into a slide. Arrows could be placed to show where the students should move their mouse to and click to enable commands in the software, showing them exactly how to navigate through the various menus.

The format of these tutorials would show a slide with a written description of each step of the lab assignment followed immediately by another slide showing how to do it in SolidWorks™. This format was chosen, as opposed to an interactive, intelligent tutoring system, because it is easy to update and change as the software upgrades are released from year to year, or if the lab assignments change. Also, interactive tutorials would require an enormous amount of programming time for a teaching assistant to update, assuming they had the programming skills. Figure 3.1 shows an example of the format of the tutorials.

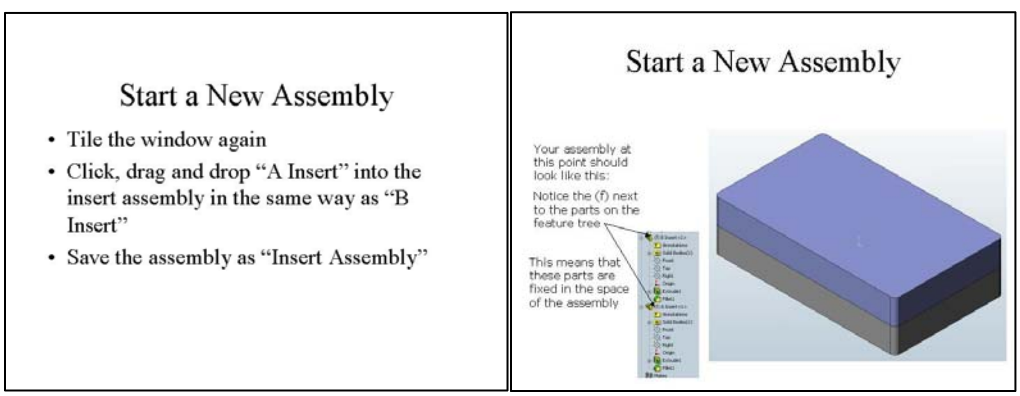


Figure 3.1 Sample of the tutorial format developed for the tool design labs

There are a total of four separate tutorials used in each of the laboratory assignment throughout the semester. Appendix A shows an example of the first tutorial. They are described as follows:

- **Introduction to the SolidWorks**. This serves as an introduction on how to use the software. It guides students through designing a simple c-clamp, including assembly of the components and generating a mechanical 2-D drawing. Based on previous semesters it is estimated that the student will take about three hours to complete this tutorial.
- **Go/no-go Gage Assignment**. This tutorial shows how to design a go/no go gage, a tool used to measure that accuracy of a hole or a shaft. While students on their own have to figure out the size and the shape of the tools they are designing, this tutorial shows them how to engrave text on the face of the tool and change the properties of dimensions in a mechanical drawing. The estimated time to complete this tutorial is two and a half hours if the student knows all of their design parameters in advance. This estimate is based on how long the students took to complete this tutorial in previous semesters.
- **Fixture/Jig Assignment**. This tutorial guides the students through the design of a fixture and a jig by importing part files from online databases and orienting these parts in an assembly. It is estimated that the student will take about four hours to complete this tutorial assuming that the student is fully aware of their design parameters. This estimate is based on how long the students took to complete this tutorial in previous semesters.
- **Injection Mold Assignment**. The fourth tutorial deals with design and assembly of an injection mold. Through this assignment the student is introduced to the idea of an intermediate assembly in order to get the mold insert cavities and assembly features such as extruded and revolved cuts. This tutorial is estimated

to take about five hours to complete as long as the student knows their design parameters. This estimate is based on how long the students took to complete this tutorial in previous semesters.

These tutorials were developed to instruct the students using SolidWorks™ 2003 CAD software. The first tutorial, which covers the clamp assignment mentioned above, took about twenty hours to develop. The second tutorial, the go/no-go gage design assignment, took about ten hours to develop. The third tutorial, the fixture/jig assignment tutorial, took about fifteen hours to develop. And finally, the Injection Mold tutorial took about twenty-five hours to develop. This included determining the design of the tutorial in a way that would show the students exactly what they needed to know in order to complete the assignment.

SolidWorks CAD Software is updated almost every year. These new versions tend to result in the changes in the graphical user interface (GUI) or the addition of new features that were not available in previous versions of the software. Because of this fact, these tutorials are designed so that a teaching assistant could update them quite easily. Table 3.1 shows the approximate time it would take someone to go through each tutorial and update them to the newer versions of SolidWorks software as it comes out each year. These estimation times are based on the times it took to update the tutorials to the current version just prior to the semester this study took place.

Table 3.1 Tutorial development times

Tutorial	Initial Hours to Complete	Estimated Hours to Update
#1 C-Clamp	20	8
#2 Go/No-go Gage Design	15	6
#3 Fixture/Jig Design	15	9
#4 Injection Mold	25	20

3.2 THE STUDY

Because of the demands of the normal laboratory and class assignments which occur throughout the semester, an experiment was set up to determine the effectiveness of the tutorials without adding to the students' workload. The hypothesis to be tested in this experiment was the null hypothesis, or that the tutorial has no effect on how well the students learn the 3-D CAD software while doing the laboratory assignments. More specifically the hypotheses tested were:

(c) There is no significant difference in the quiz score, which for test the learning of basic 3-D CAD principles as they applied to the lab assignments, between the students who used a tutorial and those who did not.

(d) There is no significant difference in the amount of time taken by each student to complete a given design assignment that utilizes the skills gained from the lab assignments.

To test these hypotheses, the students taking tool design were divided into two groups. One group of students used the tutorials as a source of help for completing the lab assignments. In addition to using the tutorials, a teaching assistant would be available to answer questions and help explain concepts that were unclear. The teaching assistant would also be able to give software demonstrations to the lab if most of the students in that lab section requested it. This group was called the "treatment group." The control group did have a teaching assistant available to them as a source of help but did not have access to the tutorials.

A pretest was administered at the beginning of the semester to show a starting point as to where each of the students were in terms of their knowledge of CAD software, more specifically 3-D CAD software. This pretest consisted of the following items:

(a) A short design project that the students were suppose to complete on their own.

(b) Three questions dealing with how well they did on completing the assignment.

For the first part of the pretest, the students recorded the time they took to complete the project. On the second part the students answers were given a value form one to five depending on how well the students' understanding was of what was asked.

Throughout the semester, as students completed lab assignments, three quizzes were given to determine what the students learned. Each of these three quizzes consisted of two sections:

(c) Ten questions that require an explanation of concepts learned from the lab assignments.

(d) A short design project that incorporates the skills learned by doing the lab assignments.

Data was collected from both the pretest and these three quizzes and analyzed. From the ten-question section of the quizzes, a graded score was used. From the short design project section of the quiz, the students were asked to record their time. This section shows the details of how this study was set up.

3.2.1 PRETEST

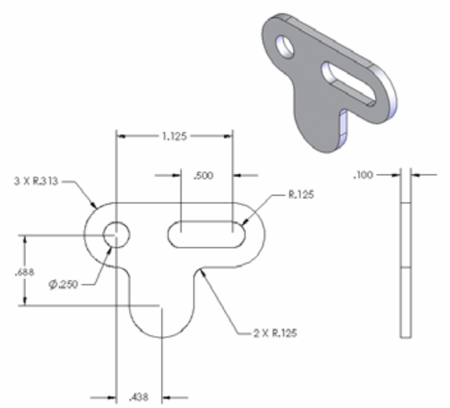
At the beginning of the semester all of the students in the class were given a pretest or pre-evaluation as to where they were in terms of their knowledge of CAD software. This pretest was given for the purpose of the study and is not typical for the tool design class. The pre-evaluation is shown in Figure 3.2.

MFG 431 TOOL DESIGN

<u>Initial CAD Survey</u>

Assignment

1. On your own, without the help of any classmates, draw the following part in a 3D Cad system.



2. After completing this answer the following questions on a separate piece of paper.
   a. How long did this take you to complete?
   b. List the steps you took to complete this.
   c. What were some of the struggles you had with this?
   d. How familiar are you with 3D modeling and CAD systems?
   e. How do you feel about using SolidWorks this semester?
3. Put your name on this paper and turn it into Bro. K. by Monday Sept 8th at 5:00 PM

Figure 3.2 Initial CAD survey

Data was taken from this pretest and used in the final analysis of the study. For question (a), the students recorded the time they took to draw the part in a 3-D CAD system. The second, third and fourth questions were taken and awarded a score from one to five based on the following criteria:

- For the second question, or question (b), a score of five was given if the student listed the steps of completion in a manner that demonstrated that they had a working knowledge of the software. A score of one was awarded if the students didn't demonstrate that they knew how to complete the assignment.

- For question (c), if the student indicated that they didn’t have any struggles with this they were given a five. If they listed a lot of struggles they had with it then they were given a one for this question.
- For question (d), if the student explained that they were very familiar with the CAD software and especially SolidWorks™ then they were given a five. However, if the student didn’t know how to use the software then they were given a one.

Since the final question was designed to see how the students felt about learning this particular software package, it wasn’t used as part of the data.

The teaching assistant who graded the scores of the pretest was the same person who graded all of the students’ pretests. This teaching assistant had many years of experience and skill not only in the field of 3-D CAD design but also as a tool designer.

The data from this pretest was used in the statistical analysis to determine how much the students who used the tutorials had learned compared to those that didn’t.

3.2.2 LAB SETUP

MET 431 tool design is a three credit hour class which, in a typical semester, is taught twice a week for an hour each class period. In addition to this, there is a two-hour laboratory session taught every week in a campus computer lab. In these labs the students are given laboratory assignments that are separate from the assignments handed out in class. Each lab assignment is designed to help the students become familiar with CAD software and to see how it applies to designing manufacturing and production tools.

For this research, the class was divided into two groups of students. As previously mentioned, one group was the control group (without tutorial) and the other was the treatment group (with tutorial). There were a total of five lab sections associated with this class, the students in the three labs which occurred during the first half of the week became the treatment group and the students in the two labs during the last half of the week became the control group. Table 3.2 shows the weekly layout of the lab and which lab sections were designated the treatment and control groups. The labs that are highlighted blue were the treatment group and the labs highlighted red were the control group.

Table 3.2 Weekly layout of the lab sections

Monday	Tuesday	Wednesday	Thursday	Friday
Lab 1	**Lab 2**		**Lab 4**	**Lab 5**
	Lab 3			

The students were not previously assigned to a specific control group as they enrolled for the lab times that best fit their schedules. All of the students had different backgrounds and experiences in 3D CAD prior to taking the tool design class. It was noted that there were students of various skill levels in both test groups. The purpose of the pretest score was to account for these different skill levels of the students. The statistical model weighs the pretest score with the rest of the data collected.

The tutorials used for this research were designed specifically for SolidWorks™ software. Even though it was strongly suggested the students to use SolidWorks™, they were not required to use it to do the lab assignments. Those students who were more familiar with other CAD software packages were allowed to use them to do their assignments. The data collected from these students were not included in this study.

3.2.2.1 CONTROL GROUP

There were initially 18 students in the control group, 6 in the earlier lab and 12 in the later lab. Two students in the later lab opted to use different CAD software than what the tutorials were designed for so they weren't included in the study. This left a total of 16 students in the control group.

The students in these labs had access to a teaching assistant to assist them in their assignment. The teaching assistant provided occasional in-lab demonstrations of how to do each assignment, answered questions, and provided individual instruction to class members in each lab as they asked for it.

The students did not have access to any of the tutorials being tested for this thesis. However, other resources were provided online by means of online educational distribution software called Blackboard™. This included a SolidWorks™ tutorial from the manufacturer that showed the basics concepts of the software but didn't provide a step-by-step method of doing the assignments in the lab.

3.2.2.2 TREATMENT GROUP

In the treatment group there were initially 18 students. These labs had the number of eight, eight, and four, respectively. From this group two students decided to use other 3-D CAD software so their learning of the software wasn't measured. This left a total of 16 students for the treatment group.

In addition to having access to all manufacturers' tutorials and the teaching assistant's help and demonstrations that the control group had, this treatment group was able to use the tutorials developed specifically for this class. These tutorials were made available to them online via the Blackboard™ system.

3.2.3 TESTS FOR LEARNING

In addition to the pretest mentioned above, there were three quizzes administered to the students of both the treatment and the control group throughout the semester. Each of theses quizzes had two sections associated with them. Once again, these sections were:

(a) Ten questions that require an explanation of concepts learned about the 3-D CAD software from doing the lab assignments.

(b) A short design project that incorporates the skills learned by doing the lab assignments.

It was assumed that students who had learned more about the software and how to use it would not only score better on quizzes about that software, but would take less time to complete a given assignment because they would be more familiar with the software.

These sections of the quizzes were used to test the hypotheses discussed earlier in this chapter.

3.2.3.1 QUIZ #1

The first quiz covered the material that was learned by doing the first lab assignment. This assignment, as mentioned above, gives the student an opportunity to design and assemble the components that make up a simple C-Clamp in a 3D CAD system and construct a 2D mechanical drawing of those components. Figure 3.3 shows the ten-question quiz that was designed to test how well the students understood the concepts taught in this first assignment. Figure 3.4 shows the small design project quiz that tested how effectively the students used the software based on what they learned from the first laboratory assignment.

MET 431
SolidWorks Comprehension Quiz #1

Short Answer Questions:

1. A part in SolidWorks is built with features. What are features?
2. How do you begin a new part document?
3. How do you start a sketch?
4. What is the default sketch plane?
5. Two circles are placed in a sketch. How do you make them vertical to each other?
6. Give two examples of a feature that requires a sketch profile.
7. Give an example of a feature that requires a selected edge.
8. In an assembly feature tree, what does the “(f)” preceding the component mean? What does “(-)” mean?
9. What is the difference between “Edit Sheet” and “Edit Sheet Format”?
10. How do you place dimensions into a drawing?

Figure 3.3 Short written answer section of Quiz #1

Performance Quiz:

Model up the following drawing as a part file in SolidWorks and answer the following questions:

1. How long did this take you to model up?
2. What features did you use to create this part?
3. How do you feel about your progress in SolidWorks?

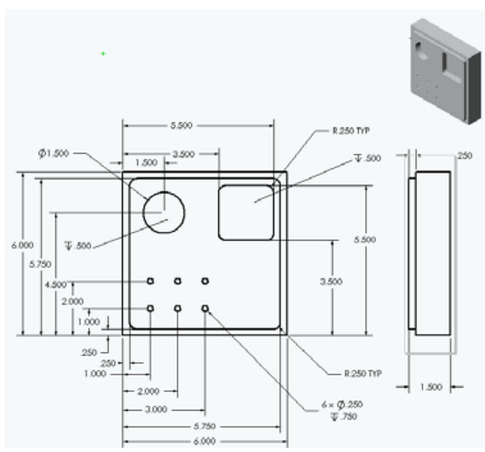


Figure 3.4 Performance Quiz #1

3.2.3.2 QUIZ #2

The students took the second quiz after completing the second lab assignment. The material the second quiz covered dealt with the design of a go/no-go gage used in many machine shops to measure holes and cylinders. The skills learned by doing this assignment included using and manipulating sketched text to make features, and manipulating dimensions in a drawing to redefine the accuracy and add tolerances. This quiz covered these topics and the concepts learned in the first assignment. Figure 3.5 shows the ten-question quiz and figure 3.6 shows the small design project quiz.

MFG 431
SolidWorks Comprehension Quiz #2

Short Answer Questions:

1. What is a Fillet feature?
2. What is a section view in a drawing?
3. How is a section view created?
4. What is the difference between **Edit Sheet Format** and **Edit Sheet**?
5. How do you change the drawing standard from ISO to ANSI?
6. How do you change the accuracy on a single dimension in a drawing?
7. How do you change the accuracy on all the dimensions of a drawing?
8. How do you move a dimension from one view to another?
9. How do you create text in a sketch?
10. This red feature is 1.000 inch long, what are two ways to make it 2.34562 inches long?

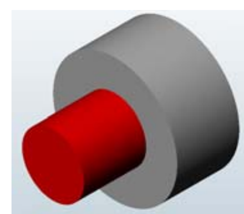


Figure 3.5 Short answer section of Quiz #2

Performance Quiz:

Model up the following drawing as a part file in SolidWorks and answer the following questions:

1. How long did this take you to model up?
2. List specifically the features uses in this model. What does it say in your feature manager? (EX. Boss extrude1, Cut Extrude 1 etc.)
3. How do you feel about your progress in SolidWorks?

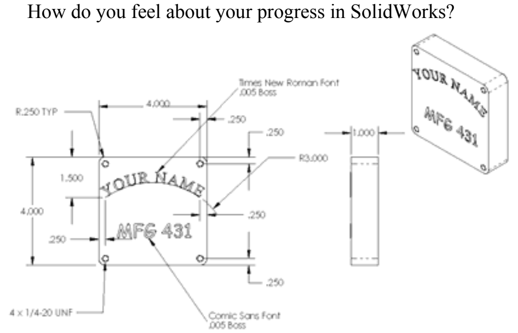


Figure 3.6 Performance Quiz #2

3.2.3.3 QUIZ #3

After completing the third lab assignment in Tool Design the students were give Quiz #3. This quiz covered the material learn in this assignment as well as material covered in previous assignments. Figure 3.7 shows the ten-question quiz that covers the material of the third tutorial as well as the preceding two tutorials. Figure 3.8 shows the small design project quiz that tested the students' effectiveness at the use of the 3-D CAD software with the background of the first three tutorials.

MET 431

SolidWorks Comprehension Quiz #3

Short Answer Questions:

1. How do you start a new Assembly document?
2. There are three ways to insert a component into an assembly. List two of them
3. In an assembly feature tree, what does the "(f)" preceding the component mean? What does "(-)" mean?
4. What is the difference between aligned and anti-aligned for a mate?
5. Two cylindrical components are in an assembly. How do you constrain them so they are 4 inches apart?
6. How do you move a component in an assembly?
7. How do you edit a mate in an assembly?
8. When you insert the first component into the assembly, how do you make it so the origin of the component is aligned with the origin of the assembly?
9. What is the easiest way to access the reference planes of a component in an assembly?
10. How do you make an exploded view of an assembly?

Figure 3.7 Short answer section of Quiz #3

Performance Quiz:

Take the parts in J: groups/mfg431/quiz3 and assemble them in the shown manner. The two plates should be directly above each other and 2 inches apart.

1. How long did this take you to model up?
2. How did you constrain the pins and bushings?
3. Are all of the components in the assembly fully constrained?
4. How many mating relations did you apply to each pin, bushing, plate?
5. How do you feel about your progress in SolidWorks?
6. How comfortable are you with working in assemblies in SolidWorks?

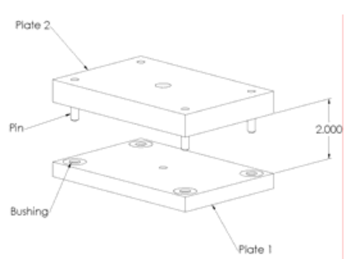


Figure 3.8 Performance Quiz #3

3.3 DATA COLLECTION AND ANALYSIS

Data was taken and analyzed from both the pretests and the three quizzes given throughout the semester. The teaching assistant used the same criteria for all of the students graded each of the three quizzes. The pretest and the quizzes were gathered and graded by the following criteria:

On the pretest, the students were asked to record the time it took them to design the simple part from the given mechanical drawing. In addition to this, the three short answer questions were graded on a scale of one to five based on how well the students answered each of the questions.

On each of the three quizzes, the short answer question sections and the timed sections were analyzed separately.

3.3.1 TEN-QUESTION WRITTEN ANSWER GRADING CRITERIA

For the short answer sections of the quizzes, each of the ten questions was graded on a scale of one to five points depending on how correct the answer was based on how well the students understood the concept being asked by the question. The same criteria were used to determine the scores of each question on the quizzes. The criteria are as follows

- A score of five was given to the question if the answer was completely correct and the student demonstrated they had a complete understanding of the material about which the question was asked.

- A score of four was given if the student showed a basic comprehension of the concept but either didn't use the exact terminology, or failed to point out the specifics of the material.
- A score of three a given to the question if the answer portrayed the correct idea, but was too vague.
- A score of two was given if the answer was wrong but showed that the student was aware of what the question was asking.
- A score of one was given if the answer to the question was totally wrong.

Certain questions required multiple answers or a list of answers. Scores awarded were based not only on how well the question was answered but also on whether or not all of the desired answers were there. Table 3.2 shows a sample question and the grade awarded to it.

Table 3.3 Examples of a graded question answers and the scores given to them

Sample Question: How do you move a component in an assembly?	
Student Answer:	Graded Score:
"Unconstrain it"	1
"Click on smart drag, or free move drag in the left tool bar, the left click part keeping the clicker down→drag part"	2
"Click (select) the component then 'move component'"	3
"Select the move tool"	4
"Click on the move icon, then select the component face, and drag it"	5

The first answer to the question in table 3.2 was given a 1 because the student obviously didn't know what the answer was so they guessed. On the second response the student had some idea as to what the answer was but their explanation was still very to confusing to determine what they were saying so they were given a two on that response. The third response was still vague but the student was on the right track for the correct answer. The fourth response was given a four because the student mention that there was a moving tool that had to be used but they didn't explain what was to be done with that moving tool once it was selected. The fifth response was the correct response, and so it was awarded a five. Criteria similar to this were used to determine the scores of all the answers to the questions on this section of the quizzes.

The scores to the answers were taken and added up to give the final score out of fifty points for each of the short question sections of the three quizzes.

3.3.2 PERFORMANCE GRADING CRITERIA

For the timed sections of the quiz, the students were told to record how long it took them to complete the project associated with every quiz. This time, in minutes, was taken and recorded for every student for every quiz.

3.3.3 ANCOVA MODEL

The data was entered into a spreadsheet format so that the scores of each quiz could be analyzed. This included the short answer sections of the quizzes and the timed sections of the quizzes. This data was analyzed statistically using an analysis of variance model with a covariate (ANCOVA) to determine any statistical significance between the two groups of students for both the short answer and timed sections of the three quizzes.

Some of the students in both the treatment and the control groups failed to turn in one of their quizzes. This resulted in missing data for these students. These individual observations or quiz scores were left out of the analysis. Students who didn't turn in a pretest at the beginning of the semester were not included in the study.

The ANCOVA model was set up to show what effects contributed the most significantly to each of the students' exact answers. According to this model a student's short answer quiz score is based on the effects of the following factors:

- The use of the tutorials in the lab.
- The lab that the students attended and the use of those tutorials in that lab.
- The three quizzes the students were taking.
- The interaction effect between the use of the tutorials and the three quizzes.
- The interaction effect between the lab the students attended, the three quizzes and the use of the tutorials in those labs.
- The pretest score.

The effects of these same factors were also tested for the design project section of the quiz. The models for these two quiz sections were set up as follows:

For the short answers question part of the quiz:

$Y_{ijkl}=\mu+\alpha_i+\beta_{j(i)}+\gamma_k+(\alpha\gamma)_{ik}+(\beta\gamma)_{jk(i)}+x_{ijkl}+\varepsilon_{ijkl}$

Y_{ijli} is the total score of all three quizzes.

μ is the overall mean effect or an average that any person would receive from taking the quizzes.

α_i is the main effect of the treatment condition (whether the student used the tutorials or not)

$\beta_{j(i)}$ is the main effect for the lab (nested in treatment)

γ_k is the main effect for the quizzes.

$(\alpha\gamma)_{ik}$ is the interaction effect for the treatment condition and the quizzes.

$(\beta\gamma)_{jk(i)}$ is the interaction effect for the lab and the treatment condition.

x_{ijkl} is the covariate in the analysis, or the pretest score

ε_{ijkl} is the random effects that account for the variation in the model.

Where ε_{ijkl} is normally distributed with a mean of zero and the variance of sigma squared. ($\varepsilon_{ijkl} \sim N(0, \sigma^2)$)

For the timed sections of the quiz the model is as follows:

$$\text{LOG}\ (Y_{ijk})=\mu+\alpha_i+\beta_{j(i)}+\gamma_k+(\alpha\gamma)_{ik}+(\beta\gamma)_{jk(i)}+x_{ijkl}+\varepsilon_{ijkl}$$

Y_{ijk} is the total time of all three quizzes.

μ is the overall mean effect or an average that any person would receive from taking the quizzes.

α_i is the main effect of the treatment condition (whether the student used the tutorials or not)

$\beta_{j(i)}$ is the main effect for the lab (nested in treatment)

γ_k is the main effect for the quizzes.

$(\alpha\gamma)_{ik}$ is the interaction effect for the treatment condition and the quizzes.

$(\beta\gamma)_{jk(i)}$ is the interaction effect for the lab and the treatment condition.

x_{ijkl} is the covariate in the analysis, or the pretest time.

ε_{ijkl} is the random effects that account for the variation in the model.

Where ε_{ijkl} is normally distributed with a mean of zero and the variance of sigma squared. ($\varepsilon_{ijkl} \sim N(0, \sigma^2)$)

On this model, the log of the time was taken because time responses tend to follow a logarithmic scale on the data collection.

Based on these models, the data were tested for any statistical significance for any of those variable described. More specifically, the data were tested to determine if the treatment had any effect on the students' quiz scores. The results of this analysis are described in the following chapter.

CHAPTER 4

RESULTS

The thesis statement of this study (in the form of the null hypothesis) states that there will be no significant difference in the improvement of learning for tool design students who used the tutorials as opposed to students who did not use the tutorial to complete their laboratory assignments. How well the students learned was measured by the three quizzes taken during the course of the semester. There were two parts to each of the quizzes; ten-question section that required a short answer and a section that required the student to record the time it took them to complete a short design project. These were the two aspects that were tested. In this regard the specific null hypotheses that were tested were:

1. There is no significant improvement in the quiz scores, which test the learning of basic CAD principles, between the students who used a tutorial and those who did not.
2. There is no significant improvement in the amount of time taken by each student to complete a given design assignment.

This chapter is organized into two different sections, each section dealing with one of these hypotheses. The first section deals with the results associated with how well the students scored on the short answer question section of the three quizzes with respect to the treatment condition (using the tutorials). The second section deals with the results of the timed portion of the three quizzes with respect to the treatment condition. For these results the statistical analysis performed are for a 95% confidence interval and assuming a .05 level of significance. The complete results are shown in Appendix B.

4.1 THE EFFECT OF THE TREATMENT CONDITION ON SHORT ANSWER QUESTION RESPONSES

As mentioned in Chapter 3, the individual answers to all three of the quizzes were graded on a scale of one to five. These numbers were totaled for each quiz for each student in all the labs. Figure 4.1 shows a graph of the data collected for the quiz scores along with the pretest score. This shows the overall trends of the effects that having the tutorial available in the lab had on the quiz scores of the students.

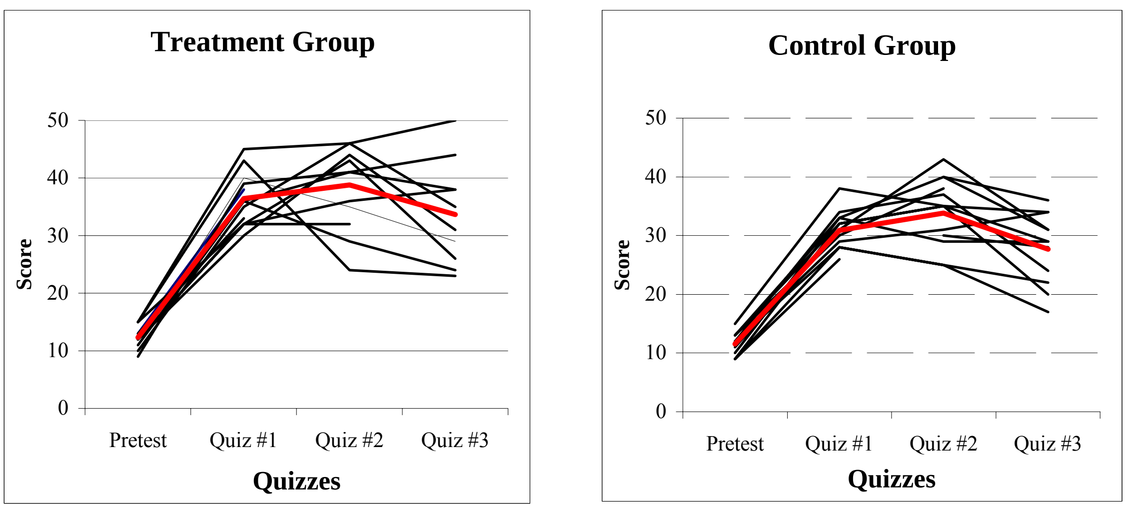


Figure 4.1 Graphs of student quiz scores from the ten-question written answer section of the three quizzes. The red line represents the averages.

From the red average line on these two graphs it can be seen that the overall data show that the average quiz score were higher among students that used the tutorial. The average question scores of the data for the three quizzes confirm this in table 4.1.

Table 4.1 Average quiz scores for the three quizzes.

Treatment Condition	Quiz Number	Number of Students	Sample Mean
Control	1	14	30.1429
Treatment	1	17	35.1765
Control	2	14	33.8571
Treatment	2	13	38.3077
Control	3	15	26.6667
Treatment	3	15	31.9333

The ANCOVA model was applied to this data to verify the significance between the two groups. Table 4.2 presents this analysis for the combined data of the three quizzes. The LS mean column represents a statistically adjusted average for the test scores. This average takes into consideration the pretest scores as a covariate and adjusts to how well the students responded to it. The column labeled "Standard Error" represents the variance of the LS Means column. The column labeled "Pr > | t |" shows the statistical significance between those two means. This number is less than the .05 confidence level of significance, showing that the treatment effect of having a tutorial in the laboratory does have an effect on the quiz scores.

Table 4.2 Overall averages for the three quiz scores.

Treatment Condition	LS Mean	Standard Error	Pr > | t |
Control	30.9	1.0154307	**0.0010**
Treatment	36.0	1.0827030	

From the ANCOVA model, the effects of the main variables that influenced the students' quiz scores were analyzed to determine which of these effects were statistically significant. The variables are listed below:

- The use of the tutorials in the lab.

- The lab that the students attended and the use of those tutorials in that lab.
- The three quizzes the students were taking.
- The interaction effect between the use of the tutorials and the three quizzes.
- The interaction effect between the lab the students attended, the three quizzes and the use of the tutorials in those labs.
- The pretest score.

Table 4.3 shows the ANCOVA test results for the effects of the variables described in the model. The variables that showed a significant effect on the total quiz scores for the students taking the ten-question short-answer quiz are the ones in which the p value is less that 0.05. From the table we can see that those variables were (a) the use of the tutorials in the lab and (b) which of the three quizzes the students took. Each quiz covered different materials as they were taught in the labs. Because of this, it was expected that the quizzes would prove to a significant variable.

Table 4.3 Results from the statistical analysis of the effects of the tutorial on the quiz scores.

Effects on the Quiz Scores	DF	F Value	Pr > F
Using the Tutorial	1	11.92	**0.001**
Lab section (Nested in Tutorial Use)	3	1.48	0.2295
Quiz	2	6.07	**0.0038**
Interaction Between Tutorial Use and Quiz	2	0.23	0.7932
Interaction of Lab and Quiz (with a nested Tutorial Use)	6	0.69	0.6576
Pretest scores	1	0.52	0.4751

The other variable in the students' quiz scores for the ten-question short answer section of the quizzes was the effect of whether or not the students had access to the tutorials. As seen from the tables 4.3 and 4.2, the p-value is 0.001. This is well below the .05 confidence level for statistical significance.

4.2 THE EFFECT OF THE TREATMENT CONDITION ON TIME TO COMPLETION OF A PROJECT

The second section of the quizzes that was used to determine how well the tutorials aided the students in the learning of 3-D CAD design is the recorded time the student took to complete a design project. These times were recorded and analyzed according to the ANCOVA model. The variables that were looked at to determine if there was any significance to their effects on the time it took student to complete the project were:

- The use of the tutorials in the lab.
- The lab that the students attended and the use of those tutorials in that lab.
- The three quizzes (design project section) the students were taking.
- The interaction effect between the use of the tutorials and the three quizzes.
- The interaction effect between the lab the students attended, the three quizzes and the use of the tutorials in those labs.
- The pretest score.

Figure 4.2 shows the graphed times of the control and treatment groups for the quizzes and the pretest.

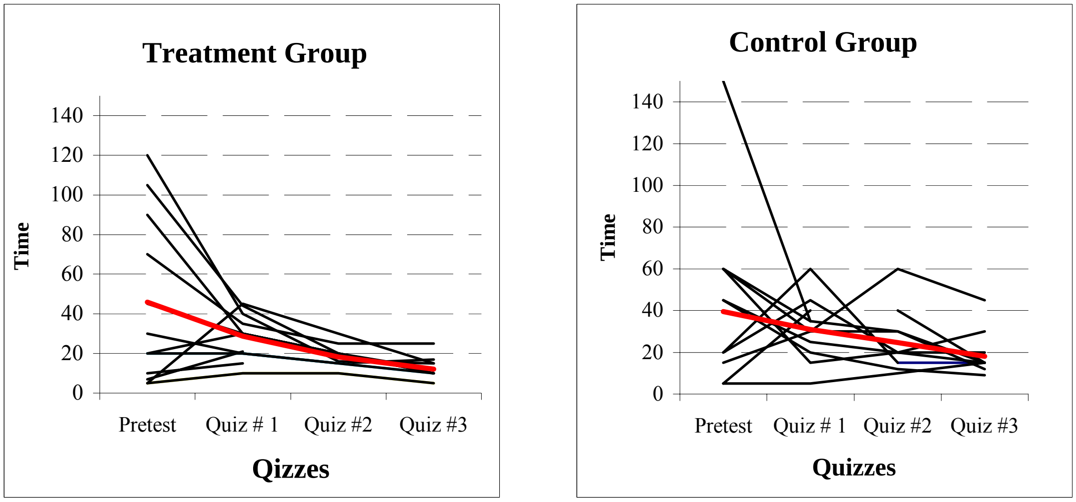


Figure 4.2 Graphs of the times students took to complete a design project. The red line represents the averages.

This data was analyzed according to the previously described model. Once again, students' scores were not included in the study if they didn't turn in a pretest.

Since timed data in general tends to be skewed logarithmically, the model used to analyze the timed data was similar to the short answer question model; only it was done as a logarithmic function rather than a normal function. Table 4.4 show the average times from each of the three quizzes along with the logarithmic averages of those times. Figure 4.3 shows the graphs of the logarithmic time between the control group and the treatment group.

Table 4.4 Averages of the times for the three quizzes.

Treatment Condition	Quiz Number	Number of Students	Sample Mean	Logarithmic Mean
Control	1	13	32.6923	3.487140
Treatment	1	16	32.5000	3.481240
Control	2	12	24.5833	3.202067
Treatment	2	13	21.2308	3.055453
Control	3	14	18.0714	2.894331
Treatment	3	15	12.7333	2.544221

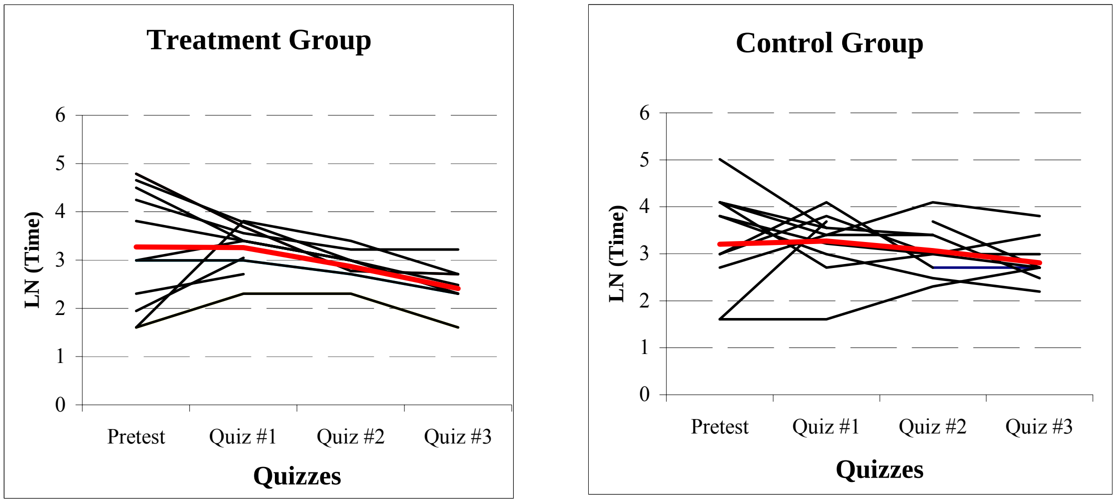


Figure 4.3 Graphs of the times it took for student to complete the design project section of each quiz on a logarithmic scale. The red line represents the averages.

The averages shown in table 4.3 demonstrate that the treatment groups on average took less time to complete each design project. Using the ANCOVA model, the timed data was analyzed to determine if this treatment condition was a statistically significant variable in determining the students' ability to complete a design project. The total timed averages are shown in table 4.5 along with the variance of those averages. The column labeled "Pr > | t |" shows the statistical significance of the treatment effect. Once again, the "LS Mean" and "Logarithmic LS Mean" columns represent a statistically adjusted average for the test scores. This average takes into consideration the pretest scores as a covariate and adjusts to how well the students responded to it. The column labeled "Standard Error" represents the variance of the "Logarithmic LS Means" column.

Table 4.5 Overall averages for the three timed sections of the quizzes.

Treatment Condition	LS Means	Logarithmic LS Mean	Standard Error	Pr > | t |
Control	20.44657	3.01781538	0.07677595	**0.0987**
Treatment	16.93131	2.82916445	0.08111994	

Table 4.6 shows the ANCOVA test results for the effects of the variables described in the model.

Table 4.6 Results from the statistical analysis of the effects of the tutorials on the quiz scores.

Effects on the Quiz Scores	DF	F Value	Pr > F
Using the Tutorial	1	2.81	**0.0987**
Lab section (Nested Tutorial Use)	3	2.60	0.0599
Quiz	2	11.74	**<.0001**
Interaction Between Tutorial Use and Quiz	2	1.50	0.2322
Interaction of Lab and Quiz (with a nested Tutorial Use)	6	0.31	0.9298
Pretest	1	5.01	**.0289**

It can be seen from the table 4.8 that the variables that had the most effect in determining the amount of time the students took on the design project was both the pretest score and which quiz the student was taking to get the time. The quiz the students took was significant because each of the design projects on those quizzes were different from each other. It was expected that the students would take a different amount of time to complete each quiz.

Tables 4.5 and 4.4 show the p value for the treatment condition. This number ended up being 0.0987 which was greater that the 0.05 level of significance. This shows that the effect of having a tutorial in the lab does not affect the ability of a student to complete a given design project faster than if the student didn't have access to the tutorial.

The other variable whose effects were statistically significance (p value under 0.05) was the pretest time the students took on the initial design project. The time it took to complete the initial design project was had a greater effect on the time it took to complete the design project section of the quizzes than using the tutorials in the labs.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 REVIEW OF STUDY

MET 431 is a class in the manufacturing program that requires students to use 3-D Computer-Aided Design (CAD) to complete laboratory projects in the field of manufacturing tool design. To aid the students in the completion of these projects, tutorials have been developed that serve as a guide through every aspect of these assignments. Since this 3-D CAD software sometimes can be complicated and difficult to understand, and since a well qualified teaching assistant might not be readily available from year to year; these tutorials serve as a great resource for instruction in tool design principles as well as 3-D CAD software for students.

The purpose of this study was to determine how effective these tutorials are in the learning process of this CAD software. This was done by having 16 of the students use the tutorials in conjunction with their usual laboratory studies and the 16 students not use the tutorials. The responses from the students were tested by means of three quizzes take throughout the course of the semester. These quizzes had two parts to them: a short answer question part and a small design section part. From this, data was collected and analyzed.

The Short Answer Question Responses

The short answer question part of the quizzes consisted of basic questions about how to perform certain functions in the software that was suppose to have been learned by doing the assignments. This part of the quizzes was graded based on how well the students answered the questions. After the quizzes were graded the data was collected and analyzed to test the null hypothesis.

The null hypothesis states that there is no significant difference in the quiz scores, which test the learning of CAD principles, between those students who used a tutorial and those who did not. According the collected data and its analysis, this null hypothesis is rejected. The results obtained from the statistical analysis (all statistical analysis in this study use a 95% confidence interval and a significance of 0.05) suggests that students who had access to the online tutorials for their lab assignments scored four to six points higher on the quizzes (the p-value was 0.0001, F=11.92).

The Completion of a Design Project

The second part of each of the quizzes consisted of a small project to be completed on the CAD software. This was aimed at testing how well the students actually functioned in the use of this software. The data for this part of the study was the time it actually took the students to complete the project. This data was collected and analyzed to test the null hypothesis.

The null hypothesis states that there is no significant difference in the amount of time taken by each student to complete a given design assignment. Based on the analysis of the data collected, this statement is true. The analysis yielded a p-value of .0987. This means that even though the average times of the treatment group was lower than the control group there wasn't a statistically significant difference between these two groups.

5.2 CONCLUSION FROM THE WRITTEN ANSWER QUIZZES

Based on the data collected from the students, it is concluded that the tutorials effectively aid in the learning of CAD principles as they apply to designing manufacturing tools. The students who used the tutorials had a better understanding of the tools and commands in the software to answer the questions on the quizzes. This means that the tutorials are effective in teaching students the user interface and other functions of the software when compared to the students who didn't use the tutorials in their lab assignments.

This conclusion is based on the fact that students' written quiz scores were four to six points higher for those who used the tutorials when compared to those who didn't use the tutorials. This data was proven to be statistically significant. ($F=11.92$, $p=0.001$)

5.3 CONCLUSION FROM THE PERFORMANCE QUIZZES

Since there is no significant difference in the amount of time the students used to complete the design project part of the quizzes it is concluded that the tutorials have no significant effect on the design time for a given project. This is based on the fact that there was no statistically significant difference in the times recorded from the two groups. ($F=2.81$, $p=.0897$)

5.4 OTHER CONCLUSIONS

These tutorials should prove effective in teaching future tool design students the fundamentals of 3-D CAD as they apply to tool design. For instance, these experiments were conducted using a teaching assistant who was well experienced with the 3D-CAD software and tool designing principles. Even though the same teaching assistant was used for both experimental groups of students, the group that had access to the tutorials still outperformed the students without the tutorial on the quizzes. It is not known whether there is an experienced teaching assistant available to work each semester. These tutorials offer a means to teach the students how to use the software on their own without the help of a teaching assistant.

These tutorials should be utilized in tool design for future semesters. The costs to implement these tutorials are outweighed by the benefit as shown by this study. According to table 3.1 the total estimated hours required to update each tutorial, as software upgrades are made available, are about 43. A teaching assistant can be hired to easily update the tutorials. Since MFG 431 is only offered twice a year the teaching assistant could use the semesters during which the class isn't offered and update the tutorials to the newer versions of the software. This would require less than ten hour of work each week during these semesters for the teaching assistant. Also, by updating the tutorials, the teaching assistant can become better acquainted with the software and the lab assignments so they are better able to teach the labs.

This study also shows the effectiveness of tutorials in the learning of computer skills. While using tutorials doesn't improve the time the students take to complete projects, tutorials can improve the quality of learning that takes place. Through this, students learned skills more effectively.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

During the course of this study, opportunities for further research in this same field became apparent. These areas of study would help strengthen the understanding of how effective the use of web-based tutorials help students of tool design understand how to use CAD in their assignments. The ideas are shown below:

- Study effective ways to update the tutorials as the new software upgrades are released from year to year. Or to expand the tutorials to other software packages like SolidEdge™ and ProE™.
- Develop interactive tutorials that provide feedback to the students.
- Study whether the tutorials are more effective when offered over the Internet or printed out in a book.
- Expand the study to include the attitudes of students as they used the tutorial. In a questionnaire that utilizes a scale of one to five, from most effective to least effective the following questions could have been explored.
    - What they thought about the tutorials.
    - How they felt the tutorials helped them.
    - What they thought could be improved in the tutorials.
- Study what affect the tutorials had on the actual completion time of their lab assignments.

- Study the effectiveness of other online tool design education resources. For example, DME plastics university (http://www.dmeuniversity.net/english/default.cfm) and Tooling University (http://www.toolingu.com/default.aspx) both offer online learning tutorials.

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APPENDICES

APPENDIX A:

EXAMPLE OF TUTORIALS FOR MFG 431 LAB ASSIGNMENTS

A 1.1 CLAMP TUTORIAL INTRODUCTION

Introduction to SolidWorks for Tool Designers

Chapter 1

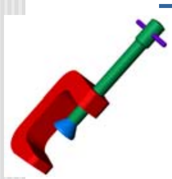


Table of Contents

- **Introduction to SolidWorks**
- Parts
- Assemblies
- Drawings

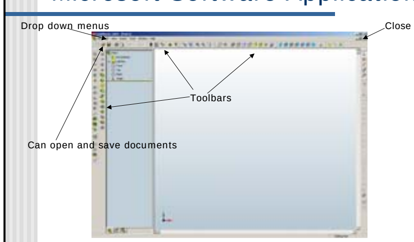
Introduction to SolidWorks

- SolidWorks is similar to any other Microsoft software application
- Drop down menus
- Tool bars
- Feature manager and graphics area
- Right click menus
- The assignment

SolidWorks is Like Any Microsoft Software Application

- Main layout
- Can open and save documents
- Uses "Cut and Paste"
  - Can cut and past any item
  - Can copy and past any item

SolidWorks is Like Any Microsoft Software Application



Dropdown Menus

- On the top of the screen notice the dropdown menus
- These have commands which are used in designing the part

Dropdown Menus

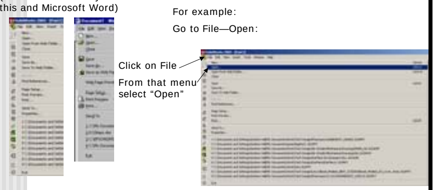
File menu drops down

(Notice the similarity between this and Microsoft Word)

A lot of instructions given in this tutorial will refer to these dropdown menus

For example:

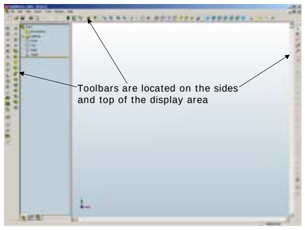
Go to File—Open:



Tool Bars

- Tool bars are tools off to the side of the main area
- These have commands which help with design

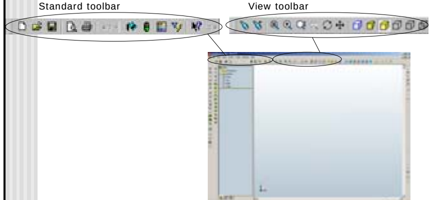
Tool Bars



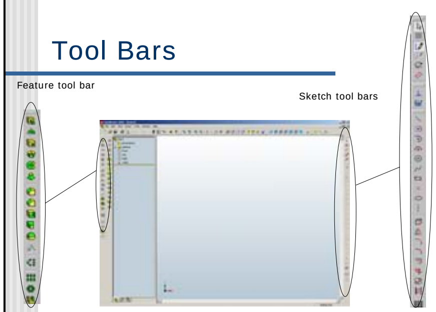
Tool Bars

- Some important tool bars to notice
  - Standard toolbar
  - View toolbar
  - Features toolbar
  - Sketch toolbars

Tool Bars



Tool Bars

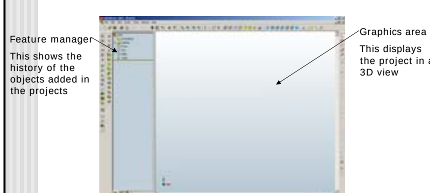


Feature Manager and Graphics Area

- Two major areas on the SolidWorks display area
- Feature manager
- Graphics area

Feature Manager and Graphics Area

There are two major areas in the display area

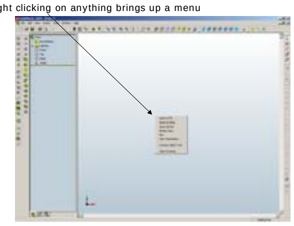


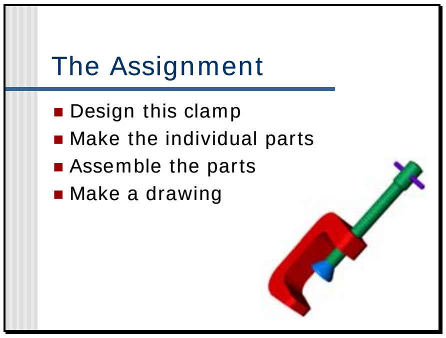
Right Click Menus

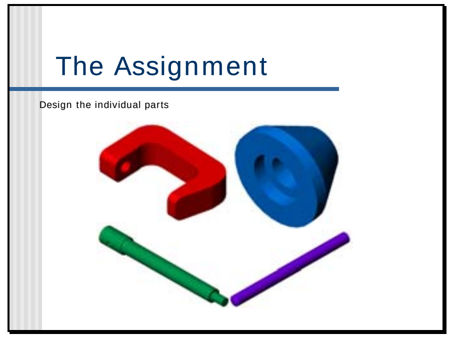
- Right clicking on anything in SolidWorks produces a menu
- This menu activates commands which helps in the creation of the project

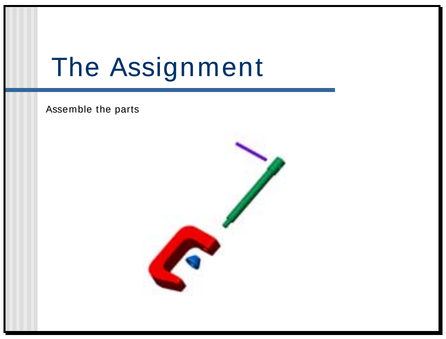
Right Click Menus

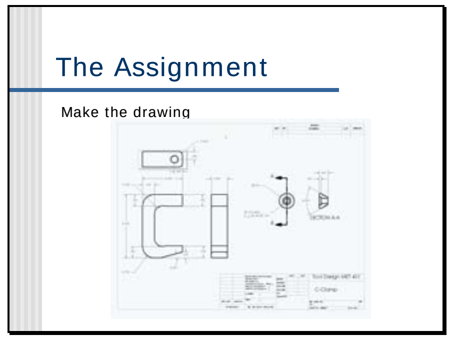
Right clicking on anything brings up a menu



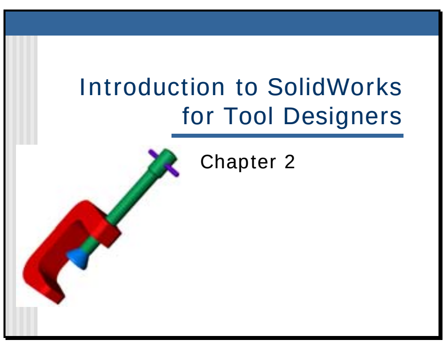


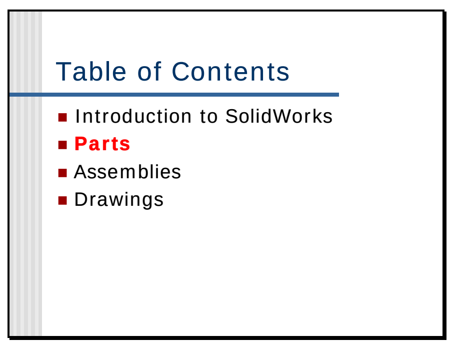


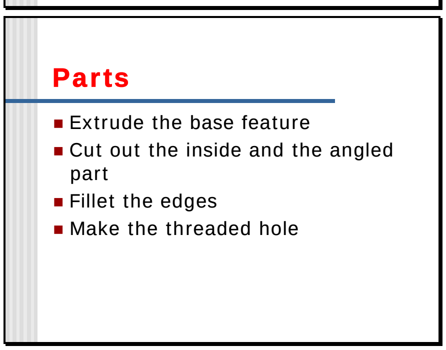


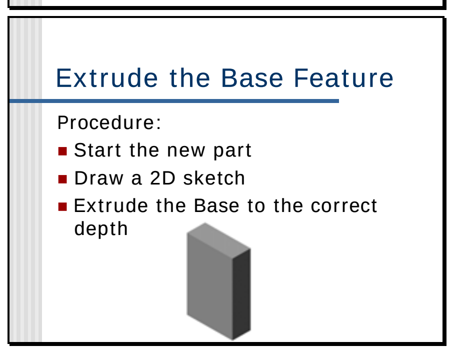


A 1.2 CLAMP TUTORIAL PARTS 1





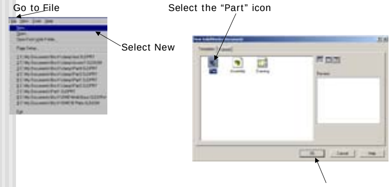




Start the New Part

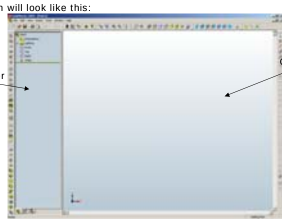
- Go to File—New
- Click on the "Part" icon
- Hit OK

Start the New Part



Start the New Part

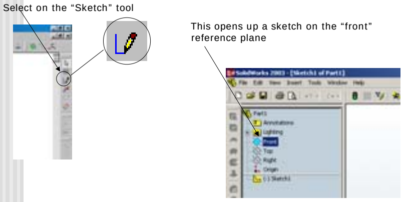
The screen will look like this:



Draw a 2D Sketch

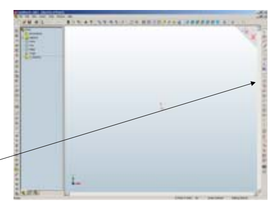
- Start a new sketch by selecting on the "Sketch" tool from the "Sketch" toolbar on the right side of the screen
- This will start a 2D sketch on a reference plane
- Notice the sketch tools are now active on the Sketch toolbars

Draw a 2D Sketch



Draw a 2D Sketch

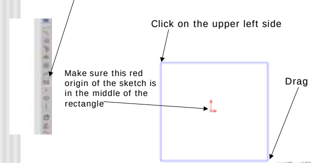
A sketch is now open



Draw a 2D Sketch

- Click on the "Rectangle" tool from the "Sketch Tools" toolbar
- To place the rectangle, click on the right corner of the screen and while holding down on the mouse button drag diagonally down to the bottom right
- This will place a rectangle on the screen

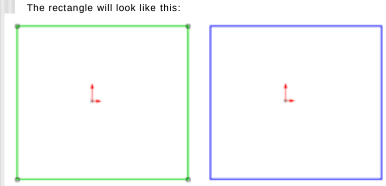
Draw a 2D Sketch



Final dimensions of the rectangle will be added later

Draw a 2D Sketch

The rectangle will look like this:

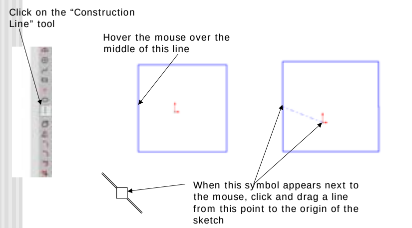


Final dimensions of the rectangle will be added later

Draw a 2D Sketch

- Select on the "Construction Line" tool from the "Sketch Tools" toolbar
- Hover the mouse over the left vertical line of the rectangle
- When the "Snap to Midpoint" symbol appears next to the mouse, click and drag a line from that point to the origin

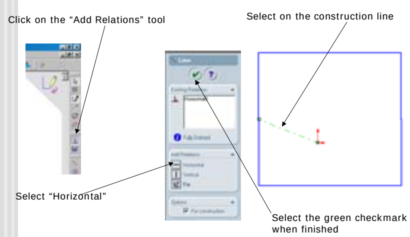
Draw a 2D Sketch



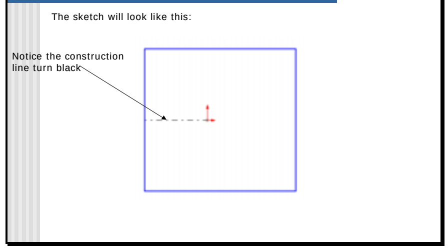
Draw a 2D Sketch

- Click on the "Add Relations" tool from the "Sketch Relations" toolbar
- Select the newly created construction line
- Select on "Horizontal" under "Add Relations" in the property manager
- Click on the green checkmark

Draw a 2D Sketch



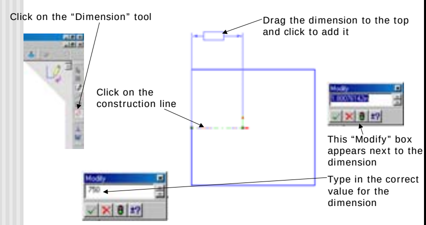
Draw a 2D Sketch



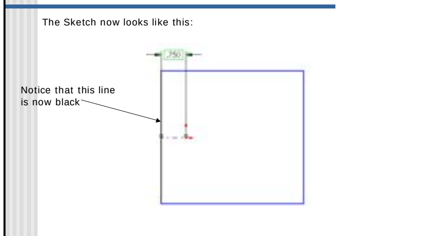
Draw a 2D Sketch

- Click on the "Dimension" tool
- With the dimension tool selected, click on the construction line
- Drag the dimension up past the top line of the rectangle and click to drop it
- A "Modify" box appears
- Type in the dimension of the line in the dimension box

Draw a 2D Sketch



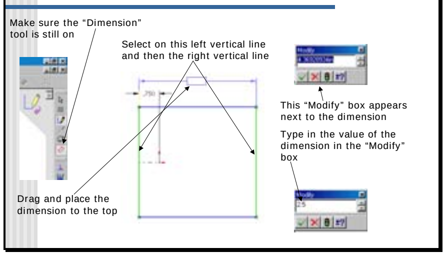
Draw a 2D Sketch



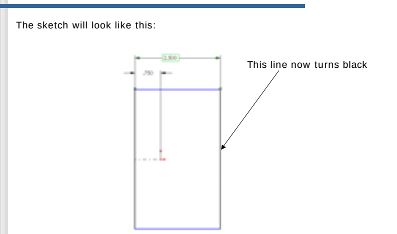
Draw a 2D Sketch

- Make sure the dimension tool is still on
- With the dimension tool on, select the left vertical line of the rectangle and then select the right vertical line
- Drag the dimension to the top of the screen and place it
- In the "Modify" box that appears from placing the dimension, type in the dimension value

Draw a 2D Sketch



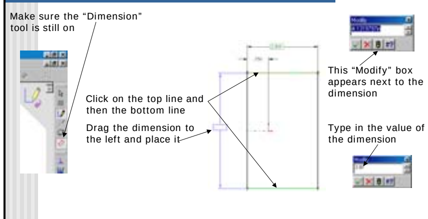
Draw a 2D Sketch



Draw a 2D Sketch

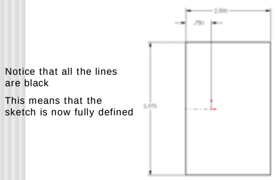
- Make sure the dimension tool is still on
- With the dimension tool on, select the top horizontal line of the rectangle and then select the bottom horizontal line
- Drag the dimension to the left of the screen and place it
- In the “Modify” box that appears from placing the dimension, type in the dimension value

Draw a 2D Sketch



Draw a 2D Sketch

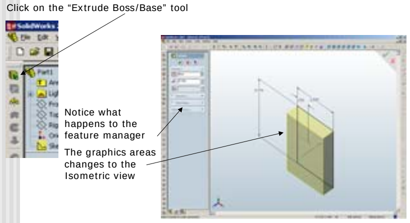
The sketch will look like this:



Extrude the Base to the Correct Depth

- This sketch is now ready to be extruded
- Click on the “Extrude Boss/Base” tool from the “Features” toolbar
- Notice what happens to the feature manager

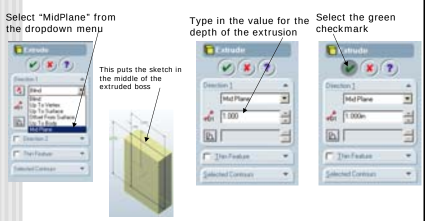
Extrude the Base to the Correct Depth



Extrude the Base to the Correct Depth

- Go to the Property manager
- In the “Direction 1” dropdown menu select “MidPlane”
- This puts the sketch plane in the middle of the extruded boss
- Type in the depth of the extruded boss
- Select the green checkmark

Extrude the Base to the Correct Depth



Extrude the Base to the Correct Depth

The graphics area will now look like this:

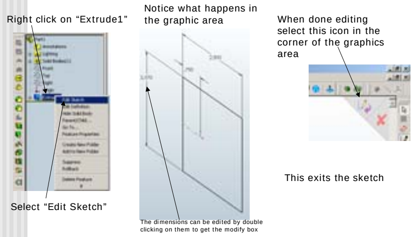
Orienting the Part

- Rotate the part by holding down the middle scroll button of the mouse and moving the mouse
- Zoom in and out by holding down the “Shift” key while holding down the middle scroll button of the mouse and moving the mouse
- Also, using the scroll button will zoom in and out
- Pan around by holding down the “Ctrl” key while holding down the middle scroll button of the mouse and moving the mouse

Editing the Sketch

- The dimensions of this part can be edited by right clicking on “Extrude1” in the Feature Manager
- From the resulting menu select “Edit Sketch”
- Notice what happens in the graphics area
- When the sketch is done being edited click on the icon in the corner to exit the sketch and return to the part

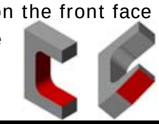
Editing the Sketch



Cut Out the Inside and the Bottom Angle

Procedure:

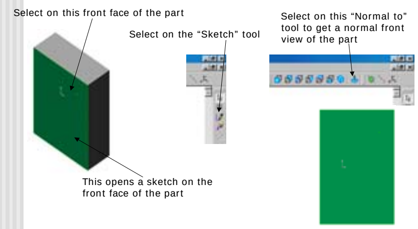
- Start a new sketch on the front face
- Draw the 2D cut out sketch
- Extrude the cut
- Start a new sketch on the front face
- Draw the angled line
- Extrude the cut



Start a New Sketch on the Front Face

- Select on the front face of the newly created block in the graphics area
- Click on the "Sketch" tool
- This opens a new sketch on the front face of the part
- To view normal to the sketch, select the "Normal to" tool from the view tool bar

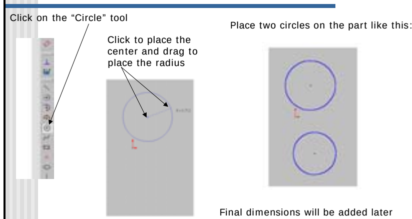
Start a New Sketch on the Front Face



Draw the 2D Cut Out Sketch

- This sketch is extremely complicated!—pay attention!
- Select on the "Circle" tool from the Sketch Tools" toolbar
- Draw two circles vertical from each other
- This is done by clicking once to place the center of the circle and dragging to place the size of the circle, or by clicking once to place the center of the circle and clicking again to place the outer diameter

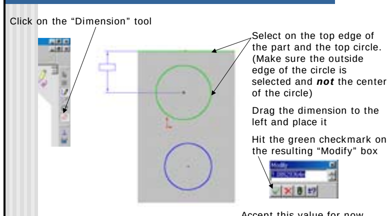
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

- Click on the "Dimension" tool
- Click on the top edge of the part and click on the circle (**not the center of the circle**)
- Drag the dimension to the left and place it
- Click on the green checkmark on the "Modify" box which appears next to the dimension

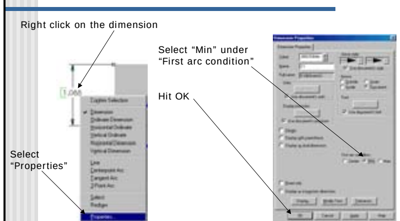
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

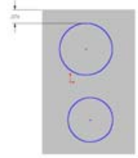
- Right click on the newly placed dimension
- From the resulting menu select "Properties"
- Under "First arc condition" select "Min"
- Hit "Apply"

Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

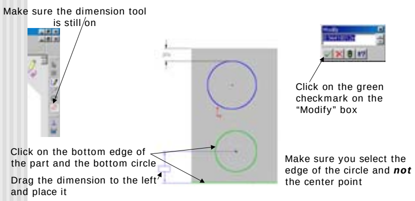
The dimension now looks like this:



Draw the 2D Cut Out Sketch

- Repeat the previous step for the bottom circle
- Make sure the dimension tool is still on
- Select the bottom edge of the part and the bottom circle (**not the center of the circle**)
- Drag the dimension to the left and place it
- Click on the green checkmark

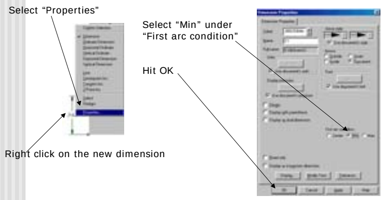
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

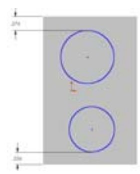
- Right click on the newly placed dimension
- From the resulting menu select "Properties"
- Under "First arc condition" select "Min"
- Hit "Apply"

Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

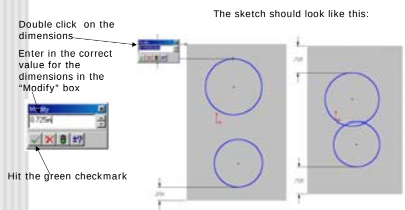
The sketch now looks like this:



Draw the 2D Cut Out Sketch

- Double click on each dimension
- In the "Modify" box enter in the correct value
- Hit the green checkmark

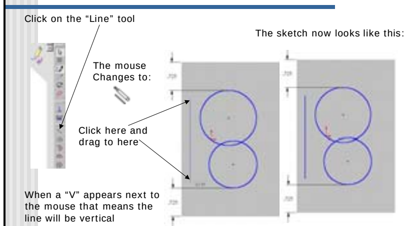
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

- Click on the "Line" tool from the "Sketch Tools" toolbar
- Place a vertical line on the face of the block as shown
- Click the mouse once to start the line and move the mouse down
- Notice a that there is a line previewed when moving the mouse around
- Move the mouse so that the line is vertical, a "V" will appear next to the mouse
- Click a second time to place the line
- Hit the "Esc" key on the keyboard to exit the "Line" tool

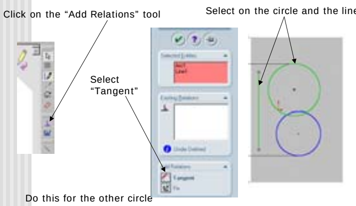
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

- Click on the “Add Relations” tool from the “Sketch Relations” toolbar
- Select the vertical line and one of the circles
- Under “Add Relations” in the Property Manager select on “Tangent”
- Hit “Apply”
- Do the same with the other circle and the vertical line

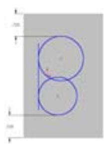
Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

The sketch should look like this:

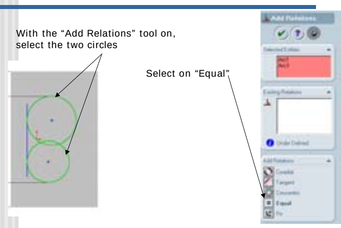
This added the relation of making the line tangent to the circles



Draw the 2D Cut Out Sketch

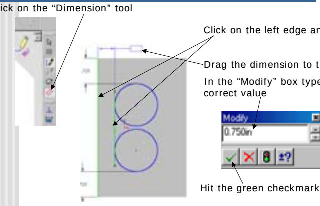
- With the “Add Relations” tool on, select the two circles
- Select “Equal” and hit “Apply”
- Click on the “Dimension” tool
- Add a dimension from the left edge to the vertical line
- Drag the dimension to the top and type in the correct value in the “Modify” box

Draw the 2D Cut Out Sketch



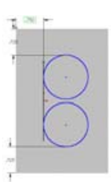
This makes the two circles equal in size

Draw the 2D Cut Out Sketch



Draw the 2D Cut Out Sketch

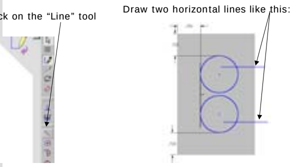
The sketch will now look like this:



Draw the 2D Cut Out Sketch

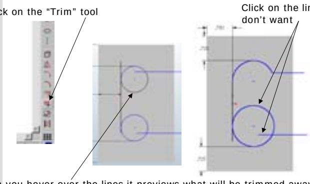
- Click on the “Line” tool from the “Sketch Tool” toolbar
- Draw two horizontal lines as shown
- Click on the “Trim” tool from the “Sketch Tool” toolbar
- Hover the mouse over the line segment that will be cut away
- Notice how it changes colors
- Click on all the line segments that are not wanted

Draw the 2D Cut Out Sketch



While holding the mouse down and dragging, when an “H” appears next to the mouse that means the line is horizontal

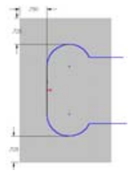
Draw the 2D Cut Out Sketch



When you hover over the lines it previews what will be trimmed away

Draw the 2D Cut Out Sketch

The sketch should look like this:



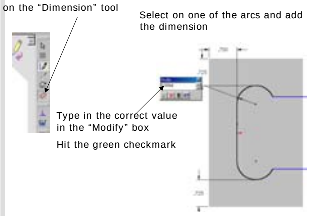
Draw the 2D Cut Out Sketch

- With the "Dimension" tool on, add a dimension to the arcs
- Type in the correct value for the dimension in the "Modify" box
- With the "Dimension" tool on, add dimensions from the top edge to the top horizontal line
- With the "Dimension" tool on, add dimensions from the bottom edge to the bottom horizontal line

Draw the 2D Cut Out Sketch

Turn on the "Dimension" tool

Select on one of the arcs and add the dimension



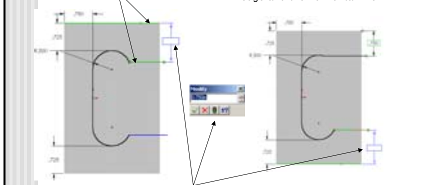
Type in the correct value in the "Modify" box

Hit the green checkmark

Draw the 2D Cut Out Sketch

Add a dimension between the top edge and the horizontal line

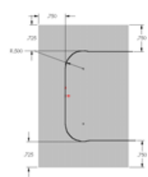
Add a dimension between the bottom edge and the horizontal line



Type in the correct value in the "Modify" boxes that appears

Draw the 2D Cut Out Sketch

The sketch now looks like this:



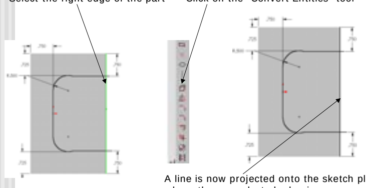
Draw the 2D Cut Out Sketch

- Select the right edge of the part as shown
- Hit the "Convert Entities" tool from the "Sketch Tools" toolbar
- This takes an existing edge on the part and coverts it to a sketch entity on the sketch plane
- Click on the "Trim" tool and trim the line to make the sketch closed

Draw the 2D Cut Out Sketch

Select the right edge of the part

Click on the "Convert Entities" tool

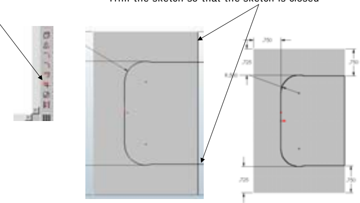


A line is now projected onto the sketch plane where the pre-selected edge is

Draw the 2D Cut Out Sketch

Click on the "Trim" tool

Trim the sketch so that the sketch is closed

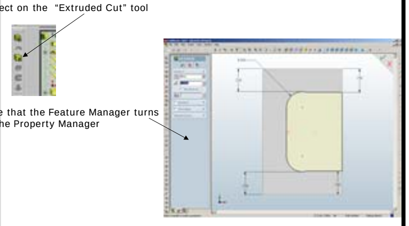


Extrude the Cut

- Click on the "Extruded Cut" tool from the "Feature" toolbar
- Notice that the Feature Manager changes to the Property manager
- Under the "Direction 1" drop down menu in the Property manager select "Through all"
- Click on the green checkmark in the top of the Property manger

Extrude the Cut

Select on the "Extruded Cut" tool



Notice that the Feature Manager turns into the Property Manager

Extrude the Cut

Select "Through All" in the dropdown menu

Click on the green checkmark

The part will now look like this:

Start a New Sketch on the Front Face

- Select the front face of the part again
- Open a sketch on this face by selecting the "Sketch" tool
- View normal to the sketch plane by selecting the "Normal to" tool from the view toolbar

Start a New Sketch on the Front Face

Select on this front face

Select on the "Sketch" tool to open a sketch on this face

View normal to the sketch by selecting this tool

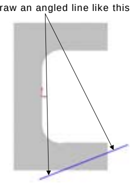
Draw the Angled Line

- With the sketch open, select the line tool from the "Sketch Tools" tool bar
- Draw the line as shown
- Click on the "Add Relations" tool
- Select the bottom endpoint of the line and the bottom edge
- Select "Coincident" and hit "Apply"

Draw the Angled Line

Select the line tool

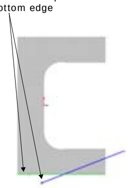
Draw an angled line like this



Select the "Add Relations" tool

Draw the Angled Line

Select on the bottom endpoint on the line and the bottom edge



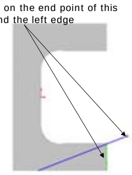
Select "Coincident"

Draw the Angled Line

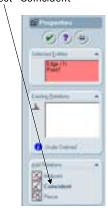
- Select the right edge of the part and the other endpoint of the line
- Select "Coincident" and then hit "Apply"
- Click on the "Dimension" tool
- Select on the bottom edge and the angled line
- Drag and place the dimension on the left
- Type in the correct angular value in the "Modify" box

Draw the Angled Line

Select on the end point of this line and the left edge



Select "Coincident"



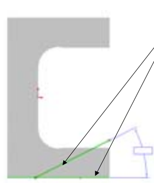
Draw the Angled Line

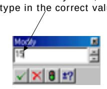
Click on the "Dimension" tool

Select on these two lines

Drag the dimension to the left

In the "Modify" box, type in the correct value





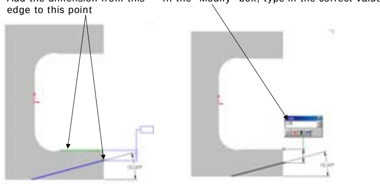
Draw the Angled Line

- Add the dimension from the endpoint of the line to the shown edge
- Type in the correct value in the "Modify" box

Draw the Angled Line

Add the dimension from this edge to this point

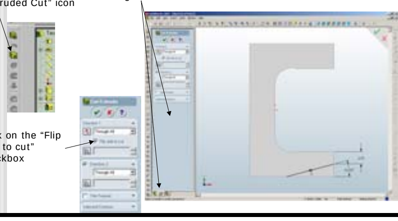
In the “Modify” box, type in the correct value



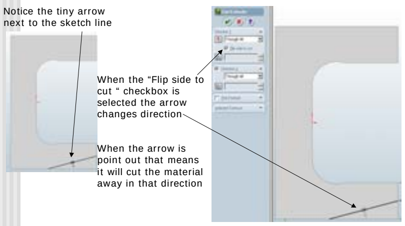
Extrude the Cut

- Click on the the “Extruded Cut” tool
- Notice the Feature Manager changes to the Property Manager
- Click on the “Flip side to cut” checkbox in the Property Manager
- Notice tiny arrow next to the line and how it changes direction when you click on the “Flip side to cut” checkbox

Extrude the Cut



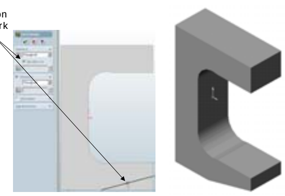
Extrude the Cut



Extrude the Cut

- With the arrow pointing outward, select the green checkmark on the Feature Manager
- Cuts can be made just by drawing a line and choosing which side to cut away

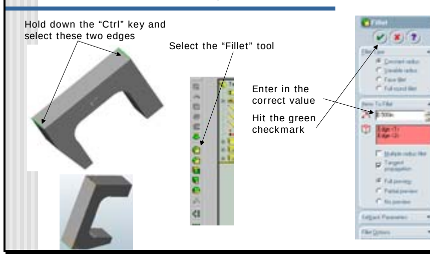
Extrude the Cut



Fillet the Edges

- Hold down the “Ctrl” key and select the two back edges
- Hit the “Fillet” tool from the “Feature” toolbar
- In the Property Manager, type in the correct value
- Hit the green check mark in the Property Manager

Fillet the Edges



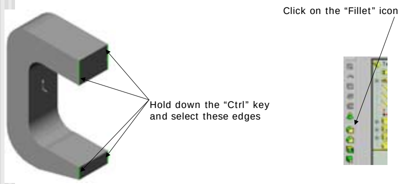
Fillet the Edges

The part should look like this:

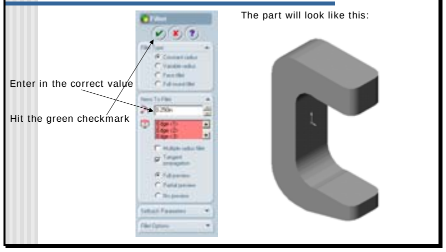
Fillet the Edges

- Hold down the “Ctrl” key and select the shown edges
- Click on the “Fillet” tool from the “Feature” toolbar
- Enter in the correct value and hit the green checkmark

Fillet the Edges



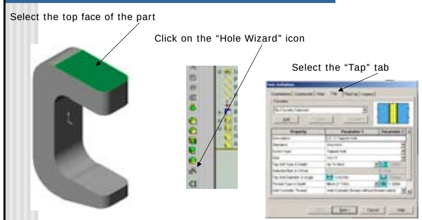
Fillet the Edges



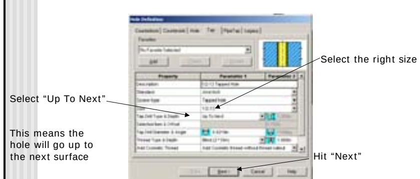
Make the Threaded Hole

- Select the top face of the part
- Click on the "Hole Wizard" tool from the "Feature" toolbar
- Select on the "Tap" tab from the resulting "Hole Wizard" box
- Enter in the desired specs of the hole
- Hit "Next"

Make the Threaded Hole



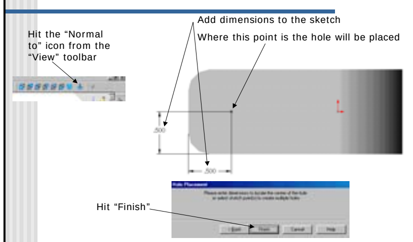
Make the Threaded Hole



Make the Threaded Hole

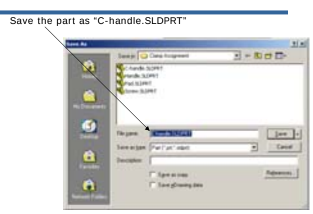
- Hit the "Normal to" tool from the "View" toolbar
- Add dimensions to the sketch
- Where the sketch point is, the hole will be placed
- When the dimensions are placed, hit "Finish" in the "Hole Placement" box
- Save the part as "C-handle.SLDPRT"

Make the Threaded Hole



Make the Threaded Hole

Make the Threaded Hole



APPENDIX B:

RESULTS FROM THE PRETESTS AND THREE QUIZZES

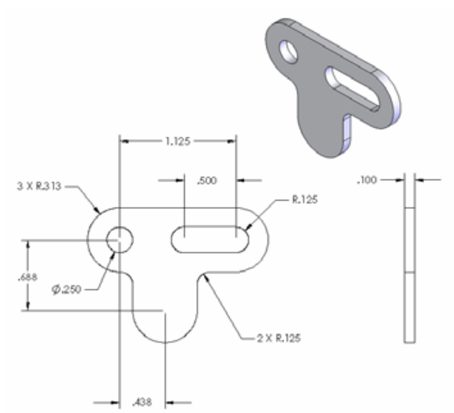
B 1.1 PRETEST

MFG 431 TOOL DESIGN

Initial CAD Survey

Assignment

4. On your own, without the help of any classmates, draw the following part in a 3D Cad system.



5. After completing this answer the following questions on a separate piece of paper.
   a. How long did this take you to complete?
   b. List the steps you took to complete this.
   c. What were some of the struggles you had with this?
   d. How familiar are you with 3D modeling and CAD systems?
   e. How do you feel about using SolidWorks this semester?
6. Put your name on this paper and turn it into Bro. K. by Monday Sept 8th at 5:00 PM

Figure B.1. Initial CAD survey

Table B.1. Results for Pretests

Student	Lab	A (Time)	B	C	D
ST001	Mon 4:00	7	5	5	3
ST002	Mon 4:00	10	5	3	5
ST003	Mon 4:00	5	5	5	5
ST004	Mon 4:00	45	5	3	3
ST005	Mon 4:00	5	5	5	5
ST006	Mon 4:00	120	3	1	5
ST007	Mon 4:00	30	4	4	4
ST008	Mon 4:00	60	3	3	3
ST009	Tue 12:00	20	5	3	4
ST010	Tue 12:00	20	5	5	5
ST011	Tue 12:00	60	1	1	1
ST012	Tue 12:00	20	5	4	3
ST013	Tue 12:00	10	5	4	4
ST014	Tue 12:00	5	5	5	5
ST015	Tue 12:00	70	5	4	3
ST016	Tue 12:00	60	4	4	4
ST017	Tue 2:00	90	4	2	4
ST018	Tue 2:00				
ST019	Tue 2:00	16.5	5	4	4
ST020	Tue 2:00	105	4	3	4
ST021	Thu 12:00	5	5	4	4
ST022	Thu 12:00	60	5	4	4
ST023	Thu 12:00	5	5		4
ST024	Thu 12:00	5	5	5	5
ST025	Thu 12:00	25	5	3	4
ST026	Thu 12:00	15	5	4	4
ST027	Fri 12:00	45	4	3	4
ST028	Fri 12:00				
ST029	Fri 12:00	60	4	3	3
ST030	Fri 12:00	25	4	3	4
ST031	Fri 12:00	60	4	3	2
ST032	Fri 12:00	15	4	2	3
ST033	Fri 12:00	20	5	4	4
ST034	Fri 12:00	20	5	4	4
ST035	Fri 12:00	45	4	4	4
ST036	Fri 12:00	20	4	4	4
ST037	Fri 12:00	60	4	4	4
ST038	Fri 12:00	150	4	2	3

B 1.2 QUIZ #1

MET 431

SolidWorks Comprehension Quiz #1

Short Answer Questions:

11. A part in SolidWorks is built with features. What are features?
12. How do you begin a new part document?
13. How do you start a sketch?
14. What is the default sketch plane?
15. Two circles are placed in a sketch. How do you make them vertical to each other?
16. Give two examples of a feature that requires a sketch profile.
17. Give an example of a feature that requires a selected edge.
18. In an assembly feature tree, what does the "(f)" preceding the component mean? What does "(-)" mean?
19. What is the difference between "Edit Sheet" and "Edit Sheet Format"?
20. How do you place dimensions into a drawing?

Figure B.2. Short written answer section of Quiz #1

Performance Quiz:

Model up the following drawing as a part file in SolidWorks and answer the following questions:

4. How long did this take you to model up?
5. What features did you use to create this part?
6. How do you feel about your progress in SolidWorks?

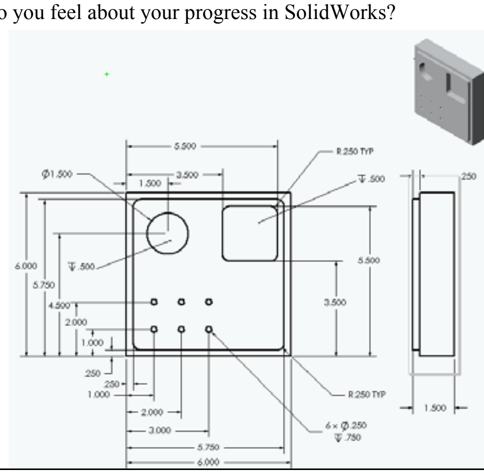


Figure B.3. Performance Quiz #1

Table B.2. Results for Quiz #1

		Question Numbers										
Student	Lab	1	2	3	4	5	6	7	8	9	10	Time
ST001	Mon 4:00	4	5	5	5	4	5	5	1	1	3	21
ST002	Mon 4:00	2	5	5	3	2	2	5	1	5	3	15
ST003	Mon 4:00	5	5	5	5	5	5	5	5	2	3	10
ST004	Mon 4:00	5	5	5	5	2	5	5	1	4	3	30
ST005	Mon 4:00	4	5	5	1	5	5	5	3	5	5	10
ST006	Mon 4:00	3	5	5	5	3	4	5	1	5	3	40
ST007	Mon 4:00	4	5	3	5	3	1	5	1	2	3	20
ST008	Mon 4:00	2	5	3	4	3	5	1	1	4	3	120
ST009	Tue 12:00	3	5	4	5	4	3	3	1	1	3	30
ST010	Tue 12:00	4	3	4	1	3	5	3	1	5	3	20
ST011	Tue 12:00											
ST012	Tue 12:00	4	5	4	5	3	5	1	4	2	3	20
ST013	Tue 12:00	3	2	2	1	2	3	3	1	1	1	
ST014	Tue 12:00	5	5	5	5	3	5	5	5	1	3	45
ST015	Tue 12:00	3	5	3	5	3	5	1	1	1	3	35
ST016	Tue 12:00											
ST017	Tue 2:00	2	5	4	5	3	5	5	1	4	1	30
ST018	Tue 2:00											
ST019	Tue 2:00	4	5	3	5	1	3	5	1	4	4	30
ST020	Tue 2:00	5	5	3	5	5	3	3	1	3	3	44
ST021	Thu 12:00											
ST022	Thu 12:00	4	5	4	4	3	3	1	1	4	4	35
ST023	Thu 12:00	4	3	3	5	2	1	3	1	1	3	40
ST024	Thu 12:00	5	5	2	5	5	5	3	1	3	4	5
ST025	Thu 12:00	3	2	5	5	5	5	2	1	1	5	15
ST026	Thu 12:00	5	5	5	1	5	4	2	1	1	3	20
ST027	Fri 12:00	3	4	3	5	2	2	3	1	4	4	70
ST028	Fri 12:00	3	5	2	2	1	4	1	1	1	2	15
ST029	Fri 12:00	2	5	5	5	3	1	3	1	5	3	
ST030	Fri 12:00											30
ST031	Fri 12:00	2	5	4	4	2	5	1	1	1	3	
ST032	Fri 12:00											60
ST033	Fri 12:00	2	5	3	5	2	2	1	4	3	3	
ST034	Fri 12:00											25
ST035	Fri 12:00	3	3	3	3	3	5	3	1	1	3	45
ST036	Fri 12:00	3	4	3	5	3	3	3	1	1	3	
ST037	Fri 12:00	4	5	2	1	2	4	3	1	1	3	35
ST038	Fri 12:00	3	5	4	4	3	5	1	1	3	3	20

B 1.3 QUIZ #2

MFG 431
SolidWorks Comprehension Quiz #2

Short Answer Questions:

11. What is a Fillet feature?
12. What is a section view in a drawing?
13. How is a section view created?
14. What is the difference between **Edit Sheet Format** and **Edit Sheet**?
15. How do you change the drawing standard from ISO to ANSI?
16. How do you change the accuracy on a single dimension in a drawing?
17. How do you change the accuracy on all the dimensions of a drawing?
18. How do you move a dimension from one view to another?
19. How do you create text in a sketch?
20. This red feature is 1.000 inch long, what are two ways to make it 2.34562 inches long?

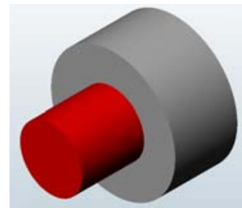


Figure B.4. Short answer section of Quiz #2

Performance Quiz:

Model up the following drawing as a part file in SolidWorks and answer the following questions:

4. How long did this take you to model up?
5. List specifically the features uses in this model. What does it say in your feature manager? (EX. Boss extrude1, Cut Extrude 1 etc.)
6. How do you feel about your progress in SolidWorks?

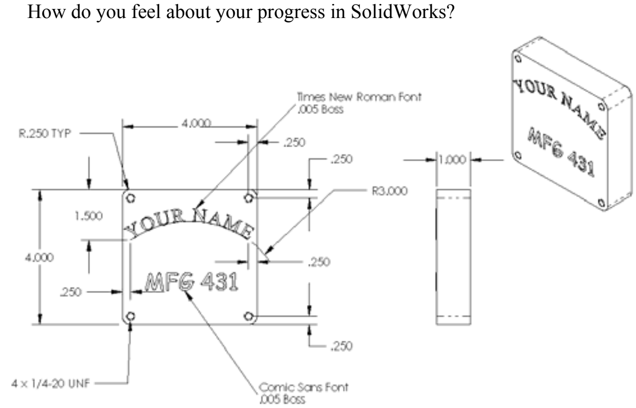


Figure B.5. Performance Quiz #2

Table B.3. Results for Quiz #2

		Question Numbers										
Student	Lab	1	2	3	4	5	6	7	8	9	10	Time
ST001	Mon 4:00											
ST002	Mon 4:00											
ST003	Mon 4:00	5	5	5	5	5	5	5	4	2	5	10
ST004	Mon 4:00	3	4	2	2	4	5	4	4	4	3	20
ST005	Mon 4:00	5	1	3	3	3	1	2	1	2	3	10
ST006	Mon 4:00	5	5	5	4	4	2	5	5	3	3	16
ST007	Mon 4:00	5	4	3	5	5	3	5	3	5	5	15
ST008	Mon 4:00	5	5	3	5	3	2	5	1	4	4	60
ST009	Tue 12:00	5	5	4	1	3	1	1	5	4	3	20
ST010	Tue 12:00	5	5	5	5	5	3	1	2	2	3	15
ST011	Tue 12:00											
ST012	Tue 12:00	4	5	5	5	1	1	1	2	3	2	15
ST013	Tue 12:00											
ST014	Tue 12:00	5	5	5	3	5	5	3	3	5	5	30
ST015	Tue 12:00	5	4	5	5	5	3	5	5	5	2	25
ST016	Tue 12:00											
ST017	Tue 2:00	4	5	5	5	5	5	5	5	3	4	20
ST018	Tue 2:00											
ST019	Tue 2:00											
ST020	Tue 2:00	2	4	5	5	4	5	5	5	3	3	20
ST021	Thu 12:00	4	5	5	5	5	5	5	1	2	3	15
ST022	Thu 12:00	3	3	1	5	3	5	2	1	3	3	
ST023	Thu 12:00											
ST024	Thu 12:00	5	4	5	3	3	5	3	1	3	3	10
ST025	Thu 12:00	4	5	4	5	4	5	1	2	3	4	23
ST026	Thu 12:00	5	4	2	5	4	4	3	5	1	2	30
ST027	Fri 12:00	5	5	2	5	5	5	5	5	3	3	12
ST028	Fri 12:00	5	5	2	3	2	5	2	1	3	3	
ST029	Fri 12:00	5	5	5	5	1	5	5	2	3	4	20
ST030	Fri 12:00	4	4	2	1	5	1	1	5	5	2	40
ST031	Fri 12:00	5	3	1	1	2	2	2	2	5	2	60
ST032	Fri 12:00											
ST033	Fri 12:00	2	5	3	5	4	4	3	5	3	4	15
ST034	Fri 12:00											
ST035	Fri 12:00	3	4	3	5	1	4	1	1	1	2	20
ST036	Fri 12:00	4	4	3	1	3	1	5	1	4	5	20
ST037	Fri 12:00											
ST038	Fri 12:00	5	4	4	5	3	1	1	5	4	3	30

B 1.4 QUIZ #3

MET 431

SolidWorks Comprehension Quiz #3

Short Answer Questions:

11. How do you start a new Assembly document?
12. There are three ways to insert a component into an assembly. List two of them
13. In an assembly feature tree, what does the "(f)" preceding the component mean? What does "(-)" mean?
14. What is the difference between aligned and anti-aligned for a mate?
15. Two cylindrical components are in an assembly. How do you constrain them so they are 4 inches apart?
16. How do you move a component in an assembly?
17. How do you edit a mate in an assembly?
18. When you insert the first component into the assembly, how do you make it so the origin of the component is aligned with the origin of the assembly?
19. What is the easiest way to access the reference planes of a component in an assembly?
20. How do you make an exploded view of an assembly?

Figure B.6. Short answer section of Quiz #3

Performance Quiz:

Take the parts in J: groups/mfg431/quiz3 and assemble them in the shown manner. The two plates should be directly above each other and 2 inches apart.

7. How long did this take you to model up?
8. How did you constrain the pins and bushings?
9. Are all of the components in the assembly fully constrained?
10. How many mating relations did you apply to each pin, bushing, plate?
11. How do you feel about your progress in SolidWorks?
12. How comfortable are you with working in assemblies in SolidWorks?

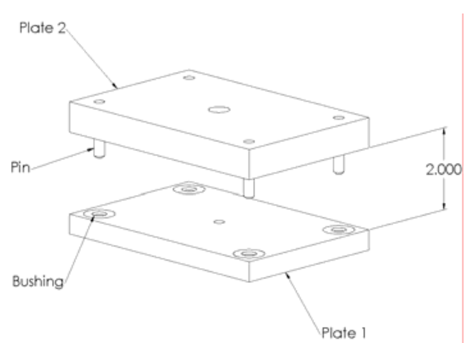


Figure B.7. Performance Quiz #3

Table B.4. Results for Quiz #3

		Question Numbers										
Student	Lab	1	2	3	4	5	6	7	8	9	10	Time
ST001	Mon 4:00	4	5	1	1	5	4	5	1	1	1	17
ST002	Mon 4:00	5	2	1	1	3	3	5	4	4	4	10
ST003	Mon 4:00	5	5	5	5	5	5	5	5	5	5	5
ST004	Mon 4:00	5	2	1	3	5	4	5	1	2	1	10
ST005	Mon 4:00	5	2	5	1	3	2	1	2	1	1	5
ST006	Mon 4:00	5	3	5	5	5	5	5	5	5	1	15
ST007	Mon 4:00	5	3	1	3	1	2	3	1	4	3	17
ST008	Mon 4:00	5	2	2	1	2	5	4	5	2	1	20
ST009	Tue 12:00											
ST010	Tue 12:00	5	5	5	3	5	4	5	1	4	1	10
ST011	Tue 12:00											
ST012	Tue 12:00	5	1	5	1	4	1	2	1	3	1	10
ST013	Tue 12:00											
ST014	Tue 12:00	5	2	3	1	5	5	3	2	4	1	15
ST015	Tue 12:00	5	3	1	1	5	3	3	5	4	1	25
ST016	Tue 12:00											
ST017	Tue 2:00	5	3	5	5	2	2	4	3	4	2	12
ST018	Tue 2:00	2	2	1	1	3	3	2	4	2	1	10
ST019	Tue 2:00											
ST020	Tue 2:00	5	3	1	5	5	5	5	4	4	1	10
ST021	Thu 12:00	5	3	5	2	1	5	5	1	3	1	15
ST022	Thu 12:00	5	3	1	5	1	4	4	1	4	1	15
ST023	Thu 12:00	4	2	1	2	2	4	2	2	1	1	12
ST024	Thu 12:00	5	2	1	1	2	1	3	1	3	1	15
ST025	Thu 12:00	4	3	1	4	3	4	2	1	1	1	15
ST026	Thu 12:00	5	4	1	4	2	5	2	1	4	1	12
ST027	Fri 12:00	3	3	1	4	2	5	5	2	5	1	9
ST028	Fri 12:00	5	2	1	4	1	2	1	1	1	1	
ST029	Fri 12:00	5	3	5	4	1	3	5	4	3	3	15
ST030	Fri 12:00	5	5	1	1	2	5	5	2	1	1	15
ST031	Fri 12:00	4	2	1	1	1	5	1	1	5	1	45
ST032	Fri 12:00											
ST033	Fri 12:00											
ST034	Fri 12:00											
ST035	Fri 12:00	4	4	1	1	1	2	1	1	1	1	20
ST036	Fri 12:00	5	3	5	5	1	3	4	3	4	1	30
ST037	Fri 12:00	2	5	1	5	2	2	3	1	3	1	20
ST038	Fri 12:00	5	2	5	5	5	1	4	1	5	1	15