ABSTRACT

MATTHEWS, BRIAN. The Effects of Direct and Problem-based Learning Instruction in an Undergraduate Introductory Engineering Graphics Course. (Under the direction of Dr. V. William Deluca and Dr. Eric N. Wiebe.)

In this study, the researcher examined the effects of problem-based learning and compared any statistical gain in knowledge, skill, and attitude to traditional teaching of engineering graphics. Problem-based learning was hypothesized to have a positive effect on knowledge, skills, and attitude of students in a traditional engineering graphics course.

The study sample was forty-eight ($N = 48$) students in a Foundation of Graphics course at North Carolina State University. The quasi-experimental study involved a pre-test / post-test control group, using a single control and single treatment group consisting of 24 persons per group.

The independent variable was pedagogical strategy, and the dependent variables of knowledge pre-test and knowledge post-test measured graphic content knowledge, allowing for direct gain comparisons of engineering graphics to the control and treatment groups. Other dependent variables comprised a CAD skill evaluation that measured students' skill in creating a three-dimensional CAD model and an attitude survey (MSLQ) to compare attitude associated with traditional versus problem-based learning. The pedagogical PBL treatment was a series of 20 in-class exercises, where students worked in small groups to complete small-problem scenarios, including reverse engineering of parts.

To determine whether groups differed on more than one dependent variable, an ANOVA was used to analyze data and investigate difference and gain between traditional-

instruction and problem-based learning for knowledge, skills, and attitude. Each ANOVA investigated if any significant difference or gain ($p < 0.5$) existed between groups and was used to determine gain between dependent variables.

The means on the pre- and post-tests measured if the two groups were significantly different in their prior knowledge and skill. The comparison of means and ANOVA of the MSLQ survey score revealed no significant differences in attitude. The result of hypothesis #1 (knowledge), $F(19, 23) = 2.12$, $p = 0.24$, indicated no significant gain. The result of hypothesis #2 (skill), $F(1, 23) = 0.03$, $p = 0.85$, indicated no significant difference, and the result of hypothesis #3 (attitude), $F(21, 527) = 1.57$, $p = 0.50$, indicated no significant difference. Further studies were recommended using similar or other variables to determine if more benefits can be attributed to problem-based learning when teaching engineering graphics.

THE EFFECTS OF DIRECT AND PROBLEM-BASED LEARNING INSTRUCTION IN AN UNDERGRADUATE INTRODUCTORY ENGINEERING GRAPHICS COURSE

by
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BIOGRAPHY

Brian Matthews was born and raised in Thornton, England, a small West Yorkshire village on the edge of the Yorkshire Dales. He graduated from Great Horton High School in 1962. To gain professional qualifications in Construction, Architecture, and Education, he attended Bradford, Liverpool, and Manchester universities over the next 10 years, and was also employed in various design / build companies to help pay his way through college.

After graduating from Manchester with post-graduate honors and a Lectureship in Higher Education in 1973, he worked as a Lecturer and Overseas Officer for the British Overseas Development Ministry setting up new colleges in Guernsey, Channel Islands, Antigua, West Indies, and Lae, Papua New Guinea. He taught architecture, construction, management, and graphics at the college level, returning in between tours to teach at Leeds College and Leeds Polytechnic / University before moving to the USA.

He moved permanently to Raleigh in 1986 where he met his American wife, Etta. From 1986 to 1998, he was Architectural Department head at Wake Technical College, Raleigh, and head of the AutoCAD Training Center. As an AutoCAD expert, he also taught at North Carolina State University as adjunct faculty in the Extension service. In 1998 he joined NC State as a Lecturer in the Graphic Communications Program.

Brian has also edited, co-authored, and written numerous books on Architecture and AutoCAD, such as the AutoCAD Reference Library, AutoCAD Concise Guide, AutoCAD 2000 3D Modeling & Design. He is a member of the Architectural Association, Institute of Building, Institute of Management, Who's Who Worldwide, Who's Who Business Leaders, and also a member of Epsilon Phi Tau, Phi Kappa Delta, and Omicron Tau Theta.

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CHAPTER ONE

INTRODUCTION

This study used a teaching pedagogy of problem-based learning (PBL) to compare any significant changes in knowledge, skills, and attitude to the traditional teaching of engineering graphics. Although PBL is generally believed to better prepare students for learning and groupwork, it has yet to be fully embraced throughout our educational system. Yet, traditional engineering graphics, with its roots firmly embedded in the Industrial Revolution and the 1795 projection methods of Gaspard Monge, still leans on the transmission of knowledge to the solution of an ill-structured problem, the content of which is centered about a set of structured objectives. In turn, these objectives are coupled to standard techniques and solutions and are taught as theoretical, practical, and graphic topics, which are often followed by preformatted homework exercises or tutorials (Belhot, Guerra, & Kuri, 1998).

This instructor-centered *ceteris paribus* approach to finding solutions for engineering problems is important for uniformity and stability in traditional instruction, especially while engineering graphics as a profession is undergoing change, a change where the essential skill for an engineer is the ability to communicate clear design ideas via freehand sketching or engineering drawing documentation to find creative graphics solutions through visualization. Raudebaugh (1996) indicated that engineers are no longer required to create finished drawings, they just need to be aware how 3-D drawing data are presented and approached to meet current industry standards. This change stems from the arrival of computer-aided technology, a tool that single-handedly transformed 2-D engineering board work into 3-D computer-aided design (CAD). Similar changes were proposed in North Carolina State University Graphic Communications Department staff meetings and recent professional engineering design graphics conferences (Clark & Scales, 1999; Meyer & Booker, 1991).

The literature implied an overall need that graduates of engineering are and want to be creative, and the engineering industry wants thinkers and problem-solvers, so likewise we should use education techniques that foster creativity in students (Kellar & Kellogg, 2000). One solution may be through teaching that allows students to solve problems creatively through an active-learning approach, termed problem-based learning or (PBL) for short. Regarded as an active-learning inquiry method, PBL is based on the principle of using problems as a starting point for the acquisition and integration of new knowledge. Techniques such as problem-based learning can instill skills, attitudes, and experiences to enrich engineering to include greater understanding of visualization, problem solving, sketching, and 3-D modeling. It is a process by which a group of students actively engages in learning and contributes, as opposed to sitting passively in a lecture hall, listening to, and memorizing facts (Silberman, 1996).

A recent article by Clough and Kauffman (1999) supported using a problem-based learning approach as a means of improving engineering education. They suggested that "we have to provide our workforce [and students] with skills, attitudes and experiences that will enable them to seek both lifelong facts and knowledge, along with the ability to use those skills as and where they need" (pp. 527-534). Another change suggested by Johnson (1992) for improving engineering education is that "industry needs workers to be both thinkers and problem solvers" (p. 51). To do this, we must use innovative and creative ways to teach the process and not teach in a vacuum but provide an eloquent variance from traditional education and re-anchor the accountability and responsibility students are given for their own learning in engineering graphics through student-centered learning of problem-based learning (Johnson, 1991).

Need for the Study

In order for engineers to retain a competitive edge, they need to be provided with up-to-date knowledge and skills, the ability to problem solve and visualize from 2-D to 3-D and vice-versa, and the attitude to adapt to change. Consequently, engineering graphics education is undergoing change, and the literature suggests those engineering skills, attitudes, and experiences enrich the engineering experience to include greater understanding of visualization, problem solving, sketching, and three-dimensional modeling. The professional organizations and literature (Johnson, 1992; Woods, 1996b) suggest we produce workers who are creative problem solvers and we use innovative methods, such as PBL, to allow engineering students to develop problem-solving and teaming skills for open-ended design and graphic solutions.

Within the literature of Albanese and Mitchell (1993), we see widespread support about the benefits of problem-based learning, its motivational effects on students working open-ended problems and its beneficial long-term effects on lifelong learning. Success in an engineering curriculum has long relied on the ability to creatively solve problems as visual solutions by drawing or sketching orthographic or isometric solutions to a design project as two- and three-dimensional visualizations of a design (Miller & Bertoline, 1991b). However, there is little information on the use and application of problem-based learning methods to engineering studies. There is even less information on the scholarly application of this method to real-life problems in engineering graphics and its use as a visualization tool.

Aside from the industrial and educational need for change, the literature indicates many critical engineering reports and engineering professionals who seek active change in engineering education. One of the latest to emerge is Engineering Criteria 2000 (EC2000), which focuses on outcomes assessment for demonstrating program success, and is endorsed by the Accreditation Board for Engineering and Technology. The EC2000 document attempts to encourage accountability and continuous improvement in engineering education, to which many 2- and 4-year schools already seek active change in engineering studies, especially since the mid 1950s when Dr. Grinter of VPI chaired the 44-member American Society for Engineering Education (ASEE) committee that produced the Grinter Report (ASEE, 1955/1994), to become the essential blueprint for engineering science revolution in USA.

Similar to EC2000, a reprint of the Grinter Report (ASEE, 1955/1994) revisited many recommendations for engineering design and other elements in a curriculum to include "development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, and detailed system descriptions" (ASEE, 1955/1994, p. 75). To place a slant on real-life factors and constraints, it also considered "realistic constraints, as economic factors, safety, reliability, aesthetics, ethics, and social impact" (p. 75). The report was intended to address immediate concerns and have a short-term impact on the engineering profession, and the report did initially suggest sweeping changes in the engineering curriculum to include problem-solving, active-learning, and visualization techniques. It also promoted engineering education to establish the foundation of successful practice, effective teaching, and relevant research in engineering design. Later, the National Research Council (1991) in its Improving Engineering Design report also mirrored this change.

Furthermore, to improve engineering education, the National Science Foundation (NSF), the Carl Perkins Act, and the Accreditation Board for Engineering and Technology (ABET) have also approved the revision of engineering programs by funding educational grants for creative problem solving, engineering design, or applied design education or curricula. Some results of this type of work are outlined by Barr and Juric (1990), Kenley (1995), and Miller and Bertoline (1991a). Consequently, EC 2000 is just one of the latest recommendations to emerge in a long list of ongoing engineering education improvements seeking active change in engineering education.

The reform of engineering education is not restricted to 2- and 4-year schools. Through the Perkins Act and other educational curriculum grants, reform has trickled down to high school to allow problem-centered learning methods. For instance, over 5 years, from 1996 to 2001, the NC Department of Public Instruction, NC State University, and Wake Forest University Medical School hosted statewide workshops in problem-based learning (LeMaster & Matthews, 1996). The two universities used a Perkins and a 5-year NSF grant to further induce and elevate science, technology, architecture, and mechanical engineering teachers and North Carolina high-school teachers and college instructors and with problem-based learning classroom skills. In the PBL workshops, teachers were taught facilitation skills, case study creation, and PBL assessment and rubrics. As new facilitators, they were taught to relinquish control while maintaining the quality and integrity of the learning environment. To model characteristics of lifelong learners, they were taught that helping students find solutions are the keys not the right answers. The process of learning this facilitation skill enabled teachers to empower students with ownership of learning, so there would be no more "guess what I'm thinking in class." Teachers were taught to encourage different pathways for different students and to allow them to seek answers.

Teachers were encouraged to use prompt-style questions and suggestions in order to facilitate but *not* direct the class, which included: What would be helpful to do now? Is that a learning issue? How do you know that? What does that have to do with the problem? Does everyone agree with that statement? To sum up, the professional organizations and literature suggest we must produce innovative workers who are creative problem solvers and use innovative methods, such as problem-based learning, to allow engineering students to fully develop their problem-solving and teaming skills and be more creative with open-ended design and graphic solutions. Most engineering problem solving is accomplished via team and groupwork, so why not use a problem-based education approach?

Problem-based Learning and Engineering Graphics

The reasons that prompt the use of problem-based learning in engineering graphics are (a) cognitive, (b) motivational, and (c) functional. Cognitive reasons deal with comprehension and learning, and the research on traditional learning indicates that rote learning may be effective in the short term for routine tasks and tests but is ineffective for deeper understanding and retention of complex problem solving (Cognition and Technology Group at Vanderbilt [CTGV], 1992a, 1999b). Likewise in cognitive research, students have what is termed *inert knowledge,* which in traditional learning problems is used very little from the narrowness of use, but which in problem-based learning is used more fully. Cognitive research indicates that a learner has to interact with ideas in context to make sense of a problem or task. It is through thinking processes and internal dialogue or interaction with others, we achieve deep comprehension for text, graphical, and problem-solving-based activities (CTGV, 1992). Students identify, analyze, and resolve problems using inert knowledge from previous experience and courses rather than from simple recall (Jones, Rasmussen, & Moffitt, 1997).

Motivational reasons deal with incentives and attitudes and how students focus on the problem, issues, questions raised, and the teacher's assessment, nurturing, and support. Attitudes are difficult to gauge, but, if measured with care, they indicate that specific support can create a more positive attitude toward a given issue than when not supported. Lambros (2000) pointed out that PBL goes beyond this, with group dynamic elements as a social and intrapersonal side to learning. Although attitude studies are often associated with change and like or dislike, her text indicated many traditional education students move up through an academic climate of competition where success is grounded in how clearly they set themselves apart from the rest of the group and where students' attitudes and their motivational conditions of acceptance and self-awareness are often focused on themselves rather than others in a team. Also, as new students of PBL come into a learning environment, their acceptance as part of a group plays a pivotal part in their own progress and the progress of other members of that group. Lambros (2000) indicated it is this attitude in accepting other members of a group within PBL, one where students have to take the weaknesses with the strengths, that students are likely to become much more aware of their own strengths and their own weaknesses (Lambros, 2000).

Functional reasons deal with how closely the problem is aligned to the needs of the 21st century and simulates a real-world concept or helps prepare students toward technology, communication, and presentation skills arising out of the problem. Yet Bridges and Hallinger (1992) indicated that, to achieve success on a test in traditional education, students seek a right answer because their performance is measured on content-specific tasks, whereas in PBL faculty discourage one right answer and instead help students learn how to frame questions, formulate problems, explore alternatives, and make effective decisions.

Short-term memory helps us look for ideation solutions to problem solving in both traditional and problem-based education. It assists the manipulation of ideas and is where the actual mental problem-solving process is handled. This simple process of remembering for a short period of time is fundamental to our experience of the real world (Adams et al., 1988). Long-term memory, in-contrast, is a stockpile of knowledge, skill, and experience called into short-term memory as the need arises. Ledoux (2002) asserted that our memory cannot produce a carbon copy of what went before but reconstructs the prior experience to the best it can. In turn the memory recalls this restoration as new memory, based on the multiplicity of the past experience and recall. Hence, if we have a 21st century real-world memory link, hands-on skill, or an experience we can base on fact, we have better recall and can use it to our advantage to process a new problem.

Applying this to engineering graphics, comprehension, and learning can be achieved by connecting problem-based learning via graphical problem solving using visualization and other techniques. To illustrate, in graphics study we can create visuals as sketches, drawings, concept ideas, charts, diagrams, clusters, or chunks of information so space in short-term memory does not impede a problem-solving process. Cognitive psychologists agree that, for information to be retained in long-term memory, learners must construct a memory link between the new information and some inert-related information already stored in long-term memory (Gagné, 1985). Thus, sketching and drawing 2-D and 3-D visual images adds short-term ideas to our long-term memory to produce new internal memory visualizations.

The visualization research of Kosslyn (2000) indicated that the brain lets us work visual processes in problem solving, allowing the formation of mental imagery, and through the use of our visual perception to work through visual problems.

Thus the main rationale for using visualization in engineering graphics is that it connects visual thinking in a number of ways. It allows us to process and retain form for creative ideas in problem solving, to connect spatial concepts of 2-D to 3-D solutions, and, as solutions are sketched to design problems, it allows the geometric breakdown into three-dimensional modeling procedures and its subsequent modeling in engineering graphics.

Additional proof of this, according to Miller (1990), is that visualization has recently come to the forefront of graphics education research and requires the association of two- and three-dimensional representations. Oladipupo (1991) also confirmed it is the ability to relate to and form images from two- and three-dimensional worlds. Bertoline and Wiebe (2002) indicated that visualization "allows us to document completed designs, to create problem solving ideation sketches, . . . to understand a 3-D object as it exists, and to visualize the 3-D object into future possibilities" (p. 188).

Additional evidence of visualization connecting visual thinking, according to Raudebaugh (1998), is that visualization has to be some form of problem-solving process. "The use of orthographic projection as a traditional drafting method is not effective in teaching visualization skills" (Raudebaugh, p. 5). The final proof is provided by Lajoie (2000) who argued that, because a brain has no visual outlet or monitor, we use graphic communication as a tool, and visual images, sketching, and graphics all have a commonality as a communication device. They convey design ideas or design intent to a colleague, a client, or end user of a product, so that graphic communication is merely a visual tool or visualization process by which we explain how something will function or will be machined or created (Lajoie, 2000).

To apply this concept to engineering graphics, we can connect the visualization process to the flow of ideas as ideation, communication, and documentation and produce two-dimensional sketches of a three-dimensional model to eventually produce working, final assembly or toleranced drawings. For example, an engineering graphics PBL question might connect ideation and communication to a scenario where a single rough dimensioned pictorial sketch is provided. The initial question could prompt for an explanation of the pictorial and its use in graphics and how students might sketch new views to show the parts in more detail to an engineer supervisor, including what and where dimensions would be placed, to what engineering standards, and what geometry would be needed to sketch the parts? The final PBL question could move into prompting for the rough visual steps to model the part in CAD. Team members could swap a response with other groups, who would create the parts in CAD as a visualization check and present it to the class.

An alternative PBL scenario could produce and modify real parts. Using Vernier calipers and engineering sketch pads, small teams could reverse-engineer dissimilar assemblies into a series of ANSI-dimensioned sketches that need modification. The parts are shared throughout the collaborated team according to complexity, yet individually produced in the parametric modeler that are assembled and checked for interference. In turn, the modified parts may be sent to the three-dimensional prototyping printer as a 3-D model, which as part of the PBL solution, could demonstrate the technology learned and help to communicate the process into a final presentation model as students present their solution.

Statement of the Problem

The intent of this study was to determine if knowledge, skills, and attitudes as learning outcomes of graphic engineering problems would significantly improve when problem-based learning was compared to traditional instructor-based learning in engineering graphics.

Principle Research Questions

The major research focus for this study was: Does the use of problem-based learning have any effect on knowledge, skills, and attitude when compared to students enrolled in traditional engineering graphics courses?

The following research questions were identified:

1. Will there be a significant gain in knowledge scores between the traditional lecture group and problem-based learning group?
2. Is there a significant difference in CAD skill performance scores between the traditional lecture group and problem-based learning group?
3. Will there be a significant difference in attitude scores between the traditional lecture group and problem-based learning group?

Hypothesis Statements

The null hypotheses indicated that for the control and treatment groups:

$H0_1$: There will be no significant difference in knowledge gain between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_2$: There will be no significant difference in CAD skill between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_3$: There will be no significant difference in attitude between the traditional lecture (control) and the problem-based learning (treatment) groups.

Assumptions of the Study

The following assumptions were made about the research sample for the study:

1. Students in the Foundation of Graphics class would participate voluntarily in the study.
2. Students entering the course had little knowledge of 3-D computer-aided modeling.
3. The research sample had limited knowledge of problem-based learning.
4. The research sample had limited knowledge of visualization procedures.

5. Students would complete the MSLQ test to the best of their ability.
6. It was assumed that conditions for completing assigned problems are the same for all.
7. It was assumed the research individuals would be motivated to complete the study.
8. It was assumed the research sample had varying sketching skills during the study.
9. It was assumed the testing instruments used in the study accurately measure achievement, performance, and student attitude.

Limitations of the Study

The study was limited to undergraduate college students taking a Foundation of Engineering Graphics course at NC State University during the fall of 2002. Demographic limitations indicated that the random enrollment process limited the study to students mainly from the Design, Aeronautical, Engineering and Mechanical schools.

Accordingly, due to the limitation of random assignment, a quasi-experimental design study was applied to the sample. Further limitations suggest that due to the small sample size of the study, the study might not adequately represent the total population. Because of their backgrounds, some students may have had prior experience with a CAD program, been better at problem solving and teamwork than others, or may have conflict as team members within a random group.

Summary

Research indicates that active-learning and small-group teaching, both significant features of PBL, are two deeply interrelated concepts. They represent two different types of theories. Activeness is one theory about how we learn, which in effect is a learning theory. Small-group teaching, a pedogogical theory, relates to how we can encourage and support learning in others. To this end, this study used the independent variable of pedagogical strategy to measure traditional lectures and compared it to problem-based learning in engineering graphics.

Research indicates that both industry and government reports suggest broad changes in the engineering curriculum to include problem-solving, active-learning, and visualization techniques. They also invite engineering education to include the foundation of successful practice, effective teaching, and relevant research in engineering design. Problem-based learning connects visualization to engineering graphics by associating problem solving with visualization in a number of ways. It allows us to process and retain form to creative ideas during problem solving and to connect two-dimensional spatial concepts to three-dimensional solutions.

Henderson and Jordan (1995) argued there is a self-evident skill or link in visual cognition with engineering culture and technology. From conception to production, we see engineering documents intrinsically linked to visual thinking. Until recently, engineering graphics still operated in a 2-D environment, where machinists translated 2-D drawings into 3-D form, which resulted in problems in production, assembly, sales, and marketing, and where part of the team often had difficulty with the product and 2-D drawings. Part of this articulation can be rectified by the changes that engineering graphics is undergoing as 3-D solid modeling, problem solving, and visualization in both the industrial and educational environments.

Einstein said, “Imagination is more important than knowledge” (Calaprice, 1996, p. 223). A big dilemma in engineering is preparing students in how to use imagination and visualization of their thought processes as neat proportional sketches with a tolerable degree of accuracy. Visualization and problem solving in engineering graphics not only aid the visualization process but also help engineering problem clarification. The key for combining some of these suggestions may be through problem-based learning in engineering.

CHAPTER TWO

LITERATURE REVIEW

To discover the significance of problem-based learning in engineering graphics and the effectiveness of change in knowledge, skills, and attitudes, the literature review focused on multiple components of problem-based learning (PBL) research: (a) problem-solving ability, (b) individual attitudes, (c) group dynamics and social attitudes of PBL, (d) basic knowledge and its retention in engineering graphics, (e) challenges to implementing PBL, and (f) visualization in engineering. These multiple components became the broad nature and scope of the topic and the thinking behind the use of PBL in engineering. This chapter comprises the following sections:

1. Introduction;
2. Defining problem-based learning;
3. Historic development of problem-based learning;
4. Group dynamics, social attitudes and facilitation of PBL;
5. Challenges and concerns for implementing PBL in engineering education;
6. Problem-based learning in engineering;
7. Historic development of engineering graphics;
8. Basic knowledge and its retention in engineering graphics;
9. Visualization research in engineering graphics; and
10. Summary.

Introduction

For engineers to retain a competitive edge, they need the knowledge, skills, and attitudes that will provide them with futuristic problem-solving skills, the expertise to visualize in both two and three dimensions, and the ability to adapt to change. The literature reveals very few studies in the use of PBL for engineering graphics education. Yet the challenge and concern are to change our learning curriculum and teaching methods from instructor-led to student-centered learning and so provide our future workforce with the needed knowledge, skills, and attitudes of an advanced technological society.

The challenge for educators and their students, as Kenley (1995) pointed out, is to include industry partnerships, changing employer needs, and curriculum course design. Taylor (1995a, 1995b) indicated that educational improvement also involves providing students with experiences that help them adjust to a changing industry. Such thinking and analysis have permitted educational reform. This reform urges the educational system and institutions to upgrade their philosophies and teaching methodologies and to improve their ways of educating students toward their chosen career paths, whereby students are provided with realistic knowledge, skills, and attitudes in the world of work so they can achieve subsequent success in the modern global workforce. One reform Johnson (1991) suggested may be through teaching that allows students to solve problems creatively through an active-learning approach termed *problem-based learning.*

Defining Problem-based Learning

Problem-based learning is an active-learning method using group work to move from the known to the unknown. Based on the principle of using problems as a starting point for the acquisition and integration of new knowledge, the method is designed to create learning through prior learning experience and to reinforce existing knowledge. PBL is also based on constructivist values, where the curriculum moves from the whole to the part (Finkle, 2000).

Problem-based learning uses Maslow's (1968) principles of two sets of forces or needs within us, wherein "one clings to safety, the other struggles for growth" (p. 45). Our problem-solving ability, according to Silberman and Auerbach (1998), builds on this need:

> One of the key ways to attain a feeling of safety is to be connected to other people in groups. This enables challenges to be set before us as we invoke emotional support to move beyond our present level of knowledge and skill. (p. 7)

Greening (1998) emphasized that problem-based learning does not prescribe fixed and narrow pathways for learning but rather broadens our outlook. Brooks and Brooks (1993) and Jones et al. (1997) stressed (a) big concepts and curricular activities using primary source materials; (b) the role of the student as thinker with emerging theories in collaboration with others; (c) teacher roles that mediate the learning environment; (d) assessment that is ongoing and integrated with student learning; and (e) teacher observation, student exhibition, and portfolio management. Greening (1998) and Savery and Duffy (1995) proposed that PBL be student centered, a discussion of knowledge, and faculty facilitated via active discussion to combine it into a learning experience. They concurred that PBL is cognitive complexity using real-world situations to achieve viable solutions.

Historic Development of Problem-based Learning

Problem-based learning is intrinsic to traditional apprenticeships, but apprenticeships were not assessed in a standardized way. The literature suggests problem-based learning was first introduced to North American medical schools in the 1960s as a tutorial process for promoting lifelong learning. Albanese and Mitchell (1993) traced its roots back to McMaster (Canada), University of Limberg at Maastricht (Netherlands), and Harvard University (USA). The traditional school acceptance of PBL is based on Harvard Medical School, which employed a hybrid problem-based model of conferences, clinical sessions, lectures, and tutorials (Aspy, Aspy, & Quinby, 1993).

The mid-1980s saw PBL evolve as a more descriptive than analytical process, and the research of that period mostly relates to student perceptions and student performance in certain aspects of a course. Few impact studies of the time relate to graduates, the faculty, the institution, or the profession. Most literature evidence stems from a handful of medical schools, with no examples of coherent PBL curricula for other professions. In this period, the PBL model spread to form a network of professional schools, including Maastricht and the University of California at Berkeley. By the early 1990s, more than 50 medical schools had adopted PBL in some format. Today, over 80% of medical schools and many professional (e.g., architectural and construction) schools use PBL to teach professional cases (Bridges & Hallinger, 1992; Vernon & Blake, 1993). In time, overseas universities adopted and adapted PBL for medical school training, including Maastricht (the Netherlands) and Newcastle (Australia). In the United States, the University of New Mexico adopted the McMaster model (Aspy et al., 1993). Of all teaching methods, problem-based learning is best studied in a scientific sense.

Problem-based learning as a medical teaching tool has now branched into many medical institutions, such as Boston, Georgetown, Harvard, Illinois, Indiana, Michigan State, Northwestern, Southern Illinois, Mercer, Tufts, University of Hawaii, University of Illinois, University of Missouri-Columbia, University of Pittsburgh, University of Texas-Houston, and Wake Forest-Bowman Gray (LeMaster, 1996; Robbs & Meredith, 1994). Other countries using it to teach undergraduates include Australia, Canada, Denmark (Aalborg), England, France, Finland, South Africa, the Netherlands, and Sweden (Biggs & Collis, 1982). These countries currently implement and use PBL in medical and professional schools.

In summary, problem-based learning as a teaching tool is now used globally in many areas of higher education, such as schools of dentistry, health sciences, nursing, pharmacy, public health, veterinary medicine, architecture, building, business, computing, education, engineering, forestry, law, police science, social work, and other professional fields.

Group Dynamics, Social Attitudes, and Facilitation of PBL

A typical public educational system has qualities and dynamics that influence how our professional knowledge, skills, relationships, and attitudes are established and informed within the system. In the social connectivity within a school and its system, we find relationships and attitudes concerned with student–teacher, student–student, teacher–teacher, and teacher–administrator relationships (Giroux, 1988).

Lambros (2000) pointed out that PBL goes beyond this, with group dynamic elements as a social and intrapersonal side to learning. Her studies show that many traditional education students come from an academic climate of competition, where success is grounded in how clearly they set themselves apart from the rest of the group and where traditional education students' attitudes and conditions of both acceptance and self-awareness focus on themselves rather than others in a team. As traditional students join a PBL learning environment, their acceptance as part of a group can play a pivotal part in their own progress and the progress of other members of that group. It is this attitude of accepting other members of a group within PBL that students have to take individual weaknesses and strengths and, by doing so, they are likely to become much more aware of their own strengths and weaknesses (Lambros, 2000).

The teacher workshops of LeMaster and Matthews (1996) saw PBL dynamics emerge in diverse positive and negative ways, including “tension, frustration, feelings of inadequacy, leadership, exploration, commitment, acceptance and self- awareness” (p. 12). Some students of PBL were “ready to engage in group dynamics as part of their own growth, they were candid, spoke up, and were ready to accept leadership” (Lambros, 2000, p. 12). Others appeared more inclined to avoid issues of “acceptance and self-awareness either because of their own tension, discomfort, unease, or simple lack of awareness,” (p. 14) or they changed due to group dynamics (Lambros, 2000).

For example, in one lengthy PBL workshop, a shy, reticent female student had a complete change of attitude, started to take over the lead, and became increasingly aware of her own capabilities and ease with the situation. To this end, her awkward tension became positive, she became excited, she became animated, and she engaged the conversation; the group sat up, took notice, and the tension became high energy. In another PBL workshop, “a major element of in-group dynamics was curiosity and interest, which turned out to be just as ambiguous as tension” (Lambros, 2000, p. 15). A male engineering participant showed how his attitude and curiosity appeared to have two expressive sides of self-doubt and inquiry. On the one hand, when curiosity showed up as a compelling need to know the truth about the subject area or arrive at a deeper understanding of a complex issue, the emotional accompaniment he generated was excitement, along with an awareness of the fulfillment to come. It appeared to generate enthusiasm, passion, and creativity, which in turn was conveyed to the group solution. On another occasion, "when curiosity showed up as fear of not knowing or as self-doubt, his emotional accompaniment was overwhelming frustration, defeatedness, and irritation" (p. 13).

The recognition of these attitudes and elements during PBL facilitation is a pivotal skill that can only be achieved through experience and interaction with students. Lambros (2000) reported the two types of tension as destructive and energizing (negative/positive). The troublesome side of tension in group dynamics is where you might feel stymied or confused and ill at ease with a situation, like having feelings you, as a teacher or student, or rest of the group do not want to be in that situation; that is, you are in a rut and cannot move on. One way around this in-group facilitation dynamic is to have everyone vent their feelings and prompt what they, or the group, wants as a constructive contribution to team work. Often this technique has a way of clearing the air and shifting the negative tension to a positive tension. It is a case of indicating what does and does not work for each member of the group. But it is through calm facilitation authority that this is made to happen in a quiet unassuming way, such as, "Let us stop at this point and express our feelings for what is happening and what we need to do." The stakeholders can then move on, restart, and become engaged in team problems and learning content (LeMaster & Matthews, 1996).

Authority is another facilitation skill and a final element of the central relationship between the teacher and the student hardly mentioned in any of the PBL literature search

(Albanese & Mitchell, 1993; Aspy et al., 1993). Authority is an expected central relationship of a teacher in any class situation (Giroux, 1988). While, as a facilitation skill, authority regulates social and intrapersonal skills, it is not there to merely focus on mediating the learning environment. Lambros (2000) indicated that this part of active learning in PBL is connected to learning and in-group dynamics. Authority underpins the facilitation process as a pivotal contributor to group dynamics and shows us how curiosity, or the lack thereof, can lead to either deeper understanding or self-doubt and frustration. It can lead to irritation and dissatisfaction, or it can invoke feelings of inadequacy, leadership, exploration, self-awareness, commitment, and acceptance, and it underpins and is pivotal to the PBL process in the struggle for growth and safety. Lambros (2004) called this the social side of learning.

Challenges and Concerns for Implementing PBL in Engineering Education

In the quest to implement PBL as engineering knowledge, skills, and attitudes, many challenges and concerns can block the implementation of problem-based learning in a curriculum. Kenley (1995), a senior building lecturer from the University of Melbourne, Australia, stated:

> Within the professional degrees of Medicine, Architecture and Building, . . . the limitations of the traditional [teaching] method have been recognized. In order to enable students to learn the professional discipline, an alternative method [refers to the PBL method] is used which seeks to sever the reliance between the teacher's knowledge base and the student's need to learn from it. Rather, the student is empowered to seek the answers from a wide range of resources [including the

> teacher] and is guided in that learning process by a series of problems instead of a structured curriculum along academic discipline lines. (pp. 2-4)

Stepien, Gallagher, and Workman (1993) reported that corporate and government communities not only seek partnerships with industry and higher education but also require the provision of a workforce to meet economic and global competition and professional standards and integrity via higher education. Success in the workforce may depend on a person's aptitude to meet changing needs of employers. Such changes include critical thinking and group problem solving skills. College graduates must be able to deal with numerous challenges that evolve from globalization and a complex and dynamic business environment.

To develop a PBL course, educators need to restructure course design to provide real-life problems and situations (Finkle & Torp, 1995). Also, it is necessary to prepare for a paradigm shift in teacher–student relationships and possibly assume a variety of teacher roles.

> Educators are challenged to re-think the student's role in the learning process, while maintaining high student retention rates. If we place students in a PBL learning environment, our students may experience increased stress due to a different learning environment and a strategy of openness. (Stepien & Gallagher, 1993, pp. 25-28)

Challenges and concerns for PBL implementation are case creation, facilitation, attitude, and assessment (Lambros, 2004). In case creation, Greening (1998) indicated a borrowed textbook model to have low value, with paper scenarios ranked in the mid range, as opposed to speaking to a real person or a video recording that ranked higher. Albanese and

Mitchell (1993) suggested a few concerns, as evidenced in the case-study literature: (a) the process of change due to pre-conceived non-constructivist modes of learning, (b) the problems of assessment, and (c) problems relating to inherent difficulties with PBL as a mode of learning.

Problem-based Learning in Engineering

When applying problem-based learning to engineering students, who are familiar with traditional talk-and-chalk classrooms, they are likely, at first, to be uncomfortable with problem-based learning. It is up to the instructor to convince the students that they are researchers looking for information and a problem solution. The students often expect the instructor to describe what they have to do, as a cookbook approach to learning. The attitude of engineering students is that they normally want to know just what they have to do to get a grade (Belhot, 1999). The students find moving into a non-traditional learning or PBL format scary and horrifying, as it can lead to irritation and dissatisfaction.

Other elements of individual dynamics can help carry students through times of disappointment and frustration. Lambros (2002) suggested one attitude to surface early was the element of commitment and indicated this attitude may have initially been a commitment to an individual self. For example, a personal commitment to become an engineer, but she suggested it quickly became a commitment to something larger than oneself and seemed inclusive of a commitment to others. This element of observed commitment shows up in different ways, such as sharing and caring for others in the team, especially as they help out as partners (Lambros, 2002).

Partnerships and prompting as facilitation also come in many forms, for example, by partnering through the facilitation process and through the instructor as a meta-cognitive coach. A coach who also thinks and prompts about solutions to the problem is one way to motivate and stimulate in students the PBL conduct expected of them, producing a positive attitude to learning. Facilitation questions are encouraged. What is going on here? Can anyone explain to me where we are at in the problem? Students are encouraged to divide and share the work through task delegation and to use technology. Further questions include: What do we need to know more about? What can we do in a more effective way? What should it look like visually? What is missing from the graphic? Is this better sketched as a 2-D or 3-D sketch? Facilitation is the process that keeps groups aligned and moving toward the engineering objectives and the imaginable two- or three-dimensional solution to the problem.

LeMaster and Matthews (1996) indicated that engineering facilitation rules are as follows:

1. Do not rush students, especially in the beginning.
2. Do not take the problem away from the students by being too directive.
3. Do not give students too much information because you are afraid they will not find it.
4. Do not be afraid to say. “That sounds like a learning issue” instead of giving the answer.
5. Do not be afraid to be uncomfortable—growth is uncomfortable, for you and the students.

6. Do not become the expert in the group just because you have the information they need.

7. Do not intervene as soon as you sense they are going off track—remember, mistakes are okay. (LeMaster & Matthews, 1996)

In the application of this principle to engineering, a big dilemma in engineering was preparing students in how to use imagination and visualization of their thought processes as proportional sketches with a tolerable degree of accuracy. In engineering graphics we need imagination for design. As Einstein said, "Imagination is more important than knowledge" (Calaprice, 1996, p. 223). Visualization is an area of graphics that can form a specialization in itself, for as humans we can receive visual input but we have no output mechanism for visually representing ideas, except in mental imagery and dreams. Unfortunately, these visions are not easily shared. Hence, humans need visual assistance to help them represent ideas visually (LaJoie, 2000).

Developing engineering sketches through visualization and spatial skills is an effective means of engineering communication, and many researchers have looked at spatial learning (Baartmans & Sorby, 1996; Branoff, 1999; Parolini, 1994; Sorby, Manner, & Baartmans, 1998). But other factors in engineering also need consideration. For example, in his study of the brain, Restak (2002) pointed out that people who take part in art, painting, sculpture, woodwork, ceramics, and jigsaw puzzles have significant spatial ability. Sorby et al. (1998) indicated that other factors, such as childhood toys, might significantly aid future development for careers that require spatial ability. Legos, Tinker Toys, sports, computer games, video games, and Erector Sets all have a common kernel, which is they help children develop spatial visualization skills (Baartmans & Sorby, 1996). In addition, “a relationship was found between the amount of experience high school students had in shop, drafting, and solid geometry and their scores on a three-dimensional spatial visualization test upon entering college” (Sorby et al., 1998, p. 6).

Historic Development of Engineering Graphics

Geometry, sketching, and drawing are graphic language tools used by engineers and architects to solve problems and convey design intent. The history of engineering graphics may be viewed from two angles: important discoveries and instrumentation technology.

Important Discoveries in Engineering Graphics

Engineers use geometry, sketching, and drawing as mathematical and visual analytical tools to converse in a common language. Research indicates these same tools also encouraged technological improvement and change, especially during the Renaissance when competition was the engine driving technological improvement in engineering, architecture, and art. This competition was among the Guilds, whose well-educated members included artisans, goldsmiths, artists, masons, metal workers, sculptors, compass makers, and so on. Renaissance engineering was also loosely intertwined with architecture. Geometry and sketching were used to instill dexterity and hand-and-eye coordination in apprentices as a means of mental training to help them solve problems and to think spatially and holistically as they captured new ideas (Bennett, 1926, 1937; Trachtenburg & Hymen, 1986).

Nevertheless, geometry, sketching, and drawing as graphic language tools were slow to emerge. Brunelleschi, Crozet, da Vinci, Durer, Eiffel, Francesca, Hall, Hood, Monge, Moyer, Palladio, and others contributed to technical breakthroughs in engineering graphics.

Though mathematical analysis of space and geometry was considered unique to the Renaissance, it led Filippo Brunelleschi, a talented sculptor and Renaissance engineer and architect, to discover perspective drawing. Single-point perspective, roughly attributed to between 1410 to 1415, was an important discovery for architecture and art (Trachtenburg & Hymen, 1986).

Multiview drawing was another discovery attributed to the Renaissance. “In the latter half of the fifteenth century and the early part of the sixteenth century,” according to Hammond, Carson, William, Gerald, and Hugh (1971), “drawings showing three related views of an object were in use. The drawings were made in what is now referred to as first angle projection and were based on orthographic projection” (p. 11). Further proof of these multiview drawings is derived from examples of the artistic works of the Italian Piero della Francesca (1416-1492) and the German Albrecht Durer (1471-1528), artists who were well versed in mathematics, geometry, and measurement, and, more specifically, artists who wrote treatises on perspective, geometry, and measurement (Cole, 1992). Gardner (1980) indicated that della Francesca produced art as a projection of a “mind cultivated by mathematics” and that della Francesca was convinced that the “highest beauty is found in those forms that have clarity and purity of geometrical figures” (p. 500). Gardner pointed out that “Francesca, a skilled geometrician, wrote the first theoretical treatise on systematic perspective,” that he was influenced in “perspective drawing by the architect Alberti at Ferrari and Rimini around 1450-01,” and that all “Piero’s works give evidence of his skill, being full of perspectives, especially a vase represented so as to show its front and back, its sides, its bottom and its mouth” (p. 500).

Gardner (1980) wrote that "Durer became the first northern artist to travel to Italy and see its underlying theories at their source" (p. 608). After "Durer's first Italian journey in 1495, he made a second trip in 1505-06, and from then on, it became his life mission to bring modern Italian Renaissance style north and establish it there" (p. 608).

These two accomplished artists, Francesca and Durer, used multiview drawings basically for anatomical reasons: they wanted to sketch body parts to correct dimensions and in perfect geometric proportion within their artistic paintings. But multiview projection as a drawing method was little used by engineers until it was rediscovered by Monge and put to practical use when the Ecole Polytechnique de France was first opened in Paris (Bennett, 1926). Likewise, multiviews as a graphic technique was also in use in China. Prior to its rediscovery by Monge, a Chinese by the name of Xi-Yao (1729) wrote geometric treatise lecture notes on perspective drawing, later revised in 1735.

Thus, artistic multiviews by Francesca and Durer eventually found a practical use in engineering, the proof of which is in a series of published lecture notes by Monge (1795) that later became the first geometry textbook in first-angle projection (Monge, 1800). This practical use of geometry did not appear in America until Crozet returned from the Ecole Polytechnique in 1816. Thus, graphics discoveries of Europe were brought to 19th-century America by Crozet a West Point professor and graduate of the Ecole Polytechnique. Crozet (1821) published *Descriptive Geometry,* one of the first books in the United States on first-angle projection. In it he showed how to use first-angle projection as the basis for presentation and calculations. The ultimate move to third-angle projection in America came in 1902 when Hall (1902) a professor from Lafayette College, Pennsylvania, wrote *Descriptive Geometry,* the first book on third-angle projection (Hammond et al., 1971).

Quickly following was the beginning of the modern direct or auxiliary method by Moyer (1904), who produced a book on *Engineering Descriptive Geometry.*

> In the direct approach, solutions to spatial problems are accomplished by projecting onto auxiliary planes of projection that show directly the desired relationships. In the direct method, the spatial system is first referred to the principal planes of projection and then the spatial system and the views are simultaneously revolved until the solution is obtained." (Hammond et al., 1971, p. 13).

The final combination of the direct method and third-angle projection came about in 1926 when Hood (1926) wrote *Drawing Descriptive Geometry by the Direct Method.* In the book, he combined the direct method and third-angle projection, which is now common to America.

Classical architectural engineering forms also appeared in America and Europe through Andrea Palladio (1508-1580), the stonemason turned engineer and architect who produced a treatise in 1570 on architecture in which he illustrated and set out the relationships of geometrical form to architecture. For some 200 years, his *Four Books of Architecture* allowed others to see and copy examples of plans, elevations, sections, and geometric relationships and also put theory into practice (Trachtenburg & Hymen, 1986). The early literature of Bennett (1926) and French (1918) also indicated how different training techniques in different countries produced unique drafting and craftsmanship skills to produce master craftsmen. French (1918) indicated how his undergraduate students were able to visualize clearly in space and form mental models of the subjects upon which they were working.

In the historic writings of Bennett (1926), we find that projection theory, as visualization in the classroom, was taught under different classification headings of sketching, technical drawing, geometry, drafting, and so on. Hammond et al. (1971) also indicated that engineering graphics as a communication tool was used to overcome the barrier of verbal language and as “an illustration can be understood by anyone who views it” (p. 11). To overcome the barrier of verbal language and learn the graphic language of engineering or architecture, Hammond et al. indicated that trainees used different ways of learning, such as copying, imitating the master, and simple problem solving as a form of cognitive apprenticeship to the master. These different ways of learning were all to the same end, providing a form of mental training as 3-D spatial visualization to engineers, drafters, or both in order to produce 2-D standard drawings for the machine shop, structure, or fabrication (Bennett, 1926). Yet, the history of engineering graphics is not just limited to important discoveries, as instrumentation technology also played an important role in these discoveries.

Instrumentation Technology in Engineering Graphics

Hand Tools

From compass to computer, instrumentation technology has driven the way engineering graphics are taught, such as whether to use hand tools or computer-driven software tools to create drawing documentation. At the outset, hand tools refer to how compasses, ink pens, and other engineering instruments have evolved. The earliest compass, for example, was made of wood, which later became forged iron and then die-cast brass. One of the oldest references to the City and Guilds was a 1442 reference to the German Guild of Compass Forgers, so referenced because they created forged iron compasses by hand. Advances in materials show that die-cast brass came into use around the 16th century, then flat-sheet brass in the 18th and 19th centuries. References are also found of Swiss instrument mechanics who started manufacturing plants, Esser in 1770 and Kern in 1819 (Oppenheimer, 1956). Compared to the German compasses, the Swiss versions were made as improved precision instruments from rolled brass sheeting instead of die-casting or hand forging. An advance in design came in 1843 when Clemens Reifler, through his German factory, produced a compass with a pivot head-and-ball motion. Reifler exported this innovation to America in 1855 (Oppenheimer, 1956).

To this end, Theodore Alteneder, a Swiss-trained apprentice in the Reifler plant from 1841 to 1848, set up an instrument manufacturing plant in Philadelphia when he came to America around 1848. He also used a new imported material, nickelsilver (alloy of copper, zinc, nickel). The new material came from China to Europe in 1820 and was used in Swiss instrument manufacturing from 1850 on (Oppenheimer, 1956). Advances slowly followed in the 20th century, with improvements through knurled wheels, friction heads, center-screw adjustment, and the spring bow-and-beam-compass, until the computer took over as a tool.

Computers

The latest tool in engineering graphics is computer-aided design (CAD), which allows engineers to draw and print in two and three dimensions and view engineering drawings as fully rendered and scaled documents. Using software as the engine and the mouse as the pen, it is an extension of the drawing board as it embodies geometric techniques and the old hand tools of scale rule, protractor, compass, triangles, and dividers in a single package. However, traditional early CAD software followed the old hand geometry patterns, that of using multiview techniques as a layout on the drawing sheet. The modelers allowed CSG solid modeling of a three-dimensional part, but it was unwieldy and engineers had trouble learning how to manipulate true solid models into multiview documents. It required explicit size definition of all geometry, and the user had to maintain geometric relationships between entities, so editing was time intensive (Matthews, 2000).

The latest CAD software in engineering graphics is the parametric or constraint-based modeler, which allows geometric relationships to be directly coded into the model as parameters or variables and the designer's true intent is built into the model. Parametric design is an important modeling paradigm in computer-aided design as it allows relationships (constraints) among the degrees of freedom of the model, resulting in efficient design modifications and variations. The geometric information is coded as parameters, which are assigned as (a) numeric values, (b) relations to other parameters through equations, or (c) relations to other parameters through geometric relationships. These parameters include (a) size and shape of the model and (b) constraints or relationships between entities, such as parallel, concentric, tangential, co-linear, and perpendicular constraints.

To conclude, until recently traditional engineering design graphics still operated in the 1795 multiview projection methods of Gaspard Monge, and they were enmeshed in a 2-D pencil or 2-D computer-drawn environment where machinists translated 2-D multiview drawings into 3-D form. Often this proved costly and time consuming as the two-dimensional views could result in problems further down the line in production, assembly, sales, or marketing. Indeed, although engineers and machinists are trained to read and translate 2-D sketches into 3-D form, any non-specialists in sales and marketing as part of the team regularly had spatial difficulty visualizing the final product from 2-D section or multiview drawings, which were reflected as counter-productive to sales. To resolve this, artists were regularly hired to produce pictorials or three-dimensional sketches as visual solutions, but these costly pictorial interpretations were frequently inaccurate (Hobson, 2002). Now through complex and sophisticated 3-D computer modeling software, 3-D changes in engineering design problems and graphics are starting to correct some of the old 2-D difficulties (Matthews, 2000).

Basic Knowledge and Its Retention in Engineering Graphics

With engineering problem solving and problem-based learning, the research indicates a gap in the three-dimensional visual–spatial approach to problem solving. It is through teaching engineering students to think three dimensionally and use visualization techniques that we can enhance their spatial cognitive and problem-solving abilities and also help construct a memory link to the new knowledge (Adams et al., 1988). However, as we look for solutions to problem solving, especially with both traditional and problem-based education, we see the manipulation of ideas and the actual mental problem-solving process in a small portion of the brain called short-term memory.

In short-term memory, most people can hold between four and nine chunks of information at a time. If they try to hold more than that, they forget (Adams et al., 1988). Long-term memory, in contrast, is an unlimited storehouse of knowledge and experience called into the short-term memory when it has to be used (Ledoux, 2002). A case in point, as Ledoux (2002) pointed out, is that we must practice to become skilled at selecting the information we actually need to work with in our short-term memory. To aid memory, for instance, we can use repetition, make charts and diagrams, create clusters, or use chunks of information so the space in short-term memory does not impede our problem-solving process.

Cognitive psychologists generally agree that, for information to be retained in long-term memory, learners must construct a memory link between the new information and some related information already stored in long-term memory (Gagné, 1985). To apply this memory link to engineering graphics, for example, we might construct a memory link by both sketching and reverse engineering a dimensioned part into two- and three-dimensional images in order to help retain the short-term ideas into long-term memory.

Yet in traditional education a number of factors contribute to learning, such as how students process information to gain knowledge via visual, auditory or tactile cues, the instructor's teaching style, the time of day, student motivation, and so on. Take a simple lecture process as an example. A brain processes information; it doesn't just receive it. If an instructor gives a lecture at a rate of 150 to 200 words a minute, how much of that minute will be spent processing the plethora of information and how much will be absorbed as new knowledge as the student tries to concentrate? People hear at a rate of 450 to 500 words a minute and, as Silberman and Auerbach (1998) pointed out, "it's hard to keep up with a talkative trainer," so we get bored and our minds wander (p. 3). Further, as Silberman and

Auerbach (1998) indicated, people are inattentive in a lecture 40% of the time, and their attention span decreases with each passing minute.

> When learning is passive, the learner comes to the encounter without curiosity, without questions, and without the interest in the outcome. When learning is active, the learner is seeking something. He or she wants an answer to a question, needs information to solve a problem, or is searching for a way to do the job. (Silberman & Auerbach, 1998, p. 5)

Since the advent of computer technology into engineering graphics some 40 years ago, the knowledge, skills, and attitudes for the practice of engineering drawing, problem solving, and teaching have been revolutionized. At one time, the use of visual thinking with a pencil, a slide rule, a scale rule, and a sketchpad (visualization) were all the basic design or analysis tools needed. Traditional teaching methods are useful for curricula where rules, procedures, formula, and so forth are applicable (Kenley, 1995). For mathematics and engineering, for example, the attraction of a traditional program is significant. Kenley indicated that the reliance on the teacher's knowledge base is less critical, and it is also supplemented by standard references and guides.

This is also true of engineering graphics, which is supplemented with engineering drawing standards, dimension rules, and tolerance rules. But these can also be learned actively by using problems and methods, such as reverse engineering, where teachers can create problems to work backward from the product to the drawing and show how standards and tolerances inter-relate to the part or the assembly of parts, and the students in turn use a hands-on approach to problem solving.

In conclusion, the current teaching method in engineering graphics is often through an instructor-based or project-centered learning method, a ceteris-paribus approach, as opposed to the adoption of a problem-based learning style that is different insomuch that it requires the use of a cognitive problem as the primary teaching mechanism (Kenley, 1995). For instance, in problem-based learning, a learning situation is presented before any knowledge is given. Once knowledge is acquired, it is applied to the problem. Through this method, the students are in control because they must select the knowledge needed to solve the problem, learn that knowledge and relate it to the problem. They select their own pace and sequence, and often evaluate themselves (Woods, 1996a).

Visualization Research in Engineering

Evidence shows that visualizing three-dimensional objects and manipulating them in the mind is important to engineers, and many graphics engineering professionals indicate that spatial visualization can be used successfully toward the solving of real problems (Deno, 1995; Miller & Bertoline, 1991a, 1991b; Parolini, 1994). In engineering, the field of spatial research has been examined by Branoff (1999), Miller (1990), Sorby et al. (1998), and others. Visualization research also appears to come under the heading of spatial ability and spatial rotation as a process of mental imagery manipulation. In an early example, Pellegrino, Alderton, and Shute (1984) subdivided and separated spatial ability into two components: spatial relations and spatial visualization. Yet the focus of their study was on the psychometric measurement of speed, power, and complexity of an individual's spatial manipulations. Pellegrino et al. (1984) focused on the ability to think quickly and on the ability to mentally manipulate complex mental models, concluding that this was a sign of spatial intelligence. Witkin, Moore, Goodenough, and Cox (1977) also cited similar results in their famous field dependent–field independent studies. Gaylean (1983) performed research that combined visualization and cognition. She presented visualization exercises that were designed as a learning aid to help students have more effective learning and to be more aware of themselves and others. She found that visualization increased cognitive accomplishment, provided more social interaction between student–student and teacher–student, and enhanced creativity.

The visualization research of Kosslyn (2000) indicated that visual imagery is produced in an area of the brain termed the visual cortex. This rear area of the brain lets us work visual processes in problem solving, allowing the formation of mental imagery, and through the use of our visual perception to work through visual problems.

Engineering projection theory and engineering graphics is both a 2-D and a 3-D image skill and cognitive process, and, to perform well, an engineer has to be able to spatially visualize in both two and three dimensions (Bertoline & Wiebe, 2002). Visual images in the field of graphics are a tool, a mental model, a mind tool or simple communication device used to convey messages and ideas. In this visual age, images, drawings, sketches, or graphics all have the same common thread: They are communication devices and are used to convey design ideas to a client or an end user who will use the product (Matthews, 2000).

Summary

Modern technological society needs engineers with the knowledge, skills, and attitudes of technically educated and creative thinkers, team players, and lifelong learners.

Today's educational system is expected to respond to the knowledge, skills, and attitude needs of our future industry, though many believe that universities and colleges are inadequately equipped for an economy that is defined by technology, abrupt change, and competing global markets. Engineering workers need to be both Gestalt thinkers and meta-cognitive problem solvers. How these workers are trained in basic engineering graphics may influence the way they perform in industry and as lifelong learners. A worker's success in the engineering workforce often depends on an ability to meet the changing needs of employers, which includes the possession of critical thinking as both individual and group problem-solving skills.

Not all studies are favorable to PBL. The research indicates that conflicting test results on basic knowledge comprehension. Albanese and Mitchell (1993) reported that, in the medical field, it was sometimes found that students schooled with problem-based learning performed worse on standardized tests, though they performed better on clinical tests and equal on essay tests to traditionally-schooled students. In another study, Albanese and Mitchell (1993) indicated that PBL students had knowledge deficits as compared with traditionally trained peers. Another study found that PBL students performed worse on immediate post-tests but over time they performed better and their scores equaled students taught in lecture mode at 3 months and 2 years, indicating that PBL knowledge is more deeply ingrained and less likely to be as easily forgotten (Albanese & Mitchell, 1993). Finally, Albanese and Mitchell indicated that approximately 20% less subject matter could be dealt with in a PBL-based curriculum, as opposed to a traditional lecture series, suggesting that the 20% is spent on processing skills.

Possessing the ability to solve problems, along with interpersonal team skills, the ability to visually think through a problem, and the benefit of connecting problem solving to engineering ideation, communication, and documentation as visualization and thinking tools for engineering graphics is often the mark of a successful leader, especially in engineering design work. As in today's educational imperative, education is still often mistakenly viewed as a mere mastery of facts, as opposed to the development of a person's ability to think debate and reason. In conclusion, facts are important, but the information and knowledge explosions, as well as ever-changing technology, have created a new educational imperative, an imperative where we must now prepare a workforce with knowledge, skills, attitudes, and experiences that will enable them to seek lifelong facts and knowledge, along with the ability to use those skills as and where they need. Through possession of these skills, they'll be able to analyze, evaluate, and solve engineering problems and their own lifelong learning.

CHAPTER THREE

METHODOLOGY

This chapter looks at methodology, procedure, and instrumentation and summarizes the major differences between the control and treatment group pedagogy. This study examined the significance of problem-based learning and compared it to traditional teaching within engineering graphics. To discover the effectiveness of change in knowledge, skills, and motivational attitude, several measurable variables were selected. The independent variable of pedagogical strategy was a comparison of traditional lecture to problem-based learning. The measurable dependent variables were (a) content knowledge, which was measured using gain scores of pre-test and post-test engineering graphics problems; (b) skill, which measured CAD skill laboratory performance by creating a timed CAD model; and (c) student attitude, which was measured by the MSLQ survey. Scores were obtained to determine the effectiveness of the study.

For the independent variable of pedagogical strategy, students received traditional instruction and problem-based learning instruction through a series of specially prepared engineering graphic exercises created for the study within the Foundation of Graphics syllabus. In the treatment group, a problem-based learning pedagogy was used, which, instead of using a one-way live teacher–student lecture style of pedagogy, included probing questions and PBL grouped student–student–facilitator interaction style. This PBL pedagogical difference and the PBL activities leading into other PBL activities were used in the study to build upon knowledge gained. Therefore, instead of following a traditional lecturing process, the researcher used prepared exercises, PBL facilitation, and probing questions as a problem-solving process for knowledge gain.

Major Research Questions

The major research question for this study was: Does the use of problem-based learning have any effect on knowledge, skills, and attitudes when compared to students enrolled in traditional engineering graphics courses? The question was based on the rationale that problem-based learning may be used as a problem-solving tool to help improve student learning outcomes in knowledge, skills, and attitudes when compared to instructor-based learning.

The following research hypotheses identify the study testing instruments and subsequent data analysis:

$H0_1$: There will be no significant difference in knowledge gain between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_2$: There will be no significant difference in CAD skill between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_3$: There will be no significant difference in attitude between the traditional lecture (control) and the problem-based learning (treatment) groups.

Subjects and Demographics

The study sample comprised two groups of 24 persons per group ($N = 48$) from North Carolina State University enrolled in either a GC211 or GC120 course, which they entered as a result of their own university major choice. Demographics showed that students' academic backgrounds and majors varied widely, with four-fifths of the sample as engineering majors and the rest non-engineering majors. Eighty-three percent of the treatment group indicated it was their first course in engineering graphics, as opposed to 53% in the control group. The remainder of the groups indicated having a previous course in high school.

Subjects participated freely in the study. Of the sample, 85% were male and 15% were female. Ethnicity of the subjects obtained the following cell counts: 4 African-American (8%), 1 Asian (2%), 37 Caucasian (78%), 1 Latino (2%), and 5 Native-American (10%). The Foundation of Graphics course also served as a development course in knowledge, skills, and attitude for higher Graphic Communication courses, where knowledge, skills, and motivational behavior were required for advanced graphics and technological activities.

In addition to their similarity, the GC120 and GC211 courses also had the following criteria for selection: (a) each section could be taught by different instructors but have similar student demographics for the target study; (b) any instructor chosen for the treatment group must have had prior experience in using problem-based learning and in teaching visual-spatial methods; (c) each course had been taught prior to the semester in which the research was conducted; (d) each course included engineering graphics theory and CAD skill for a final engineering project; (e) each course had common elements that included student–teacher interaction; and (f) subject demographics were from both engineering and non-engineering majors at the sophomore and junior levels.

Research Design of the Study and Sampling

The study was confined to two groups, a GC211 control group and a GC120 treatment group, and consisted of 24 persons per group. The study was a quasi-experimental design (see Table 1), using statistics to explore gain among variables (Campbell & Stanley, 1969). The control group, comprised of 24 students registered for the GC211 Introduction to Engineering Graphics course, had an independent instructor who taught both the lecture and CAD lab to the control group. Chosen out of 10 possible Foundations of Graphics groups, the choice of control group was due to (a) instructor access, availability, and prior teaching of similar classes using common elements that included teacher–student lecture and student–teacher lab interaction and (b) subject demographics would be from both engineering and non-engineering majors at the sophomore and junior levels. Both the control and treatment groups used the same text (Bertoline & Wiebe, 2000), used the same CAD software and tutorials, and took the same mid and final tests and quizzes.

The GC120 Foundations of Graphics treatment group used problem-based learning (PBL) for specific manufactured graphic problems without lectures, and the Graphic Communications instructor was trained to work in small groups using problem-based learning that included student–student–facilitator interaction. Students had no knowledge of the study prior to registering for the course. Students in both the treatment and control groups had the same Foundations of Graphics syllabus, the same number of CAD labs, mid-term test, end-of-term test, and MSLQ survey. Only the PBL for the treatment group was different.

Pedagogical strategy was the independent variable treatment. The dependent variables were (a) knowledge pre- and post-test to compare knowledge gain; (b) CAD skill, a comparison of a CAD lab test; and (c) MSLQ attitude survey. Table 1 shows the quasi-experimental research design.

Table 1

Quasi-experimental Research Design

Group	Pre-test	Treatment	Post-test
Treatment	O_1	X	O_2, O_3, O_4
Control	O_1	--	O_2, O_3, O_4

Note. O_1 = knowledge pre-test, week 1. X = problem-based learning treatment, week 1 through 10. O_2 = knowledge post-test, week 10. O_3 = CAD skill evaluation (timed), week 11. O_4 = MSLQ attitude survey, week 12.

The knowledge pre-test/post-test scores (O_1, O_2) measured engineering graphics content knowledge using a pre-test/post-test design as measurable dependent variables. The CAD skill scores (O_3) measured the application of a timed CAD laboratory performance test by creating a three-dimensional CAD model and comparing its quality and completeness. The attitude survey (O_4) used the MSLQ a self-report questionnaire to measure students' attitude. The researcher selected four subscale measures, intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy, to serve as indicators of student motivation.

Procedure

After gaining IRB approval in spring 2002, a pilot study was undertaken in the summer 2002 semester, with the main PBL treatment completed in fall 2002. At the outset of the study, the informed consent form (see Appendix A) was administered to the subjects. At that time, the type of research was explained to the subjects as a teaching pedagogy, and the subjects were asked to participate, but not informed of the purpose of the study, which was to determine if problem-based learning had any more motivation than a traditional lecturing method when teaching to an undergraduate Foundation of Engineering Graphics course. The procedure was to use a control group with traditional instruction and a treatment group with problem-based learning teaching methodology. This next section looks at the procedure between the control and treatment groups and the pedagogical differences between groups.

Control Group Procedure

To remove instructor bias, a second graphics instructor delivered the course content to the fall 2002, GC211 Introduction to Engineering Graphics control group in a traditional instruction format, meeting the control group twice a week for two 2-hour periods, in the classroom and in the CAD lab. After taking attendance, the instructor used either traditional PowerPoint slides, delivered web-based lectures, or used overhead transparencies, which were combined with preformatted individual classwork, sketching, graphic exercises, and homework. Students worked alone without formal group or social interaction with other students in the classroom. There was only student–teacher interaction or interaction through nearness of seating. In the CAD lab, the instructor handed out individual CAD exercises and lectured on CAD tutorials.

The control group atmosphere was formal, and students followed a set syllabus, as listed week by week in the class restricted-access web page. The link to the web page was deactivated at the conclusion of the course. The syllabus included weekly common textbook reading, sketching, graphic exercises, CAD modeling and tutorials, plus the same mid- and final-tests as followed by all Foundations of Graphics classes. Students also produced a sketchbook of sketched items, and they had engineering graphics activities that varied from two-dimensional to three-dimensional exercises as part of the standard course syllabus (see Appendix G). Control group sketching and exercises covered 2-D geometry, 2-D orthographic layout, 2-D projection, 2-D sectioning, auxiliary projection, sketching, dimensioning, and CAD modeling.

Control group students also completed an interim furniture design project. Book and handout exercises comprised multiviews, missing hidden/object lines, or views, isometrics and pictorials, and sketching dimension or auxiliary exercises. In brief, all the book and handout exercises in the control group were given individually. The students were not allowed to work in a group, and they had to work through and listen to lecture material given by an instructor (a CAD expert who had successfully taught this way for several semesters).

The control group met every alternate class in a CAD lab and accurately followed the syllabus of curricular material (see Appendix G), online CAD tutorials and CAD problems, plus 3-D models and projects (for examples, see Bertoline & Wiebe, 2002, pp. 600-640). The CAD labs were computer equipped to allow 24 students full access to the same CAD modeling program.

Treatment Group Procedure

Research design treatment centered on pedagogical differences between traditional and PBL activities and teaching methodology, both of which were specifically interspersed with probing questions in order to follow the fall 2002, GC120 Foundation of Engineering Graphics syllabus. The PBL activities in this study were used to build upon knowledge gained. The 24 students registered in the Foundation of Graphics course met with the instructor of the treatment group twice a week for two 2-hour periods.

The treatment was a series of 10 problem-based learning engineering graphics units of more than 20 in-class exercises, administered for a period of 12 weeks where the students worked in small groups of two or three to complete or work through a series of small-problem scenarios. Students were expected to work out a solution in class as much as possible. The small project and PBL engineering graphic problems were created to account for integral portions of the course that related to line weight and line types, 2-D orthographic layout, 2-D projection, 2-D sectioning, auxiliary projection, reverse engineering, sketching with Vernier scale measurement (reverse engineering included layout, dimensioning, and modeling), and CAD modeling (see Appendix C).

In delivery, the instructor for the treatment group did not use lectures with overhead transparencies, web-based lectures, or PowerPoint slides lectures mixed with individual classwork as did the instructor for the traditional-lecture control group. Instead, the treatment instructor had in-depth training in using PBL in the classroom. The treatment group centered on PBL discussion via probing questions and group activities, working in small teams on the created graphics exercises as a means to search for knowledge. Students were asked to participate in the research, but not of the comparison to another class. Students worked to the same syllabus as the control group but in a less formal atmosphere. No extra content was added to the treatment group; only the method of delivery and pedagogy was different. The students took the same mid- and final-tests as all other Foundation of Graphics classes. To assist sketching, graphics exercises were also developed in 5 mm standard grid and 5 mm isometric grid format. Like the control group, the treatment group met every other class in a CAD lab. In the CAD lab, both the control and treatment groups had similar curricular material, modeling software, CAD tutorials and CAD exercises; and both groups had to produce similar 3-D solid models and projects in the labs, which were computer equipped to allow 24 students access to the same solid modeling program. Table 2 lists the pedagogical differences between the control group and treatment group.

Table 2

Control and Treatment Group Pedagogy

Control	Treatment
Research consent form	Research consent form
Graphic pre-test	Graphic pre-test
Demographic survey	Demographic survey
GC 211 syllabus	GC 120 syllabus
PowerPoint or web-based lectures[a]	--
Individual sketching exercises[a]	20 PBL group & individual exercises[a]
Furniture design project[a]	Vernier reverse engineering problems[a]
No group interaction[a]	Group interaction[a]
Individual reading[a]	PBL group & individual reading[a]
Individual homework	PBL & individual homework[a]
CAD tutorials	CAD tutorials
Class web page	Class web page
--	PBL group work outside of class[a]

(*table continues*)

Mid-term quiz	Mid-term quiz
Graphics post-test	Graphics post-test
CAD skills test	CAD skills test
Post-MSLQ survey	Post-MSLQ survey
Individual CAD projects	Individual CAD project w/assembly[a]
100-question final exam	100-question final exam

[a] Indicates pedagogical differences.

Control Group and Treatment Group Summary

To recap, the syllabus for the GC211 and GC120 engineering graphics courses, tools, resources, and activity worksheets between the control and treatment groups started out as similar, yet what made the 12-week treatment different (see Tables 2 and 3) in this study was the PBL pedagogy and teacher facilitation. Explicitly what made the pedagogy different was the PBL treatment and instructor facilitation process. Classroom work was crucial to this study, and the treatment group used both paper-and-pencil exercises to follow the PBL graphics (see Table 3) and live group student–teacher interaction and student–student interaction.

Table 3

Project and Problem-based Learning Activity Design Summary

#	Unit type from syllabus	Task time (week)	Graphics format
1	Engineering & Metric Instruments	1	Hand sketching
2	Applying Engineering Geometry	1	CAD/hand-sketching
3	Engineering Standards/Multiviews/Geo.	1	CAD/ hand-drawing
4	Lines/Drawings with Geometry	1	CAD/ hand-drawing
5	Missing views - Eng. Drawings w/Geo.	1	CAD/ hand-sketching
6	Engineering Practice – Metal Lab Tour	1	Written paper
7	Projecting Engineering Dimensions	1	CAD/ hand-drawing
8	Projecting Engineering Sections	1	CAD/ hand-sketching
9	Projecting Auxiliary Projections	1	CAD/ hand-drawing
10	Engineering Project & Assembly	3	CAD/ hand-drawing

Problem-based learning scenarios were set into a total of 10 units over a 12-week period for the engineering graphic problems and included interview format, project format, open-ended problem format, and incomplete sketch or incomplete graphics format to a sketch or drawing problem. Hands-on sketching included incomplete views, incomplete lines, line weights, missing views, 2-D and 3-D geometry, incomplete sections, and auxiliary projections.

Students strived to complete each treatment problem in class, or, if not completed, the problem was used in class and later completed in the CAD lab. The CAD lab treatment included both visualization and CAD drawing and complemented the visual thinking process and modeling parts in CAD. This problem type of scenario was adopted to lead the students into CAD modeling through profile extrusion, geometric relations of interconnected lines, or both. This process gave students experience in how to correctly start a part or when to go back and rectify wrongly created parts, especially when they produced a part that required major corrections (i.e., as part of an assembly). See Appendix C for PBL problems and Table 3 for a list of PBL units.

Differences in Pedagogical Method

In the control group, the students worked individually rather than in teams, and the control group instructor lectured and worked with them through preformatted paper-and-pencil sketching and geometry exercises from the textbook or the class web page. With the PBL treatment group, the students were first organized into small teams or groups of two, three, or four. The purpose behind small teams or groups is that, often, at least one member of a group, depending upon group size, will have some tacit knowledge from prior learning or skill and will bring that knowledge to the table (Silberman & Auerbach, 1998).

At the outset, the treatment group was provided with exercises. The exercises were supplied to subjects as a means to start their learning and to provide them interest and motivation. The written questions on the exercise sheets served as a means for subjects to start looking up resources and to answer questions pertaining to the syllabus. Each group started out with: What do we know? What do we need to know? Where will we find resources to find that out? Individuals in the groups were learning teamwork and how to learn, interact, and ask questions.

Subsequently, a main difference between the two groups was that, instead of lecturing, the instructor moved around the room and became the facilitator, who prompted, worked with, and sat in with the different groups. Instead of just giving answers and being the available expert in that group, the instructor became the facilitator who specifically worked with each group. The instructor started prompting with questions, such as: Is that a learning issue? Do we have any resources for that? What else could we learn from this sheet?

Another difference was that feedback from students came via facilitation, assessment, missed deadlines, and observed conflicts between students, which included students who were tardy, did or did not work well with others, and lacked motivation. The facilitation feedback process was used to foster teamwork and social interaction and to ensure positive interaction and harmony within the small groups as learning feedback. This process ensured that no single person dominated the group and that all members participated as a team. The feedback also ensured that as individuals came together in small groups their personal differences, values, and attitudes did not contribute to creating conflict. Further feedback came from student-to-student teaching, where a student as part of a group would show another student how to create or work through a problem. That student, in turn, would show another student and so deepen his or her knowledge about the subject matter. A few practical examples of the differences between the control and treatment groups' pedagogical activities and materials are discussed and illustrated next.

Differences in Pedagogical Activities and Materials

Sketching differences between control and treatment groups. Both the control and treatment groups used sketching throughout the study. The control group used exercises in the textbook, whereas the treatment group used scenario sketching as shown in Appendix C.

Figure 1 shows a graphic from an orthographic sketching activity for the PBL treatment group. Various sketching scenarios were used, including probing treatment questions such as: What are the names of each of the views shown on this sketch sheet? What is line weight? What is the difference between a centerline and a center mark? Why is this line thicker on the outside of this sketch, and what is the difference between these lines? What is the alphabet of lines? Why do we lay out drawings using multiviews? What is a multiview? Can you sketch a correct profile in the correct multiview location? Can you sketch and visualize the steps to sketch out the part first on grid paper, before putting it into the CAD system?

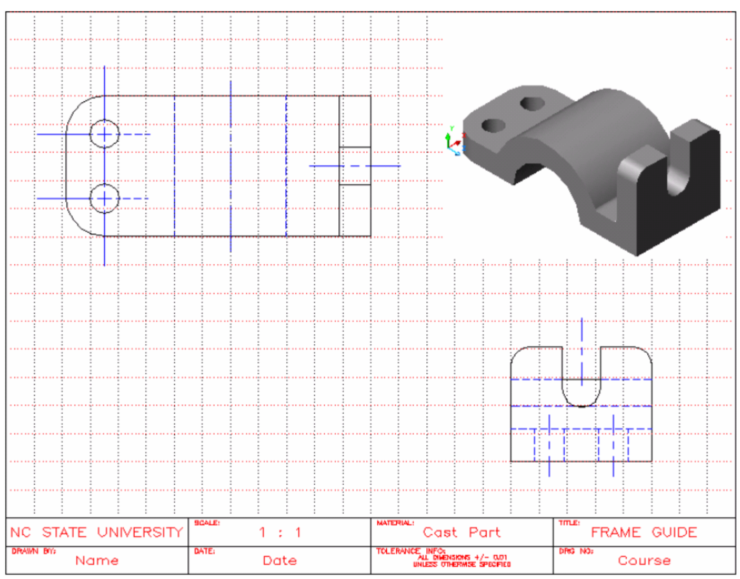

Figure 1. **A treatment group orthographic sketching example.**

Sketching for the control group on the other hand did not use probing questions or a facilitation format. After a lecture by the instructor, the control group used sketching examples from the class text as listed on the class web site. Two control group sketching examples are shown in Figure 2. The class web site instructed students to create two pictorial sketches of each of the following objects in their sketchbooks:

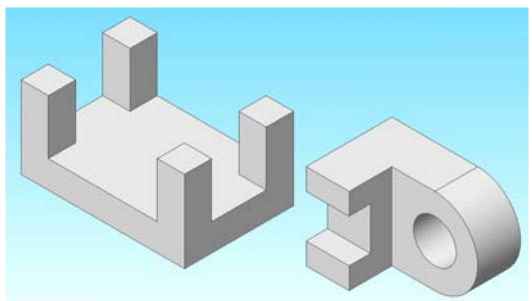

Figure 2. **Two examples from a control group pictorial sketching exercise.**

Geometry and CAD differences between control and treatment groups. The control and treatment groups used geometry throughout the study. The control group used 2-D sketching and 2-D CAD geometry exercises. The purpose was to learn how 2-D geometry is closely connected to CAD as an electronic drawing tool. The class would sketch the geometry, list the relationships, then create the part in CAD. The class web site instructed students to sketch the Rod Guide and identify the geometric relationships present. A CAD geometry sketching example for the control group is shown in Figure 3.

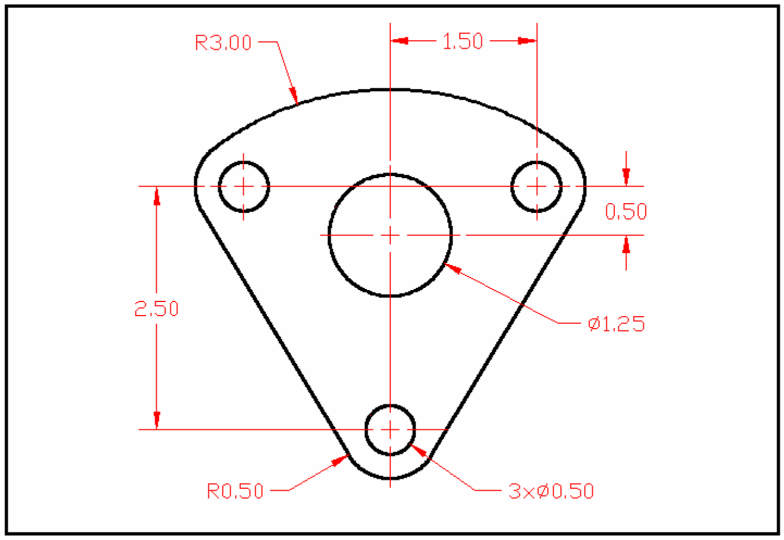

Figure 3. **A control group 2-D CAD geometry exercise.**

Nevertheless, in the treatment group, to learn how 2-D and 3-D geometry, sketching, and measurement are interconnected with engineering and CAD, the treatment group used reverse engineering of a C-clamp and other geometric activities, as shown in Figures 4 and 5.

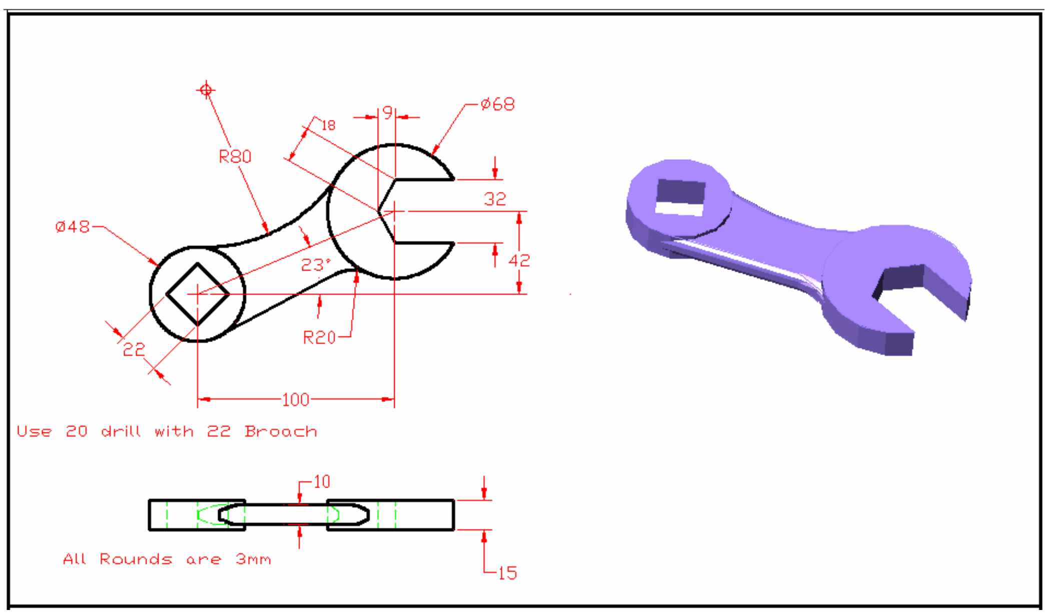

Figure 4. **Treatment group 2-D and 3-D CAD geometry problem.**

Figures 4 and 5 show treatment-group graphics. Facilitation questions to subjects for these examples included: Are all the profiles of each view correct? Can you sketch and describe how you would create the part in CAD? Do the views show correct centerlines and center marks to ANSI standard? What is the difference between a centerline and a center mark? Is the line weight correct for each of the views? What is line weight? Are the hidden lines correct? What is a fillet? Do the profile views show the correct hidden lines to ANSI standard? Are all views needed to show the part—are any views redundant?

These questions led the facilitator to ask: Why would we use a fillet or round in the design of the part? How does a fillet or round affect the design and strength of the material? If the part was a casting, what would happen if it was cast without fillets or rounds? Why do we apply tolerances between parts, and where would we find tolerance references in the text? Figure 5 shows part of a case study where treatment students would start with a paper drawing, which would be sketched in millimeters, then produced in CAD. This drawing would also be used to introduce correct multiviews, dimensioning, and the use of hidden lines, centerlines, and center marks, as used within CAD documentation.

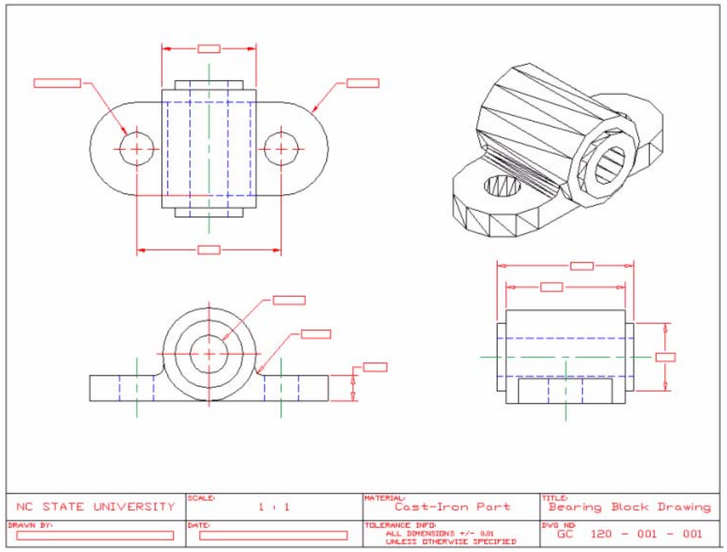

Figure 5. **Treatment group 2-D and 3-D CAD geometry and ANSI problem.**

The control group on the other hand used a different technique and different models, such as the Bearing Block and Tool Holder. The Bearing Block for the control group is shown in Figure 6. The class web site instructed students to work on modeling procedures of the tool holder and the bearing block.

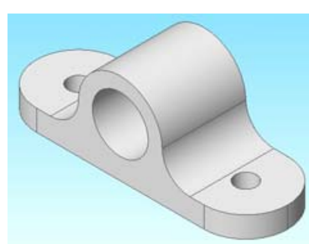

Figure 6. **Control group bearing block for 2-D and 3-D CAD geometry.**

Section differences between control and treatment groups. Other control group drawings included a section of the Tailstock. The Tailstock exercise was used to create a preformatted step-by-step tutorial of a full section as shown in Figure 7.

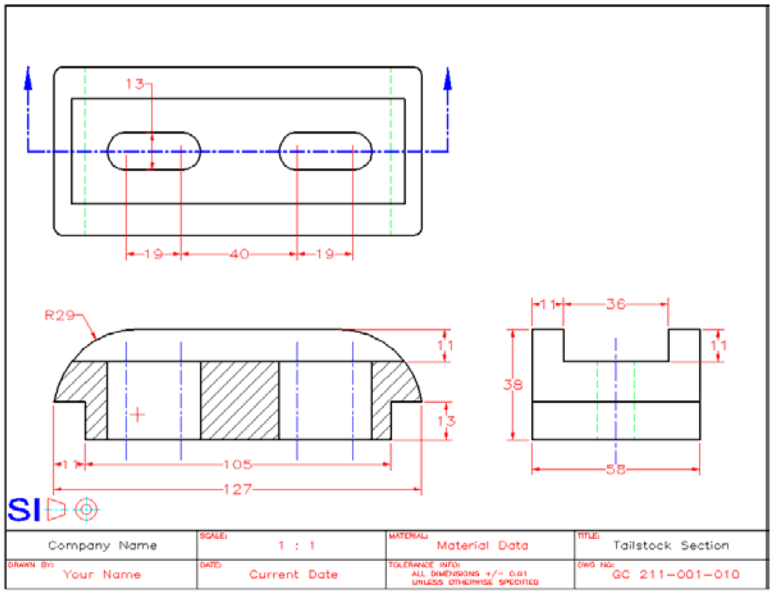

***Figure 7*. Control group Tailstock drawing to create a full section.**

To create sections in the treatment group, subjects used multiple case study sheets (see Appendix C). The sections were also used for dimensioning, multiviews, object lines, hidden lines, centerlines, and center marks. One such example was the full-section view of the Bearing drawing as shown in Figure 8.

Case problems attached to this drawing included:

1. Produce a full section of the drawing.
2. Place dimensions on the detail drawing.
3. Place counterbore dimensions on the simple part.
4. Are any of the views shown below superfluous. If so, why and which one?

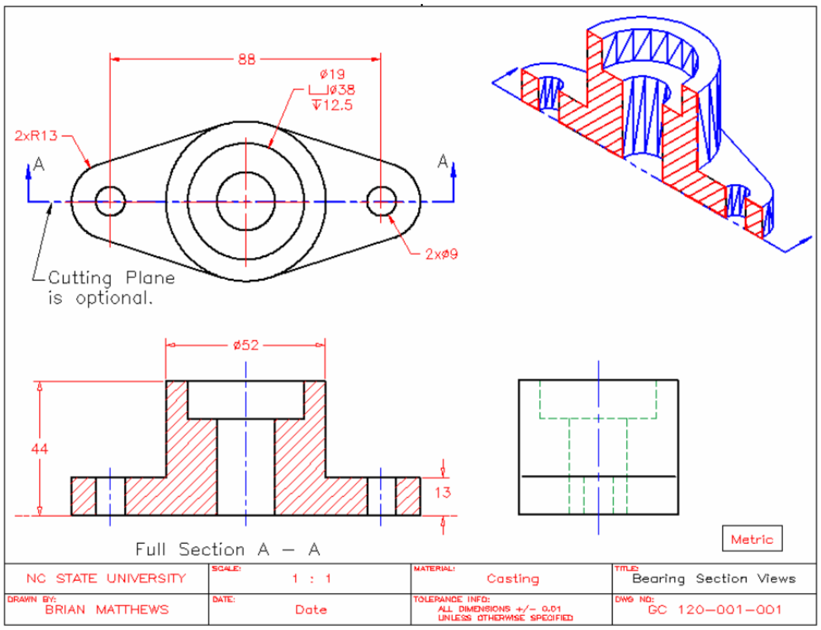

Figure 8. **Treatment group full section of Bearing drawing.**

Summary of Pedagogical Differences

In summary, the pedagogical differences between the control group and treatment group in this study were noted as:

1. In the control group, the role of expert or formal authority was assumed by the instructor in the classroom, whereas in the treatment group, the researcher's role was that of a facilitator using probing questions to guide learning.
2. In the control group classroom, the instructor was the sole transmitter of information to the students, whereas in the treatment group, the students also took responsibility for learning to create partnerships between student and teacher.

3. In the control group, the instructor organized curricular content into lectures based on the engineering context of discipline, whereas in the treatment group, the Foundation of Engineering course was based on ill-structured problems to empower students and selected concepts that would allow students to transfer knowledge.
4. In the control group, students were viewed as passive receivers of information, whereas in the treatment group, the researcher would seek to encourage student initiative, empower students, and select concepts that would allow students to transfer knowledge.
5. In the control group, students would absorb, transcribe, memorize, and repeat information for content-specific tasks, such as quizzes or exams, whereas in the treatment group, the course was based on ill-structured problems to provide a role for the student in learning.
6. In the control group, students worked in isolation, whereas in the treatment group, students would interact with each other and the faculty to provide immediate feedback about performance for improvement.
7. In the control group, learning was individualistic and competitive, whereas in the treatment group, students experienced learning in a collaborative and supportive environment.
8. In the control group, students would seek a right answer to achieve success on a test, whereas in the treatment group, the researcher would discourage only

one right answer and help students learn to frame questions, formulate problems, explore alternatives, and make effective decisions.

9. In the control group, student performance was measured on content-specific tasks, whereas in the treatment group, students would identify, analyze, and resolve problems using knowledge from previous experiences and courses, rather than by simple recall.

10. In the control group, grading was summative, and the instructor was the only evaluator, whereas in the treatment group, students could also evaluate their own contributions as well as that of other members and the entire group.

11. In the control group, the lecture was based on one-way communication where information was conveyed to large groups of students, whereas in the treatment group, students worked in small groups to solve problems. The students could acquire and apply knowledge in a variety of contexts. Students would find resources, the researcher would guide students toward information and resources, and students would seek useful and relevant knowledge to be able to apply toward job skills and employment.

Pilot Study

Before data were collected, a pilot study was conducted during the summer semester of 2002. The researcher met with two GC120 Foundation of Graphics classes, treating them as control and treatment groups over a 5-week period. All procedures used in the pilot study were the same as those designed for the full study. Procedures included testing the pre- and post-tests, in-class exercise problems, PBL problems, and the MSLQ survey.

A major alteration as a result of the pilot study was that some of the problems and exercises were reworked and the MSLQ survey was shortened to 31 instead of 81 questions. The 20+ graphic exercises were tested in the 5 mm standard grid and 5 mm isometric grid formats. They comprised multiviews, missing hidden or object lines, missing views, missing isometrics or pictorials, or new sketching or dimensioning or auxiliary exercises. Engineering graphics staff reviewed the exercises and recommended corrections as needed.

A further alteration was that due to the teaching style of the control-group instructor, he decided not to use the graphic exercises but to use exercises from the textbook, which were listed on the class web page and shown earlier in the section on Differences in Pedagogical Activities and Materials.

One more alteration was to the timed 3-D CAD model, which initially was compared to the final 3-D CAD modeling project. Its removal from the study comparison resulted from too many variables and inconsistencies among final class projects.

Instrumentation

This instrumentation section looks at knowledge pre- and post-tests, skill performance tests, MSLQ survey, and the data analysis model for the independent and dependent variables. Each instrument was administered to subjects in a controlled in-class, setting and was piloted in the summer of 2002. The various instruments compared knowledge, skills, and attitudes, comprising pre- and post-knowledge tests, timed CAD skill evaluations, and an attitude survey. Simple graphic instruments were used to determine knowledge, as both pre- and post-tests were graphic tests that included missing views of a single engineering object. The CAD instrument was an in-class modeling exercise, as outlined in the syllabus, and the attitude instrument was the MSLQ survey.

Engineering graphics is a visual language, and both the knowledge and skills tests had some form of engineering graphics overlap. Both the pre- and post-tests were used to provide some indication of the students' engineering graphics ability, as stressed by Gaylean (1983) and Johnson (1992) who indicated visualization increases cognitive accomplishment and provides more social interaction between student to student and teacher to student. Moreover, as Bransford (2000) indicated, the teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas.

A further spatial ability overlap and purpose behind the use of spatial graphics as pre-test instruments in the study was to determine the students' level of pre-engineering knowledge and pre-engineering graphics spatial ability already present (Belhot, 1999; Brooks & Brooks, 1993). As indicated by the common test rubric, this undeclared or tacit knowledge included (a) the ability to look at a simple open-ended incomplete working drawing in order to visualize a 2-D profile or 2-D image; (b) the ability to visualize missing features and neatly sketched missing lines or views using suitable line weight; (c) the ability to visualize missing hidden lines, centerlines, and center marks; and (d) the ability to use view accuracy and alignment, along with the correct sizing (scaling) of those parts or profiles.

To make the control exercises consistent and unbiased to departmental graphic and academic standards, the paper exercises were also reviewed by a minimum of two other faculty in the department. To confirm or reject hypothesis #1, the pre-test and post-test scores were designed from the equations shown below and in Table 4.

(H1a) Gain score of treatment group to gain score of control group

$[(O_2T - O_1T) - (O_2C - O_1C)]$.

(H1b) Pre-test score of treatment group to pre-test score of control group

$(O_1T - O_1C)$.

Table 4

Treatment and Control Analysis Design

Quasi-experiment	Pre-test	Treatment	Post-test
Treatment Group	O_1T	X	O_2T, O_3T, O_4T
Control Group	O_1C	–	O_2C, O_3C, O_4C

The attitude score was obtained using the 31-item MSLQ survey, administered in the 12th week, to measure student attitude, with the subjects responding to scales from the learning questionnaire. The MSLQ is a 7-point (1 = *totally disagree* to 7 = *totally agree*) Likert-type self-report questionnaire designed to measure students' motivation and use of learning strategies. The researcher selected intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy to serve as indicators of student motivation (Pintrich, Smith, Garcia, & McKeachie, 1993a, 1993b).

Knowledge Pre- and Post-test

To compare knowledge, pre- and post-test instruments were designed as measurable co-variates using engineering graphic multiview exercises. These comprised typical engineering sketch problems taken from units of the curriculum. Administered in the 1st and 10th weeks, with the instructions printed on the sheet, the tests were designed as missing 2-D or 2-D views or lines where students were expected to complete missing graphic details using their current spatial skills (Gaylean, 1983; Johnson, 1992). See Figures 9 and 10 for graphic pre- and post-tests.

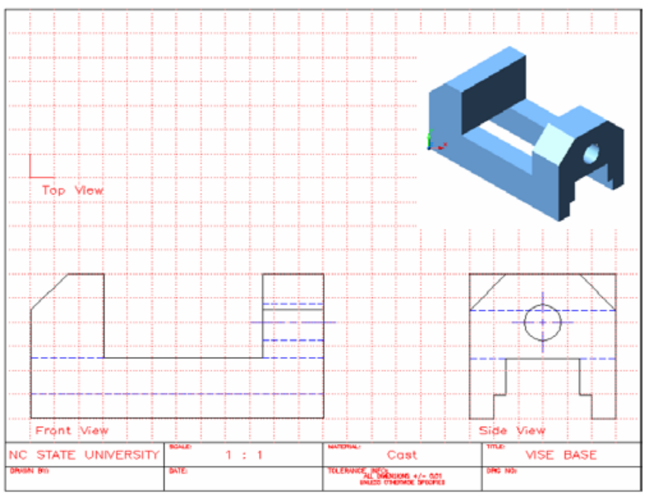

Figure 9. **Graphic pre-test.**

Individual students were expected to complete the missing views to the best of their ability, as opposed to working in small groups. Pilot-tested in the summer of 2002, the pre- and post-tests involved two missing 2-D views from an incomplete multiview drawing, whereas the post-test (shown in Figure 10) involved a missing 2-D pictorial and 2-D view.

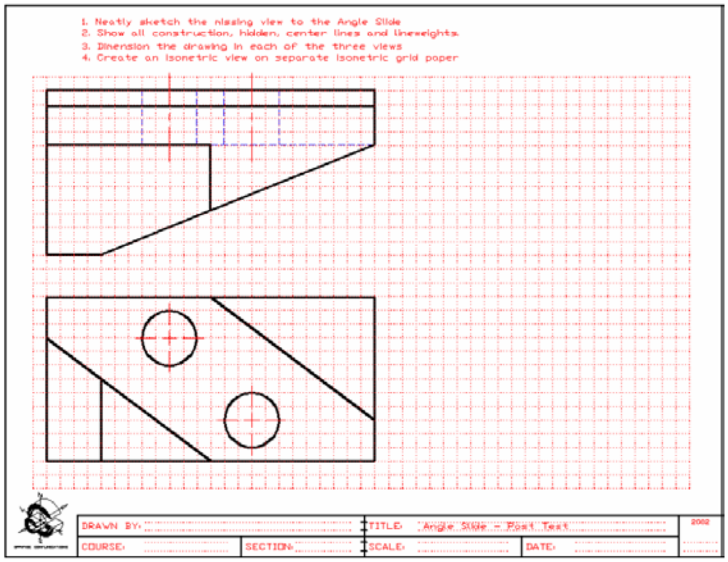

Figure 10. **Graphic post-test.**

Pre- and post-test instruments assessed subjects' engineering graphics knowledge. The exercise was designed to determine if students could visualize shape and form of a missing view of an engineering part and how they might treat lining up the missing view, along with missing object lines, hidden lines, and centerlines.

For validity, the scoring rubric was based upon the published Department of Public Instruction rubric from the public schools of North Carolina, as shown in Appendix F. To closely correlate the data, the researcher administered the rubric, and then two other faculty independently checked and scored all the pre- and post-test answer sheets to the rubric. A statistical correlation was applied to the independent rater scores. The results indicated they had equivalent scores, with a correlation value of .79 between means for the researcher and the two independent faculty and .84 between means for the two independent faculty.

Skill Performance Test

To compare practical CAD skills between the treatment and control groups, a CAD skill performance test was applied. The CAD skill scores measured the application of a timed CAD laboratory performance test by creating a three-dimensional CAD model and comparing its quality and completeness.

The CAD skill instrument used an in-class exercise of a V-Pulley drawing, which subjects produced as a 3-D CAD model during the class period. Students were required to create a closed profile on a plane, form an axis line, then revolve the profile about the axis line to form a three-dimensional model. Time was also allotted to produce quick visualization sketches of how students might plan out and create the three-dimensional component. Both sets of students produced the 3-D model, using equivalently equipped CAD labs.

As Weinstein (1988) and Bransford (2000) indicated with the design and evaluation of strategic learning, the CAD skill was measured by the completeness of the solid model and documentation (Bransford, 2000; Miller & Bertoline, 1991b). The new focus for engineers is they no longer need to make finished drawings, just be aware how 3-D drawing data are presented and approached to meet current industry standards (Raudebaugh, 1996).

MSLQ Attitude Survey

Attitude in this study was defined by the MSLQ and completed by both the GC211 and GC120 students (Pintrich et al., 1993b). Attitude studies are often associated with change and with like or dislike. The MSLQ attitude survey (dependent variable) was used to assess the major research question for the study, which concerned the use of problem-based learning and its affect on the motivational attitude of students, as compared to traditional learning in engineering graphics. To serve as indicators of student attitude and motivation, four of the six measures of the MSLQ (Part A) were selected, intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy (see Table 5). The MSLQ attitude survey was administered to subjects in the 12th week and took them 10 to 15 minutes to complete.

As an instrument to measure attitude, the MSLQ was adopted and shortened to 31 questions (see Appendix E). Because the remainder of the 81 questions and subscales of Parts B and C were superfluous to this study, they were not used. The MSLQ survey (1993) user manual (Pintrich et al., 1993a) dictated how the question results should be tabulated and provided the instrument's reliability alphas (see Table 5).

Table 5

MSLQ Subscales, Item, and Reliability Alpha Coefficients

	Part A Subscales	Item	Alpha
1.	Intrinsic goal orientation[a]	1, 16, 22, 24	.74
2.	Extrinsic goal orientation[a]	7, 11, 13, 30	.62
3.	Task value[a]	4, 10, 17, 23, 26, 27	.90
4.	Control of learning beliefs	2, 9, 18, 25	.68
5.	Self-efficacy learning performance[a]	5, 6, 12, 15, 20, 21, 29, 31	.93
6.	Test anxiety	3, 8, 14, 19, 28	.80

[a] Indicates subscale used.

Data Analysis

To determine whether groups differed on more than one dependent variable, a univariate analysis of variance (ANOVA) was used to analyze data and investigate differences between traditional instruction and problem-based learning for variables of O_1, O_2, O_3, and O_4, knowledge, skills, and motivational attitude. Each ANOVA investigated if any significant difference ($p < .05$) existed between the groups. Gall, Borg, and Gall (1996) indicated that this inferential statistic is suitable, as it can be used to determine whether three or more dependent sample means are significantly different from one another. Subsequently, the ANOVAs were used to determine the difference among dependent variables.

The ANOVA was used to determine which of the measured variables would produce a statistically significant difference between the mean scores of the groups studied. Gall et al. (1996) indicated that comparing means on student data should reveal outcomes for each hypothesis. The means of the scores on the pre- and post-tests were used to measure if the two groups were significantly different in their prior knowledge. Also, comparing the means of the MSLQ survey score should reveal any significant difference in motivation. The researcher compared the following data on knowledge, skills, and attitudes:

1. To compare knowledge: pre- and post-test achievement scores were compared to determine any significant difference in content knowledge between the control and treatment groups. Both groups were compared as gain score to gain score:

    (i) Gain score of treatment group to gain score of control group.

    (ii) Pre-test score of treatment group to pre-test score of control group.

2. To compare skill: CAD performance was evaluated to determine any significant difference in skill ability between group performance scores of the traditional lecture and the experimental problem-based learning group. This score was compared as:

   (i) CAD score of treatment group to CAD score of control group.

3. To compare attitude: MSLQ survey scores were compared to determine any significant difference in attitude between the traditional lecture and the problem-based learning group scores. These scores were compared as: MSLQ treatment to control survey, which consisted of the listed subscale scores and an overall MSLQ score as follows:

   (i) Intrinsic goal orientation, extrinsic goal orientation, task value, and self-efficacy.

   (ii) Total MSLQ score of treatment group to total MSLQ score of control group.

CHAPTER FOUR

FINDINGS

This chapter provides a description of collected data and statistical study results in two sections. The first section discusses demographic findings connected to subjects and engineering graphics. The second section analyzes statistical data relating to the pedagogical hypotheses. An alpha level of .05 was used to test for any significant gain.

To discover any effectiveness of change in knowledge, skills, and motivational attitude, several measurable variables were selected. The independent variable, pedagogical strategy, was a comparison of traditional lecture to problem-based learning. The measurable dependent variables were (a) knowledge, as measured by using gain scores of pre-test and post-test engineering graphics problems; (b) skill, as measured by the creation of a timed CAD model; and (c) attitude, as measured by the use of an MSLQ survey. ANOVA scores were analyzed to determine the study's effectiveness. To analyze data and determine any pedagogic differences between control and treatment groups for the variables of knowledge, skill, and attitude, the statistical methods employed were means and ANOVA.

Description of the Study

The intent of the investigation was to discover if knowledge, skills, and attitude as dependent variables toward pedagogic learning outcomes of engineering graphics would show any significant difference or significant gain when using problem-based learning as compared to traditional instruction. Forty-eight (N = 48) subjects, who were either college freshmen, sophomores, juniors, or seniors, participated in the study. Males outnumbered females 7:1, and many subjects were sophomores because the engineering and technology curricula required them to take the course in that year.

Analysis of Demographic Data

Subject Gender and Academic Levels

The gender count in Table 1 shows 85% of the subjects ($N = 48$) in the study were male and 15% were female, but the genders were not evenly matched between the control and treatment groups. Demographic analyses indicated that subjects' academic backgrounds and majors varied widely, with roughly four-fifths of the sample being engineering majors ($N = 48$) and the remainder (23%) being non-engineering majors. Of the control group, 58% indicated it was their first course in engineering graphics, as opposed to 83% in the treatment group. Ethnicity of the subjects obtained the following cell counts: 4 African-American (8%), 1 Asian (2%), 37 Caucasian (78%), 1 Latino (2%), and 5 Native-American (10%). Table 1 refers to both the gender and academic level of subjects.

Table 1

Gender and Academic Level of Subjects in Study Sample

Variable	Control	Treatment	Percentage
Gender			
Male	23	19	85
Female	1	5	15

(*table continues*)

Academic level			
Freshman	1	-	2
Sophomore	12	11	48
Junior	5	8	27
Senior	6	5	23

Note. $N = 48$.

Prior Graphics and Work Experience

In relating demographic data to subjects' work and prior graphics experience, 23 of the participants (47%) had some previous graphics experience in architectural drafting, art engineering drawing, or scientific visualization at the high school level. Graphics and work experience data obtained cell counts as listed in Table 2 for the control and treatment groups. After comparing these data to the pre- and post-tests of the total sample, it was noted that, although this sample did better on pre-tests and post-tests, the resultant learning curve indicated that other subjects did just as well on their final exams in both the control and treatment groups (see Table 2).

Work experience data show that 8 of the 48 participants (18%) had some work experience that included engineering graphics (see Table 2). After relating these subjects to their overall grade, subjects who had a combination of graphics and work experience sometimes performed at up to a full letter grade better than did their counterparts who had no prior engineering work experience.

Table 2

Subjects with Previous Graphics and Work Experience

Previous graphics experience	Control	Treatment	Percentage
High school courses	13	10	47
Architectural, mechanical, descriptive geometry, scientific visualization, art			
Work	3	5	18
Included engineering drawing			

Note. $N = 48$.

Age of Subjects

In both the control and treatment groups, the average age of subjects was around 21 years old, and the age range of the participants varied from 19 to 30 years old, with the average age of the subjects in the 21 to 22 years old range, which is standard for undergraduates in engineering (see Table 3).

Table 3

Age of Subjects

		Age		
Group	*n*	Mean	Minimum	Maximum
Treatment	24	21.13	19	30
Control	24	21.30	19	30

Note. $N = 48$.

Majors of Subjects

The number and types of majors varied among the 48 subjects in the study, with 13 types of academic majors represented in the sample (see Table 4). Predominant majors were aeronautical, civil, computer, construction, and mechanical engineering. Others included applied arts, industrial engineering, technology education, and textile engineering. Among the engineering majors, there were 33 males and 4 females (77% of the sample), whereas there were 9 males and 2 females (23% of the sample) among the non-engineering majors.

Table 4

Academic Majors in Study Sample

Academic majors	Treatment	Control	*n*
Mechanical engineering	8	11	19
Engineering undesignated	1	5	6
Aeronautical engineering	-	5	5
Civil engineering	3	1	4
Computer engineering	3	-	3
Construction engineering	3	-	3
Agricultural business	2	-	2
Agricultural environment	1	-	1
Arts applied	1	-	1
Computer science	1	-	1
Industrial engineering	1	-	1
Technology education	1	-	1
Textile engineering	-	1	1

Note. $N = 48$.

Next, the researcher analyzed performance, skill, and attitude hypotheses relating to pedagogy. Pre- and post-test scores are summarized, along with hypothesis results of treatment gain score to control gain score, treatment pre-test to control pre-test, and data from the MSLQ attitude survey.

Analysis of Research Questions and Hypotheses

Null Hypothesis #1—Knowledge Gain

Hypothesis #1 stated that, with the control group and treatment group, there would be no significant difference in knowledge gain between the response scores of the traditional lecture (control) group and the problem-based learning (treatment) group. Hypothesis #1, as a measurable dependent variable, was compared as gain score to gain score for both groups and was divided into two parts:

#1a: gain score of treatment group to gain score of control group

#1b: pre-test score of treatment group to pre-test score of control group.

For the control and treatment groups, the initial range of pre-test raw data varied from 35 to 99 and from 0 to 90, out of a possible score of 100. The range of post-test raw data varied from 10 to 98 and from 50 to 100. For hypothesis #1a, the ANOVA scores were compared as gain score for the treatment group to the gain score of the control group.

Mean scores for the control and treatment groups were also compared. The means of the scores for the control group pre- and post-tests indicated a gain in learning from pre-test to post-test. The means of the scores for the treatment group pre- and post-tests also indicated a gain score in learning from the pre-test to post-test. Table 5 displays mean and standard deviation scores for the pre- to post-tests for the control and treatment groups.

Table 5

Comparisons of Pre- to Post-Test Mean Scores by Group

Knowledge achievement scores	*n*	*M*	*SD*
Control group pre-test	24	51.95	23.32
Control group post-test	24	58.75	15.19
Treatment group pre-test	24	54.08	22.20
Treatment group post-test	24	69.45	15.36

Note. $N = 48$. Highest possible score = 100.

To measure hypothesis #1a as a dependent variable, the gain score of the treatment group was compared to the gain score of the control group and analyzed by an ANOVA. The measure was a direct comparison of the treatment group gain score to the control group gain score. The research hypothesis indicated there would be no significant difference in knowledge gain between groups. The ANOVA findings, $F(19, 23) = 2.12$, $p = 0.24$, supported the null hypothesis that there would be no significant difference in knowledge gain between the response scores of the traditional lecture (control) group and the problem-based learning (treatment) group. Table 6 illustrates the ANOVA results of these gain score analyses.

Table 6

ANOVA of Knowledge Gain Score

Knowledge achievement scores	SS	df	MS	F	p
Treatment group to control group					
Between groups	7406.00	19	389.78	2.12	0.24
Within groups	729.33	4	182.33		
Total	8135.33	23			

The results showed no significant difference between the control and treatment groups in knowledge gain between the response scores of the traditional lecture (control) group and the PBL (treatment) group. Consequently, the researcher failed to reject the hypothesis.

Hypothesis #1b—Pre-test to Pre-test

To test for equality of prior knowledge between groups, hypothesis #1b as a dependent variable compared the pre-test score of the treatment group to the pre-test score of the control group. Table 7 lists the comparable means of these pre-test scores.

Table 7

Comparison of Knowledge Achievement Scores for Pre-tests by Group

Knowledge achievement scores	*n*	*M*	*SD*
Pre-test to control group	24	52.25	23.55
Pre-test to treatment group	24	54.33	22.39

Note. $N = 48$. Highest possible score = 100.

For hypothesis #1b, an ANOVA was used to compare the treatment pre-test score to the control group pre-test score. The result, $F(17, 23) = 3.32$, $p = 0.07$, indicated no significant difference between the treatment group and the control group. Table 8 shows the ANOVA result, which supported null hypothesis #1b, that the pre-test score of the treatment group when compared to the pre-test score of control group would have no significant difference in knowledge gain between the response scores.

Table 8

ANOVA Results for Pre-tests

Knowledge achievement scores	SS	Df	MS	F	p
Treatment pre-test to control pre-test					
Between groups	10431.83	17	613.73	3.32	0.07
Within groups	1107.50	6	184.58		
Total	11539.33	23			

$p < 0.05$.

Null Hypothesis #2—Skill Performance

Hypothesis #2 stated that with the control and treatment groups there would be no significant difference in CAD skill performance scores between the traditional lecture group and the problem-based learning group. Hypothesis #2, as a measurable dependent variable, compared the timed CAD skill scores of the control group to the treatment group. Table 9 shows the comparison of CAD skill scores in which subjects created a CAD drawing under laboratory conditions and presents the mean and standard deviation values between groups.

Table 9

Comparison of CAD Skill Scores by Group

CAD skill performance scores	n	M	SD
Control group	24	93.04	8.38
Treatment group	24	91.58	3.23

Note. $N = 48$. Highest possible score = 100.

To determine skill performance for the control and treatment groups, an ANOVA was also used to analyze differences between the two groups. The hypothesis stated that there would be no significant difference in CAD skill between group performance scores of the control and treatment (problem-based learning) groups. The ANOVA results are listed in Table 10.

Table 10

Analysis of Variance for CAD Skill Scores

Skill performance scores	*SS*	*df*	*MS*	*F*	*p*
CAD score					
Control group	0.37	1	0.38	0.03	0.85
Treatment group	239.45	22	10.88		
Total (n - 1)	239.83	23			

$p < 0.05$.

Results of the ANOVA for group skill performance scores, $F(1, 23) = 0.03$, $p = 0.85$, indicated that for CAD skill, where the subjects created a CAD drawing under laboratory conditions, there was no significant difference in skill performance scores between groups. ANOVA results for group skill performance, as a measurable dependent variable, indicated no significant difference in skill performance scores between groups. Consequently, the researcher failed to reject the null hypothesis, that with the treatment and the control groups there would be any significant difference in skill response scores between the control group and the treatment group.

Null Hypothesis #3—Group Attitude

The variations between the MSLQ subscales 1, 2, 3, and 5 used to test subject attitude in the study are explained in this section (subscales 4 and 6 were not used). Subscale summaries and results for each of the subscale analyses are presented in Tables 11 and 12.

Table 11 lists the means and standard deviations of the scores for subscales 1, 2, 3, and 5 used in the MSLQ, and Table 12 summarizes the ANOVA results.

Hypothesis #3, as a measurable dependent variable for group attitude was based on the short version of the MSLQ and its subscales. The subscales used were intrinsic goal, extrinsic goal, task value, and self-efficacy. Hypothesis #3 stated that for the treatment and control groups there would be no significant difference in attitude scores between the control and the treatment groups. To analyze attitude data with the treatment and control groups, an ANOVA was used between the two groups. Specifically, the subscales in the MSLQ survey were listed as (a) intrinsic goal, (b) extrinsic goal, (c) task value, and (d) self-efficacy. All question values were grouped into summary tables (see Tables 11 and 12) in order to support or reject findings for null hypothesis #3.

Table 11

Comparison of Scores for MSLQ Subscales by Group

Subscale	*n*	*M*	*SD*
Value component: Intrinsic goal orientation			
Control group	24	4.74	1.49
Treatment group	24	4.97	1.59
Value component: Extrinsic goal orientation			
Control group	24	4.86	1.86
Treatment group	24	4.93	1.65

(table continues)

Subscale	*n*	*M*	*SD*
Task value component			
Control group	24	5.34	1.33
Treatment group	24	5.19	1.58
Self-efficacy–Learning performance			
Control group	24	5.64	1.22
Treatment group	24	5.23	1.29
Overall MSLQ summary (1, 2, 3, and 5)			
Subscale: control group	24	5.18	1.52
Subscale: treatment group	24	5.07	1.54
Total MSLQ: control group	24	5.09	1.61
Total MSLQ: treatment group	24	4.97	1.65

Note. $N = 48$.

Table 12

Overall and Subscale ANOVA Analyses for the MSLQ

MSLQ subscales	*SS*	*df*	*MS*	*F*	*p*
Intrinsic goal (1)					
Between groups	18.11	3	6.04	2.49	0.06
Within groups	222.79	92	2.42		
Total (n - 1)	240.90	95			
Extrinsic goal (2)					
Between groups	6.11	3	2.04	0.95	0.42
Within groups	196.37	92	2.13		
Total (n - 1)	202.90	95			
Task value (3)					
Between groups	6.97	5	1.39	0.54	0.74
Within groups	353.58	138	2.56		
Total (n - 1)	360.55	143			
Self efficacy (5)					
Between groups	25.74	7	3.68	2.29	0.03*
Within groups	294.71	184	1.60		
Total (n - 1)	320.45	191			
Overall summary: MSLQ					
Between groups	73.02	21	3.48	1.57	0.05
Within groups	1116.45	506	2.21		
Total (n - 1)	1189.48	527			

*$p < 0.05$.

Subscale 1—Intrinsic Goal Orientation

This subscale used MSLQ questions 1, 16, 22, and 24. The subscale specifically related to intrinsic goal orientation and pertained to a subject's perception and the reasons for engaging in a learning task, including the course as a whole and the degree to which a subject perceived to be participating in a task, such as challenge, curiosity, or mastery. The similar mean value scores on this subscale for control and treatment indicated comparable intrinsic goal orientation between the control and treatment groups. ANOVA results, $F(3, 95) = 2.49$, $p = 0.06$, indicated no significant difference in intrinsic goal orientation scores between groups (see Table 12).

Subscale 2—Extrinsic Goal Orientation

This second subscale used questions 7, 11, 13, and 30. The questions related to how a subject connected to or participated in a task, for the reasons of a grade, reward, performance, evaluation, or any of these. A high value, for example, as a statistical result would indicate an engagement in the learning task as a means to an end. The similar mean value scores for control and treatment indicated comparable extrinsic goal orientation between the control and treatment groups. Table 11 shows mean and standard deviation scores. ANOVA results, $F(3, 95) = 0.95$, $p = 0.42$, indicated no significant difference in extrinsic goal orientation scores between groups (see Table 12).

Subscale 3—Task Value Component

This third subscale used questions 4, 10, 17, 23, 26, and 27. The questions were indicative of how interesting, how important, or how useful a task was to a subject. For example, a high task value as a statistical result for this subscale would indicate that a subject was involved in learning and could relate to the course material in terms of interest, importance, and utility. The similar mean value scores for control and treatment groups indicated comparable task values between the control and treatment groups (see Table 11). ANOVA results, $F(5, 143) = 0.54$, $p = 0.74$, indicated no significant difference in task value scores between groups for this subscale (see Table 12).

Subscale 5—Self-efficacy and Learning Performance

This subscale used questions 5, 6, 12, 15, 20, 21, 29, and 31. The questions related to a subject's self-efficacy and expectancy for success, including judgments to accomplish a task as well as confidence in his or her skills to perform and master a task. ANOVA results for this subscale, $F(7, 191) = 2.29$, $p = 0.03$, indicated a significant difference in learning performance scores between groups (see Table 12).

MSLQ Summary for Subscales 1, 2, 3, and 5

The subscale summary showed similar mean value scores for control and treatment, and indicated more favorable values for the control than the treatment group. The means and overall summary for the MSLQ survey questions are shown in Table 11. The ANOVA summary in Table 12 shows the overall subscale results of the MSLQ, which illustrates the combined MSLQ subscales of subscales 1, 2, 3, and 5. The overall results, as a measurable dependent variable, $F(21, 527) = 1.57$, $p = 0.05$, indicated a significant difference in attitude between groups when using PBL pedagogy in engineering graphics.

Conclusion

In conclusion, the independent variable of pedagogical strategy was measured as a comparison of traditional lecture to problem-based learning. To discover the effectiveness of change, three measurable dependent variables were selected as knowledge, skills, and attitude. The measurable dependent variables for (a) knowledge was measured using gain scores of pre-test and post-test engineering graphics problems, (b) skill was measured by the creation of a timed CAD model, and (c) attitude was measured by the use of an MSLQ survey. ANOVA scores analyzed the study's effectiveness.

In brief, this study discovered that problem-based learning as an independent variable did not have an effect on attitude of subjects, when compared to traditional instruction in engineering graphics. For the overall comparison, an ANOVA was used to analyze data and find the overall difference of traditional learning versus problem-based learning for the variables of knowledge, skills, and attitude. The following research hypotheses were either rejected or accepted:

$H0_1$: The researcher failed to reject the null hypothesis that there would be any significant difference in knowledge gain between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_2$: The researcher failed to reject the null hypothesis that there would be any significant difference in CAD skill between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_3$: The researcher accepted the alternative hypothesis that there would be a significant difference in attitude between the traditional lecture (control) and problem-based learning (treatment) groups.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

This chapter starts with an analysis and summary of the main research questions and then looks at hypothesis findings and conclusions. Implications related to problem-based learning and its connections to engineering graphics literature in general are subsequently presented. The chapter closes with recommendations for future research.

Research Questions

The major research question for this study was: Does the use of problem-based learning have any effect on knowledge, skills, and attitudes when compared to students enrolled in traditional engineering graphics courses? This research question was broken down as follows:

1. Will there be a significant gain in knowledge scores between the traditional lecture group and problem-based learning group?
2. Is there a significant difference in CAD skill performance scores between the traditional lecture group and problem-based learning group?
3. Will there be a significant difference in attitude scores between the traditional lecture group and problem-based learning group?

Analysis of Research Questions and Hypotheses

The study set out to examine the effects of problem-based learning and compare any significant changes in knowledge, skills, and attitude to traditional teaching of engineering graphics. It was thought that problem-based learning would have a positive effect on the knowledge, skills, and attitude of students in a traditional engineering graphics course. To test the hypotheses, a quasi-experimental methodology was selected. The pre- and post-test knowledge gain was analyzed to test hypothesis #1, the CAD skill test was analyzed to test hypothesis #2, and the MSLQ attitude survey was analyzed to test for hypothesis #3. The following research hypotheses were either rejected or accepted:

$H0_1$: The researcher failed to reject the null hypothesis that there would be any significant difference in knowledge gain between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_2$: The researcher failed to reject the null hypothesis that there would be any significant difference in CAD skill between the traditional lecture (control) and problem-based learning (treatment) groups.

$H0_3$: The researcher accepted the alternative hypothesis that there would be a significant difference in attitude between the traditional lecture (control) and problem-based learning (treatment) groups.

Hypothesis #1

Research question #1: Will there be a significant gain in knowledge scores between the traditional lecture group and problem-based learning group?

$H0_1$: There will be no significant difference in knowledge gain between the traditional lecture (control) and problem-based learning (treatment) groups.

The research analysis measured pre-test to post-test gain scores between groups. The findings failed to reject the hypothesis that with the treatment and the control groups there would be any significant difference in knowledge gain between groups. ANOVA results point to no significant knowledge gain, although when the mean scores of pre- to post-tests were compared, they indicated a slightly higher gain for the treatment group when compared to the control group. Consequently, the lack of any significant knowledge gain in the ANOVA score was found to contradict the research of Albanese and Mitchell (1993), Aspy et al. (1993), Barrows (1996), and Lambros (2000), who indicated widespread support for the knowledge and stimulus benefits of PBL Any lack of significant difference in knowledge gain may have resulted from (a) gender and visualization skill differences between groups, (b) test administration and design, (c) non-randomization of the study, (d) the small class sizes of 24 per group, or (e) subjects' unfamiliarity with PBL.

Visualization skill is important in engineering graphics and, with more females in the treatment group than the control group, females may have had low visualization ability. Kalichman (1989) and Parolini (1994) indicated that historically females scored lower on visualization tests than did college-age males who were shown to have stronger visualization ability. Scales (2000) also indicated that this difference might be more so when creating multiview visualizations. Case in point, if a subject has low skills in visualization, he or she would not know how to deal with complicated surfaces and hidden features, which is a matter of process and knowledge (Parolini, 1994; Scales, 2000; Sorby, 1996). The knowledge tests in this study needed visual understanding of two-dimensional, line-drawn multiviews as used in engineering graphics. Subsequently, the unequal gender count between groups, with 20% more females in the treatment group than in the control group may have contributed to the lack of significant difference in knowledge gain and visualization, which is further supported by Deno (1995), Fennema and Sherman (1977), and Parolini (1994).

In reference to test administration and design, the methodology of the knowledge tests seemed sound at first, although after reflection on the study and its results, the visualization method for testing appeared not to have been truly effective. To be more effective and consistent, the pre- and post-tests needed amending toward PBL scenarios. One possible change in the redesign could be for tests to be structured as a series of multiple-choice, pre-engineering graphics visualization tests, administering the same tests in the 1st and 10th weeks of the study. Tests could be set up as missing top, front or right-side views with four possible multiple choice answers. Other multiviews could be shown, allowing subjects to choose correct pictorial multiple choice answers, or subjects could choose correct use of hidden lines, centerlines, or center marks from pictorials. In the final redesign, the amended pre- and post-tests could be pre-tested and evaluated independently to give an unbiased, but consistent, outcome.

Although the control group was a GC211 course and the treatment group a GC120 course, both courses used the same syllabus content, mid-term test, and final exam. The main difference was the GC211 course, which included an extra lecture on technical data presentation. This lecture would not have interfered with the study, as it would have been presented around the 12th week, at the close of the main study. What may have contributed to the difference between groups was the student intake and that GC211 was a Mechanical and Aerospace application course. Specifically, the GC211 enrollment was limited to students who were strictly on this career track, as opposed to GC120, which was a university-wide humanities track. And, in all likelihood, the students may have had prior engineering graphics in high school. Nevertheless, at the time of the study, this was the only group available as a control group.

In reference to unfamiliarity with PBL, a specific factor, according to Belhot (1999) and Norman and Schmidt (1992) is that, when applying problem-based learning to students who are accustomed to traditional talk-and-chalk classrooms, the students are likely, at first, to be uncomfortable with problem-based learning. Sage and Torp (1997) also argued the case that it is up to the instructor to persuade students they are researchers looking for information and a problem solution. Echoing this, the attitude of engineering students is that they normally want to know just what they have to do to get a grade. They insist that they often expect the instructor to describe what they (the students) have to do, as a "cookbook" approach to learning. Belhot (1999) also indicated that students find moving into this non-traditional learning or PBL format scary and horrifying, and it may lead to irritation and dissatisfaction.

Finally, owing to the set up of the engineering program and hypothesis #1 result, there was no way the researcher could create a true randomized study. Therefore, the study result may have been limited by the small class sizes and non-randomization of the groups, the engineering graphics subjects, and the selected variables and testing instruments. In conclusion, the use of other variables, activities, and testing instruments may have produced different results.

Hypothesis #2

Research Question #2: Is there a significant difference in CAD skill performance scores between the traditional lecture group and problem-based learning group?

$H0_2$: There will be no significant difference in CAD skill between the traditional lecture (control) and problem-based learning (treatment) groups.

Research findings supported the null hypothesis. Consequently, the researcher failed to reject the hypothesis that with the treatment and control groups there would be any significant difference in CAD skill response scores between groups. The ANOVA analysis indicated no significant knowledge difference, and means also showed a close correlation between scores in the study.

This failure to show any significant CAD skill difference in the second hypothesis could have been, in effect, because the hypotheses was trying to measure subjects' CAD skill in the use of computer software, as opposed to knowledge retrieval, which is what previous PBL research measured (Barrows, 1996; Woods, 1996b). The failure to show any significant CAD skill difference may have resulted from differences between student intake in the GC211 control group and the GC120 treatment group. The GC211 was a mechanical and aerospace application course, and enrollment was limited to students who were strictly on this career track, as opposed to GC120 that was a university-wide humanities track. Students on the GC211 track may have had prior CAD graphics in high school. Thus, differences may have been due to lack of prior computer skills in one group, more computer skills in another group, low visualization skills between subjects, gender differences, or any combination thereof. Yet, CAD skill concern in this study could also have resulted from the small size of the study and testing in the 12th week, when both groups were expected to have gained the same level of computer skill, especially if subjects had no prior knowledge of the CAD software. However, some positive outcomes of the CAD skill process indicate that it did help with visualization and decision-making, such as knowing how and when to use technology and when to choose the most appropriate CAD tool for the task.

The study's failure to reject the hypothesis did not agree with the findings of Barrows (1994) and Woods (1996a) and in their definition of problem-based learning where problems form the stimulus for learning. It also did not agree with Foa, Schwab, and Johnson (1996) who reported that teachers who can capitalize on the learning and teaching ability of their students can integrate it into the classroom more easily and successfully than by relying solely on teachers' own ability. Findings from their research show that not only are students capable of teaching skills successfully, but that fellow students may be more interested in learning a new skill from their peers than from the teacher. Any skill requires practice, and research shows that practice increases proficiency. Currently, there is no specific retrieval skill for CAD graphics. It is better to train people to retrieve defined pieces of information then test on that retrieval as a skill. In engineering, we often tend to use an approach, such that when students have learned something, they need not learn it again. Instead, we should continuously reinforce the recovery of this previously learned information and build up a subject's skill level.

In consequence to this, the knowledge and skill acquired in the context of practice would be not only more accessible for use in similar contexts but qualitatively different from the same knowledge presented outside of such context and, as such, should be measurable. To explain, in the Foundation of Graphics course at NC State, instead of two-dimensional line drawings, subjects construct three-dimensional solid models of parts, first as a fully constrained sketch, which is then extruded or revolved into a solid model, and then as dimensioned multiviews into a title sheet. However, even though modern CAD programs extract the solid model into multiviews, the CAD operator still has to understand the views, create dimensions, and annotate the part. The study found that subjects often could not visualize the correct front view in CAD. One of the biggest visualization obstacles the subjects had in the study was visualizing the correct front view of the object, lining up the views, and scaling and dimensioning. In engineering graphics, the front view is classed as the most descriptive view, with the least amount of hidden lines. Instead of the actual front view, the subjects got rear, or bottom views. They just assumed the CAD program had placed it correctly for them, as they could not visualize the correct view. As fascinating as this may be, it points to an area of further research needed in engineering graphics and spatial visualizing.

However, in the case of the CAD skill problem, instead of a Boolean extrusion, the constrained sketch profile was revolved about a centerline, then formed into a multiview and dimensioned. Some subjects found this easier to grasp than others due to their background, prior spatial and visualization skill, and prior computer skill.

Regardless of these past observations, results of this study were limited according to size of the group, the selected variables, and the testing instruments used for evaluation. Yet selection of other variables, activities, and testing instruments may have produced different results. A self-criticism of the skill component of this study, and one that could be rectified in a subsequent study, was the instrument. One possible method may be that the skill test could be set up as a series of small timed tests, instead of one long skill test. For instance, subjects could constrain a given simple sketch in one test, then extrude or revolve a sketch in another test, then finally import and dimension a given solid model into a title block, which may give a more consistent result. The tests could also be pre-evaluated for consistency.

Hypothesis #3

Research Question #3: Will there be a significant difference in attitude scores between the traditional lecture group and problem-based learning group?

$H0_3$: There will be no significant difference in attitude between the traditional lecture (control) and the problem-based learning (treatment) group.

Research findings used four MSLQ subscales. The first three subscales, intrinsic goal, extrinsic goal, and task value, found no difference between groups. The final subscale, relating to learning performance scores, expectancy for success, and a student's self-efficacy, indicated a significant difference between groups to the control group's advantage. Yet, when the four subscales were combined, the overall MSLQ summary indicated a significant difference in attitude between groups. Thus, the research findings supported the null hypothesis, and the researcher accepted the alternative hypothesis that there would be a significant difference in attitude between groups when using PBL pedagogy in engineering graphics. Again, this was to the control group's advantage.

That there was a significant difference in attitude between groups for hypothesis 3 may have resulted from the PBL treatment, as new students of PBL frequently either accept it or hate it and often have trouble adjusting to the pedagogy (Bernstein, Tipping, Bercovitz, & Skinner, 1995). Case in point about adjustment to the pedagogy, both Giroux (1988) and the Grinter Report (ASEE, 1955/1994) pointed out that the old-school model of passively learning facts and reciting them out of context is no longer adequate for students to survive in today's world. In PBL, Lambros (2000) argued that students often come from a climate of competition, where previous success would often relate to how much they set themselves apart from the group and that their success in a traditional environment is one in which they are not adjusted to small groupwork. Through this traditional educational environment, their attitude, their conditions of acceptance, and their self-awareness, they are frequently more focused on themselves rather than others in a team. Students up to the age of 25 often focus on what they have to do to get a grade, not on developing their own thinking (Wigfield, Eccles, & Pintrich, 1996).

Nevertheless, Stepian et al. (1993) also argued that often students who are familiar with traditional chalk-and-talk classrooms are more likely to be uncomfortable with PBL. These same students who are familiar with book learning feel uncomfortable in their new PBL roles, especially where they are expected to work on their own, conduct some research, and coordinate with peers. They also pointed out that often students expect the instructor to prescribe a number of tasks, procedures, ideas, or even a set number of pages for written work (Belhot, 1999; Norman & Schmidt, 1992).

Giroux (1988) and others argued that due to the power teachers have over students' lives some scholars never question a teacher's point of view and never develop their own thinking (Covington, 1987; Dolmans, Gijselaers, & Schmidt, 1992). It was in this regard, the Grinter Report (ASEE, 1955/1994) recommended increased opportunities for students to become active learners and reduce the amount of time they were expected to listen passively to others. Thus, another reason for the research findings supporting the null hypothesis may have been the student's lack of adjustment to the PBL pedagogy (Bernstein et al., 1995; Woods, 1996a). Again, the research finding was to the control group's advantage.

Even though the overall results indicate no significant difference in attitude, the significant difference of the fourth and final subscale, relating to learning performance scores, expectancy for success, and a student's self-efficacy, did indicate a significant difference between groups. This finding is supported by the research of Pintrich and Schunk (1996) who indicated that self-efficacy beliefs are important mediators in all types of achievement behavior, such that self-concept and self-perception of competence is representative of an individual's judgment and of their capabilities. Further support also comes from the research of Pintrich, Smith, Garcia, and McKeachie (1993a, 1993b).

To this end, Pintrich and Schunk (1996) showed a 2 X 2 ranking table of self-efficacy and self-perception as low self-efficacy, high self-efficacy, low outcome expectation, and high outcome expectation. The hypothesis findings showed that in their reach for success, the males in the GC211 control group would most likely have chosen the high outcome expectation, as opposed to a low self-efficacy ranking. Normally, if a gender difference is found, the difference is that females have a lower self-perception of their ability than do males, although some gender studies indicate that females can outperform males on self-efficacy (Wigfield et al., 1996). Nevertheless, Eccles, Adler, and Meece (1984) reported that gender discrepancies often indicate a response bias, such that males normally are self-congratulatory and females more modest (Eccles et al., 1984), which this hypothesis outcome reaffirms.

In conclusion, the third null hypothesis result echoes some of the conclusions of Albanese and Mitchell (1993) and Vernon and Blake (1993) who reported that, in the medical field, some students schooled with problem-based learning performed worse on standardized tests, though they performed better on clinical tests and equal on essay tests when compared to traditionally schooled students. A further study found that PBL students performed worse on immediate post-tests, but over time their scores equaled students taught in lecture mode at 3 months and 2 years. This result, they indicated, shows that PBL knowledge might be more deeply ingrained and less likely to be as easily forgotten.

Summary

Visualization is a key factor in engineering graphics, and a main motivator for this study was the endorsed reforms of the Grinter Report (ASEE, 1955/1994). The report was concerned that engineering education should establish a foundation for successful practice along with effective teaching and relevant research in engineering design. The report, initially intended to have a short-term impact on the engineering profession, suggested sweeping changes in its curriculum to include problem-solving, active-learning, and visualization techniques. The National Research Council (1991) showed similar concerns in its Improving Engineering Design Report, which echoed similar changes for educational engineering reform. The report, in part, focused on the use of innovative methods that allow engineering students to develop problem-solving and teaming skills for open-ended design and visual graphic solutions.

Arising from this, researchers supported active small-group learning, encouraging this approach as a means of improving engineering education (Clough & Kauffman, 1999).

Others (Cordeiro & Campbell, 1996; Johnson, 1992; Woods, 1996a) supported similar inquiry-based learning, where subjects formed connections between different forms of data that help them create links and draw meaningful conclusions. Doornekamp (2001) and Johnson (1992) encouraged additional improvement in engineering education, indicating that industry needed its workers to be both thinkers and problem solvers. Miller and Bertoline (1991a) showed that success in an engineering curriculum has long relied on the ability to creatively solve problems as visual solutions by sketching orthographic or isometric solutions to a design project as two- and three-dimensional visualizations. Oladipupo (1991) confirmed this, indicating it is the ability to relate to and form visual images from two- and three-dimensional worlds that allows us to think spatially.

Consequently, visualization plays an essential role in engineering graphics, particularly when sketching or drawing parts (Bertoline & Wiebe, 2002; Miller & Bertoline, 1991a). Visualization is even more important if a subject has low visualization skills, as he or she would not know how to deal with complicated surfaces and hidden features, which is a matter of process and knowledge (Parolini, 1994; Scales, 2000). Thus, visual understanding of two-dimensional, line-drawn multiviews is essential in engineering graphics. Without training, subjects may lack the spatial reasoning and comprehensive knowledge required to process multiviews. A minor visualization obstacle students have to overcome is how to visualize the correct views of an object, line up the views, then scale and dimension them. The creation of multiviews in engineering graphics requires a high degree of visualization skill and is especially true when that purpose is to create views of an object in the minds-eye in order to form surface and line projections, as either top, front, or right side views, then transfer that minds-eye visual to paper (Lajoie, 2000; Scales, 2000).

Arising from the research, three fundamental connectors formed the application between problem-based learning and engineering graphics studies. These rudimentary connectors were categorized into cognitive, motivational, and functional elements.

The cognitive research of the Cognition and Technology Group at Vanderbilt (CGTV), for example, showed that the cognitive element of problem-based learning dealt with comprehension and learning. The group indicated that traditional or rote learning may be effective in the short term for routine tasks and tests but was less effective for deep understanding and retention of complex problem solving (CTGV, 1992a, 1992b).

The second motivational element dealt with incentives and attitudes and how students could focus on the problem, the issues, questions raised, assessment, and teacher nurturing and support. Basic incentives and attitudes were difficult to gauge, but they did indicate that with specific support they could create a more positive attitude toward a given issue than when not supported (Pintrich & Schunk, 1996). Lambros (2000) went beyond basic attitudes and incentives in her research, pointing out that problem-based learning goes beyond this with group dynamic elements as a social and intrapersonal side to learning. Sage and Torp (1997) also gave insights into what it takes to become a teacher of problem-based learning.

The third functional element dealt with how up to date and closely the problem was aligned to modern needs and if the problem could simulate a real-world concept. It was also related to how the problem might help prepare students toward technological, communication, and presentation skills arising out of the problem. To this end, the cognitive, motivational, and functional elements were combined into active learning, visualization, and engineering graphics to form the focus of the study.

To conclude, cognitive, motivational, and functional elements became the building blocks and connectors for this study of problem-based learning in engineering graphics. In turn these elements connected engineering graphics to visualization, multiviews, orthographic projection, solid modeling, and a subject's motivational attitude and self-awareness into the subsequent knowledge, skills, and attitude hypotheses as set out by the narrow confines of the study. The study found that PBL did not have a significant effect on attitude and also found no significant gain to knowledge or CAD skills in an engineering graphics course.

Recommendations for Further Research

Several recommendations might be made for practitioners of engineering graphics. Despite shortcomings, late findings, and the small size of the groups, a major sequel to this study would be to use a larger sample size to validate findings observed in the limited study. The sequel could also use the MSLQ to look at attitude in engineering graphics as a more in-depth study and compare student achievement in computer-aided design to project and course work, which was not included in this study. For consistency, the same project and course work would need to be used throughout the revised study and compared to MSLQ data. Graphical changes would also be needed to amend the pre- and post-test procedures and instruments especially for ease of use and validation of instruments and rubrics.

An additional factor arose from the narrow demographic data of students who took art, sketching, or drawing classes in high school or vocational school. The narrow finding was that subjects who took art or related drawing may have had more advantage in visualizing multiviews in engineering graphics, when compared to those who had not taken previous drawing or art courses. This consideration could lead to further research in engineering graphics with a study that compares students who took previous drawing or art classes, as opposed to students who did not take classes. The comparison could use 2-D versus 3-D spatial visualization and look at the benefits (if any) of prior drawing experience. Spatial ability is important, is becoming a major factor in the teaching of engineering graphics, and determines how students relate to two- and three-dimensional modeling procedures.

A further consideration of the demographic data arose from students who had previous work experience in engineering graphics. A further area of study is needed with a larger group of students in order to compare those students who have a brief work experience in an engineering graphics field versus students who have no engineering work experience. Such a study could compare any benefits prior engineering experience may have in the university classroom and work environment. This work experience research could validate the minor benefit found late in this study, whereby students with a little work experience were found to have better grades. This finding could also be tested for a new hypothesis and relate to final grades and final projects in engineering graphics with the MSLQ survey.

Another consideration might be that gender may be related to spatial ability. It may also be unrelated, but some females in the study appeared to lack confidence in the use of computer-aided design software, and this in itself is another area of study. Backed by other studies, the gender-related study could be used to detect if females are handicapped by a lower 2-D versus 3-D spatial visualization skill. This observation could lead to further research that could be used to locate spatial problems females may or may not have in manipulating the assembly of three-dimensional models in computer-aided design for working and assembly drawings and for physical prototyping.

Visual communication is another consideration arising from the study. The study found that subjects often could not visualize and place the correct front view in CAD. One of the biggest visualization obstacles the subjects had in the study was visualizing the correct front view of the object, lining up the views, and scaling and dimensioning. Instead of the actual front view, subjects got rear or bottom views. They just assumed the CAD program had placed it correctly for them. They could not visualize the correct view.

Another recommendation would be to undertake a qualitative study using small groups and each of the case problems. The thick broad study could be videotaped and analyzed qualitatively using either passive observation or participant observation.

To conclude, and as a rapprochement between traditional lecture learning and problem-based learning pedagogies, a final consideration might be to use the Osterman feedback lecture approach in addition to PBL problems designed for the engineering graphics study. The Osterman feedback lecture uses a hybrid interactive lecture approach. It impels instructors to break the lecture into segments and ask students to reflect on problems at regular intervals (Osterman, 1985).

There are many variations, and Cooper, Robinson, and Ball (2004) suggested a similar format that they indicated can be used as an attempt to seek a compromise between those who use the lecture as their dominant method of teaching and those who believe that group and other active-learning procedures are an effective instructional strategy. They posited that their interactive lecture focuses on two concepts: cognitive scaffolding and quick-thinks. Cognitive scaffolding is a form of support provided either by the teacher or another student and helps a student bridge the gap between his or her current abilities and the intended instructional goal. Quick-thinks are brief, active-learning exercises that can be inserted in lectures or other instructional formats and require students to process information individually, collaboratively, or both (Cooper et al., 2004).

The downside, according to Woods (1996a), is that the interactive lecture method requires about 10 hours of preparation time to span six lectures. He indicated that as a lecture technique it introduces activity and cooperation. The teacher introduces the problem first and then continues to lecture. Posing the problem first will also lead toward tutor-directed modeling and PBL (Woods, 1996a).

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APPENDICES

APPENDIX A
Informed Consent Form

NC STATE UNIVERSITY

INFORMED CONSENT FORM

Title of Study *An Investigation into problem-based learning in engineering graphics*

Principal Investigator Brian Matthews Faculty Sponsor (if applicable) Dr. Eric Wiebe

You are invited to participate in a research study. The purpose of this study is: t*o determine if problem-based learning has any more motivation than lecturing methods when teaching a foundation of engineering graphics class.*

INFORMATION

GC 120 classes are asked to take part in a Motivated Strategies Learning Questionnaire *(MSLQ) survey (10* to 15 minutes is estimated to complete the online survey).

RISKS

There is no risk to any student taking part in this study.

BENEFITS

The study will look at Graphic Communication classes in engineering, and how teaching style may improve engineering education.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION

For participating in this study you will receive one homework credit as compensation. Other ways to earn the same amount of credit are to create an alternative 3D model project. If you withdraw from the study prior to its completion, you will receive no *homework penalty for non-participation.*

As students you are asked to complete the Motivated Strategies Learning Questionnaire *(MSLQ) as part of the requirements for this course. TheMSLQ test will count as a regular homework assignment. By completing the test, each student will receive full credit for the assignment regardless of his/her score. Data from students who choose not to participate in the project will not be included in the final data set.*

EMERGENCY MEDICAL TREATMENT (if applicable) Not Applicable to this research.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, Brian Matthews, at 510K Poe Hall, NCSU, or [515-1751]. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.

CONSENT

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.

Subject's signature____ Date __________________

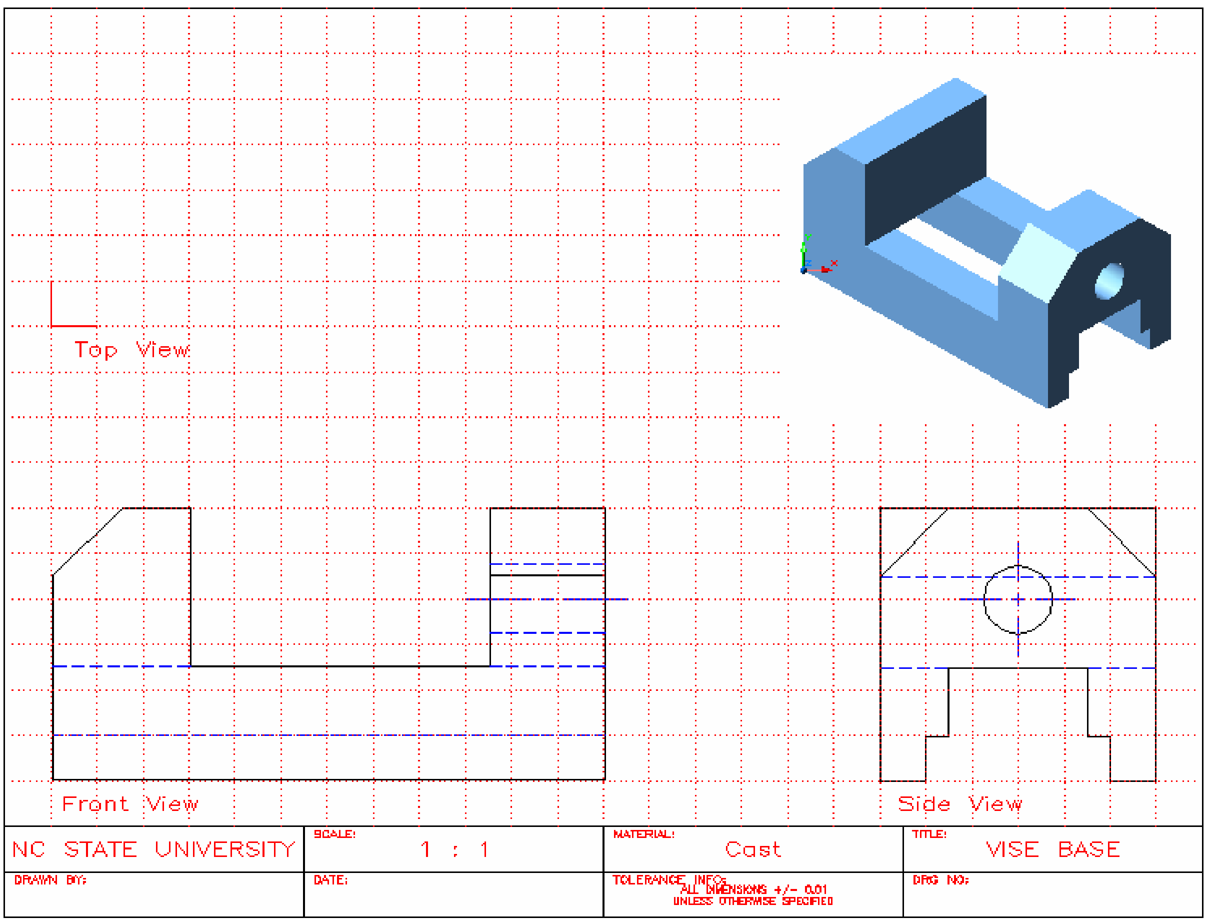
Investigator's signature____________________________________ Date __________________

APPENDIX B
Pretests

PRE-TEST-1 (WEEK ONE)

You are a candidate interviewing for a position as a junior engineer at a local engineering company. Part of the interview is produced below. Complete it to the best of your ability.

Interview Candidate Instructions: A multiview drawing with Horizontal, Frontal and Profile planes, and a Pictorial view is provided. The drawing has either a missing Top View or Front View. Complete this first sketch to the best of your ability. To the best of your ability, place dimensions in the correct locations.

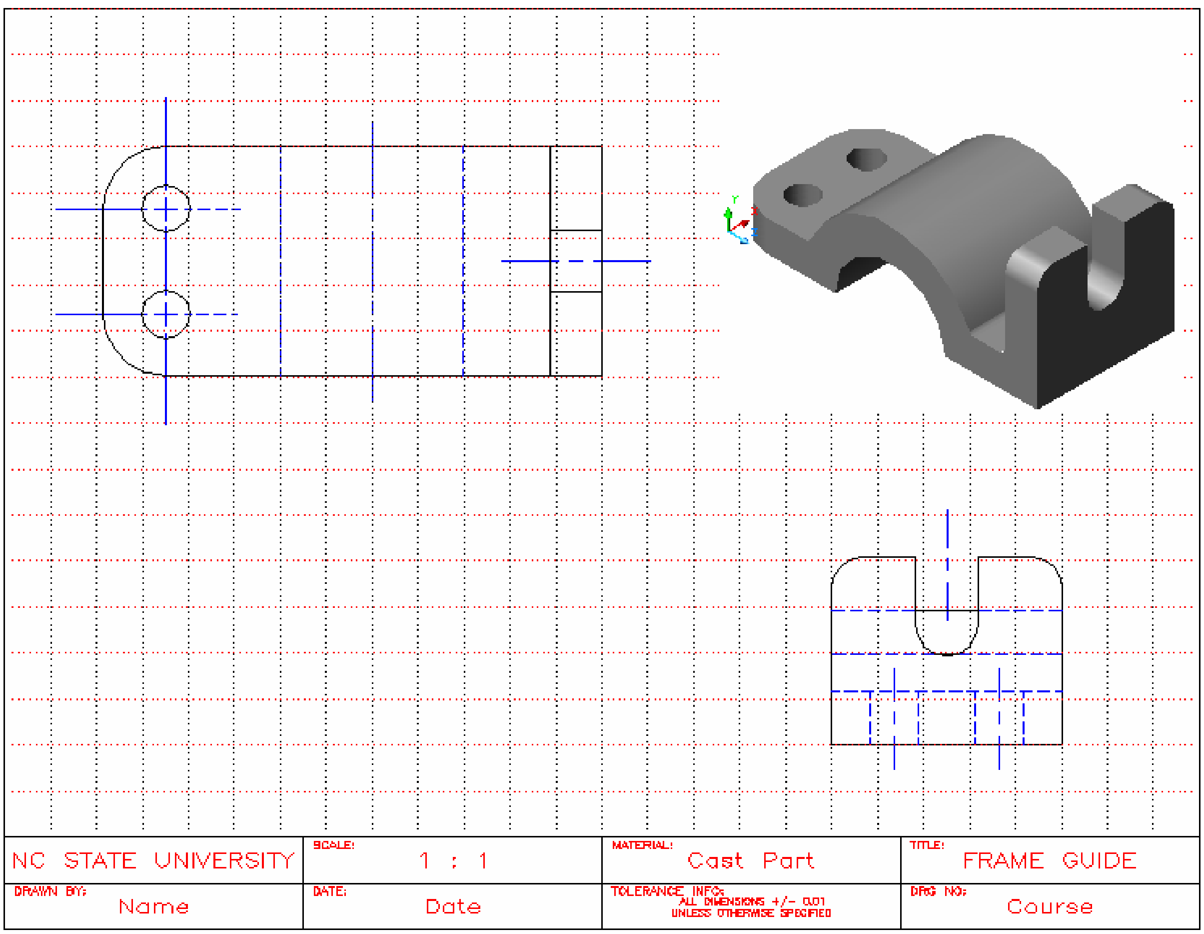


Do you need any more information to complete the missing views of the single part?

PRE-TEST-2 (WEEK ONE)

You are a candidate interviewing for a position as a junior engineer at a local engineering company. Part of the interview is produced below. Complete it to the best of your ability.

Interview Candidate Instructions: A multiview drawing with Horizontal, Frontal and Profile planes, and a Pictorial view is provided. Each drawing has either a missing Top View or Front View. Complete this second sketch to the best of your ability. Place dimensions in the correct locations.



APPENDIX C
Weekly Exercise Problems

WEEK ONE

ANSI VIEW PROBLEM

SCENARIO: You are being interviewed for an internship in an engineering consultant's office. As part of the interview your first task is to answer the questions below in reference to Graphic Communications with the provided engineering drawing, and measure the metric part by hand.

Problem instructions:

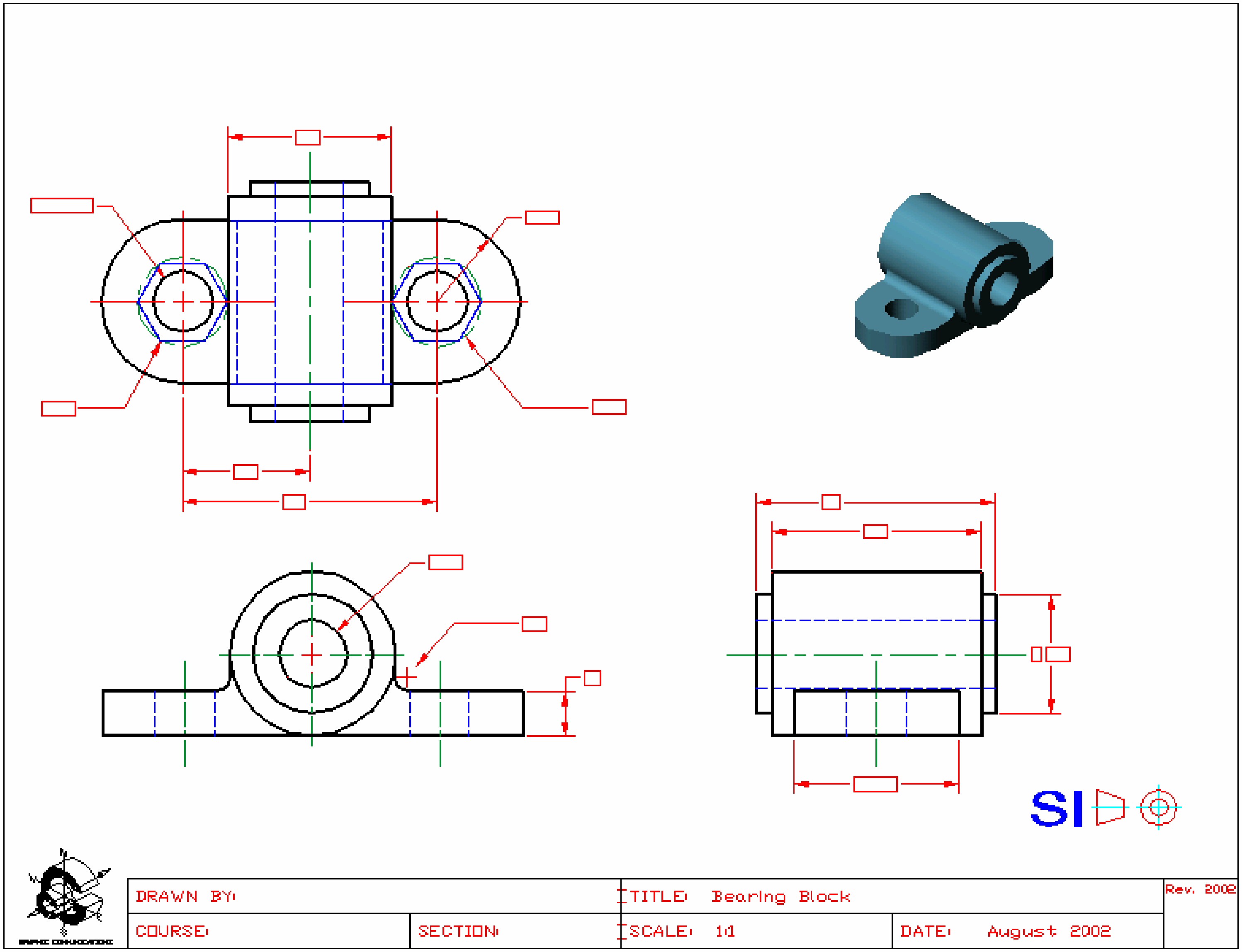
Answer the questions below in reference to engineering graphics.
Use the web to research an important figure in engineering design or engineering graphics.
Identify three new products that have appeared on the market in the past few years.

Problem questions related to the attached engineering drawing:

What are the names of each of the views/planes in the attached drawing?
Are the views to ANSI standard?
Is the solid model below drawn from different primitives or a single construction?
What is a primitive?
Is the rendered 3-D view in the correct view location – (upper right corner)?
What is the correct name for the rendered 3-D view?
Are all the profiles of each view correct?
Can you sketch and describe how you would create the part in CAD?
Do the views show correct centerlines and center marks to ANSI standard?
What is the difference between a centerline and a center-mark?
Is the line-weight correct for each of the views?
What is line weight, and why do we use it in drawings?
Are the fillets correct for the body to the base of the part?
What is a fillet?
Do the profile views show the correct hidden lines to ANSI standard?
In your opinion are all the views required to describe the part below?

WEEK ONE

At 1:1 scale - check the Bearing Block drawing and measure the dimensions.



WEEK ONE

REVERSE ENGINEERING C-CLAMP ASSEMBLY & WORKING DRAWINGS

SCENARIO: As a new engineering graphics consultant one of your first tasks is to reverse engineer and create measured working and CAD assembly drawings for the machinist and determine the dimensions necessary for the manufacture of a C-Clamp.

Problem instructions:

Answer the questions below, which relate to engineering graphics and the 3-D casting of the C-Clamp. Reverse engineer, sketch, measure, solid model and draw all the C-clamp parts.

Student questions to reflect on and new learning issues:

What is the difference between a Working drawing and an Assembly drawing?

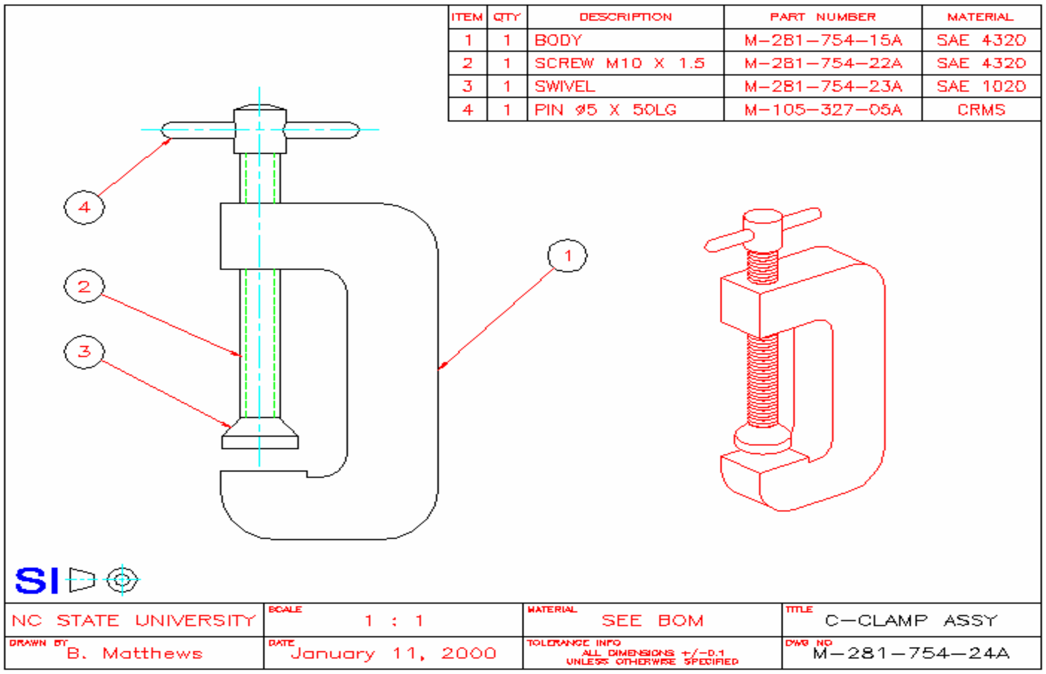
What is a section view used to describe in a working drawing?

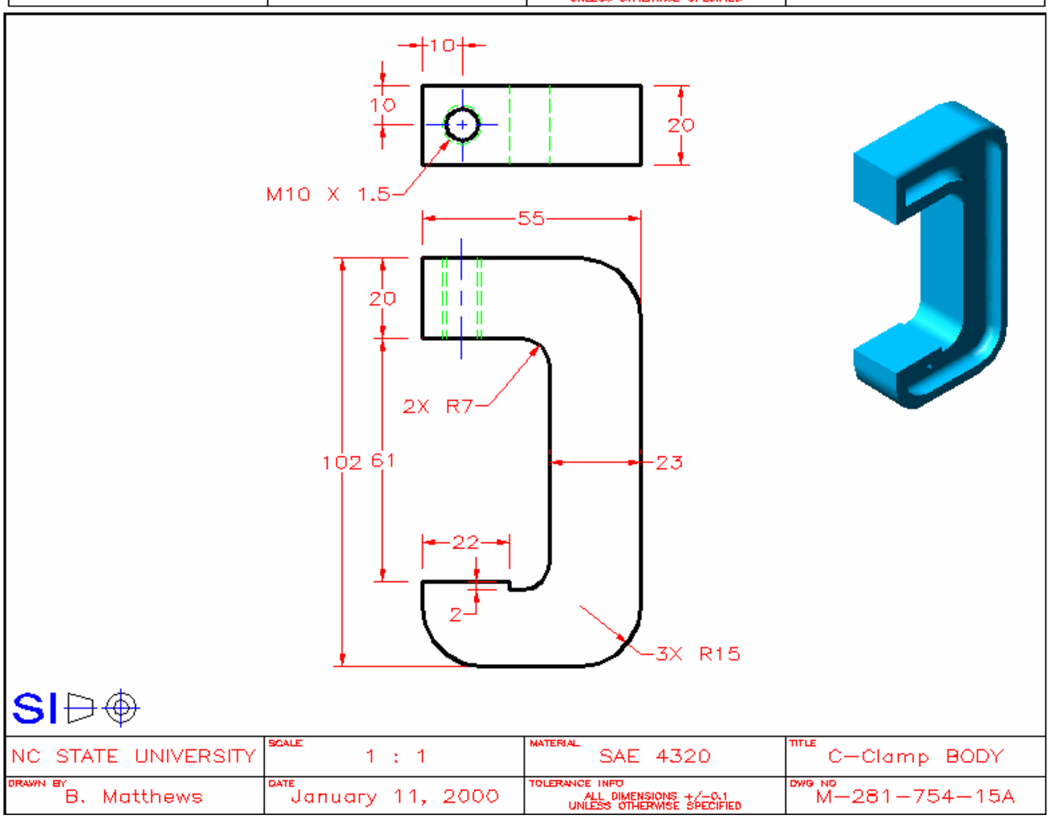
What special function does the Part List have in an Assembly drawing?

Why do working drawings have dimensions and tolerances and not Assembly drawings?

What special function do the numbers and balloons have in the Assembly drawing?

WEEK ONE





Reverse engineer, sketch and measure all the parts of your C-clamp, then produce solid models and working drawings and complete an assembly as shown in the examples above.

WEEK TWO

DRAWING STANDARDS AND LAYOUT

SCENARIO: After successfully interviewing as an intern in an engineering consultant's office one of your first tasks is to understand drawing standards and layout.

The senior designer provides you with an old sketch of a Bearing (as shown) he wants you to produce a neat Metric drawing for a new client. Specifically your job is to prepare the drawing to American drawing standards. The bearing part will be manufactured in North America in Metric.

Problem instructions: Sketch only two views of the part by hand. Which view is redundant?

Equipment problem: If your only instruments are pencils, triangles, compass, metric scale, but no protractor. Can you create the needed views to scale as neatly as shown with the few instruments available?

Is the one-off single sketch drawing worth producing in CAD? If so, why?

Is the drawing to ANSI standard?

Do you have enough information/dimensions on the sketch to produce the drawing?

Is there a better way to view the part – other than as shown?

Are any of the views redundant? If so which one and why?

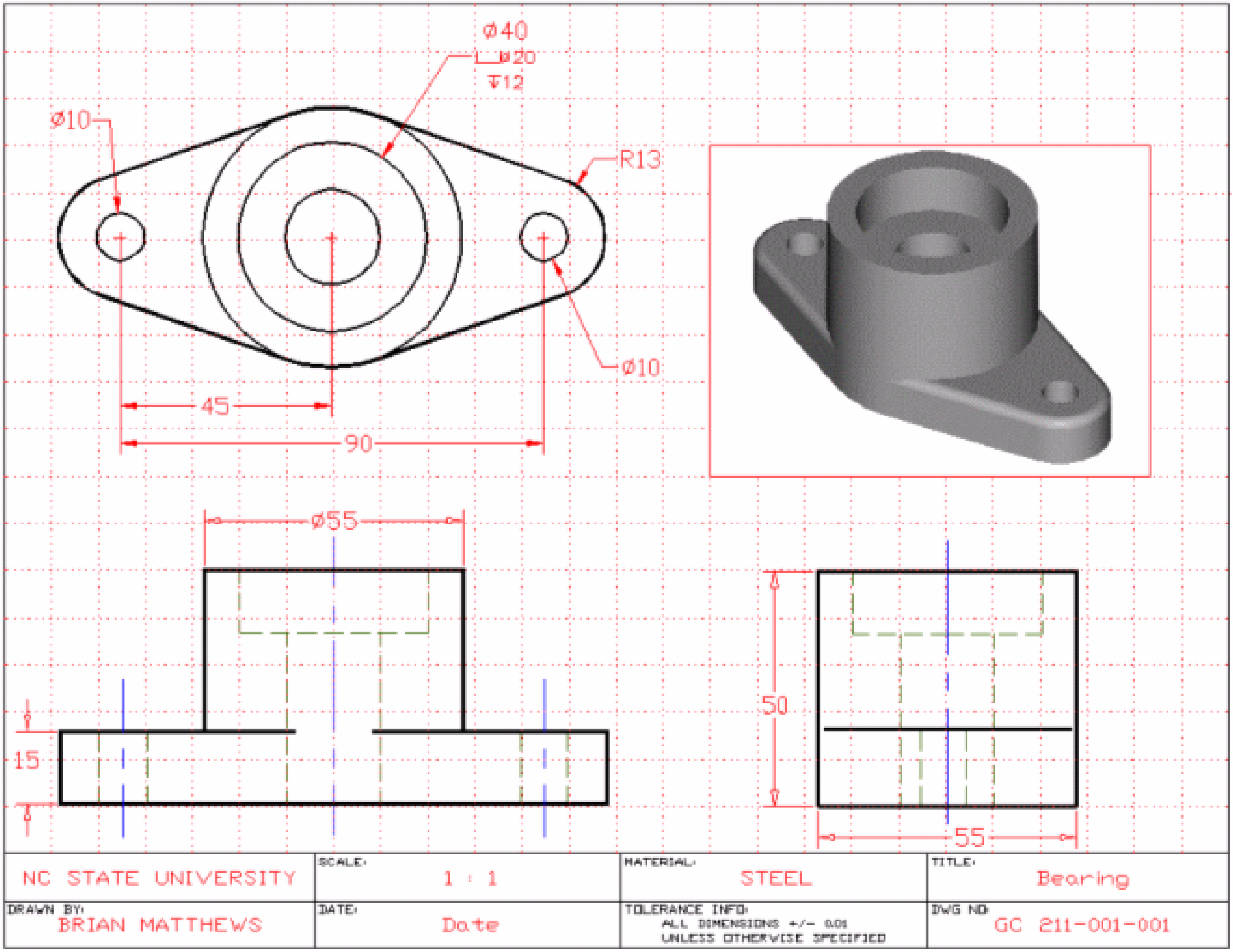
Can you locate the points of tangency?

How would the drawing be produced in CAD –Could you sketch the steps for CAD?

Why are edges rounded on the outer part of the cast base?

What is the junction called where the rounded edge meets the cylinder?

Sketch the Bearing drawing complete with dimensions.

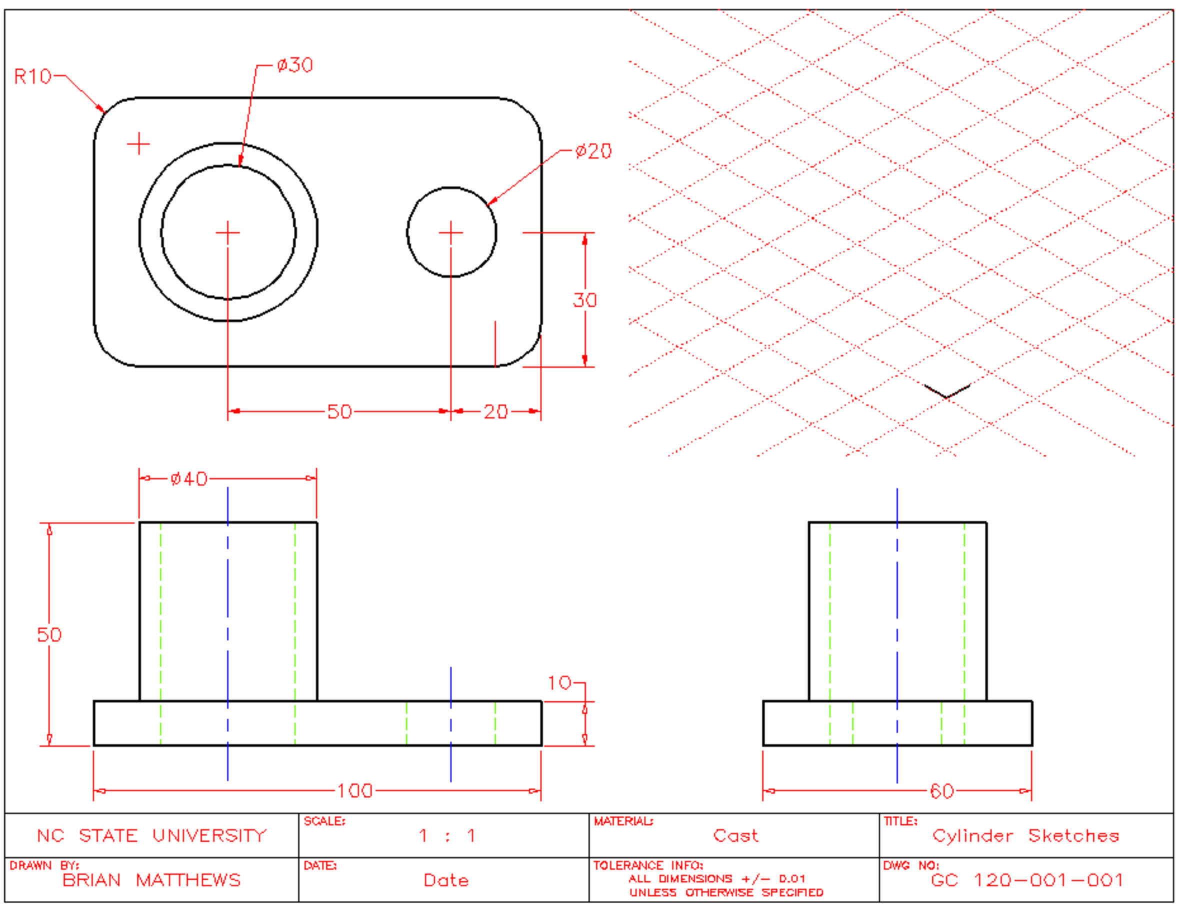


WEEK TWO

SCENARIO: As a junior engineer you need to produce neat drawings and isometric sketches for the senior designers of the company. You are requested to produce a neat isometric drawing from the Metric dimensions at 2:1 scale, for the manufacture of the part.

Problem instructions:
Sketch all views of the part by hand.
The attached sketch shows a missing isometric view to the simple drawing.
Neatly sketch the cylinder drawing in the isometric view.
Create dimensioned Top, Front and R-Side views at 1:1 scale.

Student questions to reflect on and new learning issues:
Is the one-off single sketch drawing worth producing in CAD? If not why?
Do you have enough information/dimensions on the sketch to produce the drawing?
How would the drawing be produced in CAD – Could you visualize and sketch the steps?



WEEK THREE

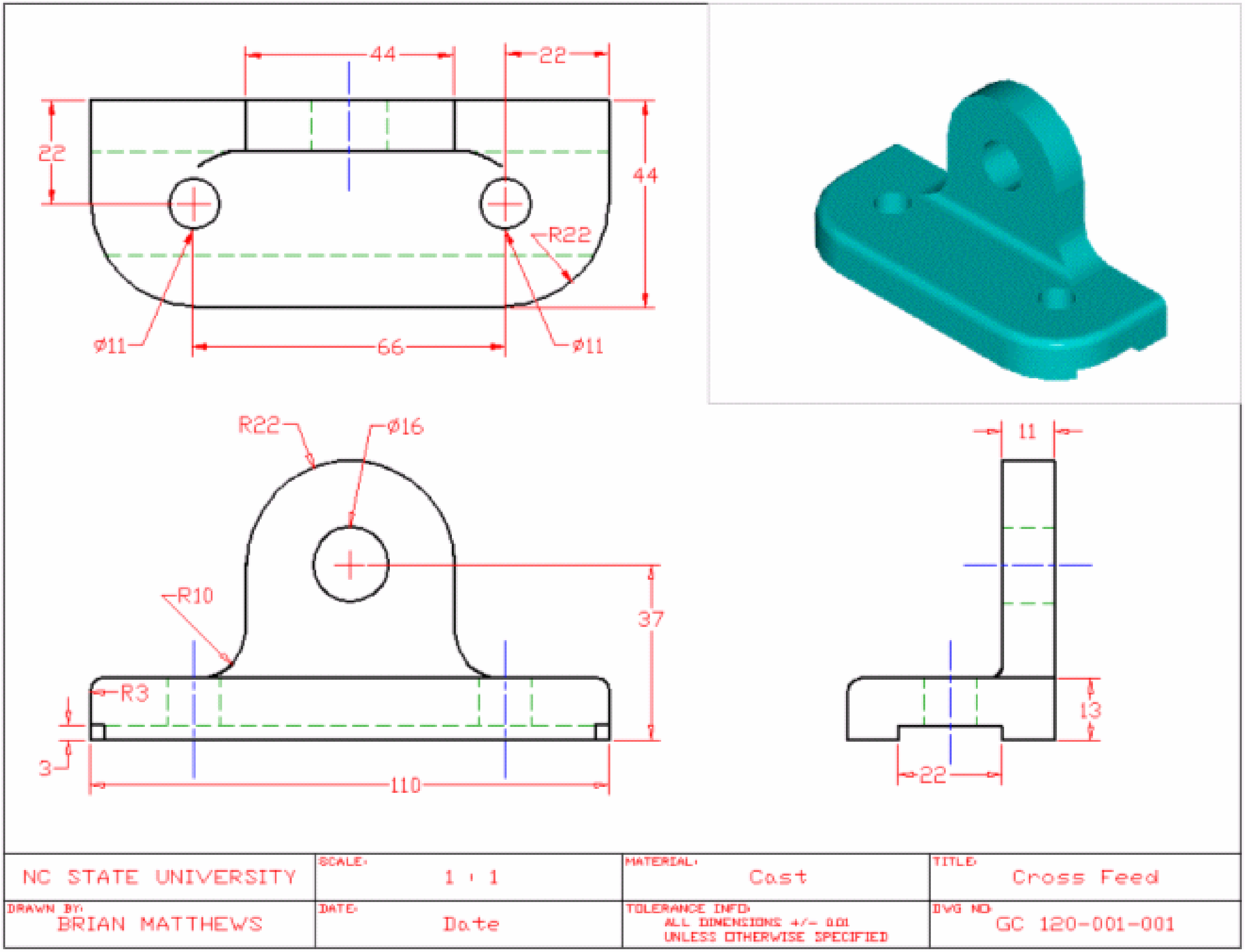
SCENARIO: After successfully interviewing as an intern in an engineering consultant's office one of your first tasks is to understand drawing standards and layout, your first contract drawing is a Cross Feed.

The senior designer provides you with an old sketch of a Cross Feed (shown below) he wants you to produce a neat Metric drawing for a new client. Specifically your job is to prepare the drawing to American drawing standards. The bearing part will be manufactured in North America in Metric.

Problem instructions: The senior designer wants you to produce dimensioned views of the Cross Feed by hand and by 3-D modeling in CAD. Create the Cross Feed drawing and show Top, Front and Right Side Views complete with dimensions.

Problem: Sketch the Top, Front and R-Side views at 1:1 scale as neatly as shown. Create the part in CAD.

Is the one-off single sketch drawing worth producing in CAD?
Why are the dimensions staggered?
Do you have enough information/dimensions on the sketch to produce the drawing?
Are any of the views redundant?
How would the drawing be produced in CAD –Could you sketch the steps for CAD?
Why are edges rounded on the outer and inner part of the base?
What are the internal and external rounded edges called in engineering terms?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13
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NC STATE UNIVERSITY
SCALE:
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MATERIAL:
Cast
TITLE:
Cross Feed
DRAWN BY:
BRIAN MATTHEWS
DATE:
Date
TOLERANCE INFO:
ALL DIMENSIONS +/- 0.01
UNLESS OTHERWISE SPECIFIED
DWG NO:
GC 120-001-001

WEEK THREE

SCENARIO: Your job is to create the geometric drawing of the wrench and place any required notes and dimensions. Specifically your job is to prepare the drawing to ANSI - American drawing standards as the part will be manufactured in North America in Metric.

Problem instructions: The purpose of this problem unit is to learn simple engineering geometry. The drawing files consist of 2-D single views and a pictorial. In addition to creating the part in CAD, can you draw the part by hand, and sketch the steps needed to produce the part in CAD?

Specific student geometry to reflect on and geometry learning issues:

How to construct simple triangles/polygons, i.e. hexagon / octagon measured across the flats.

How to use a compass to offset lines.

How to use geometry to draw a circle through 3 points.

How to draw (1) a circle tangent to two lines, (2) a circle tangent to a line and circle, (3) a circle tangent to two circles.

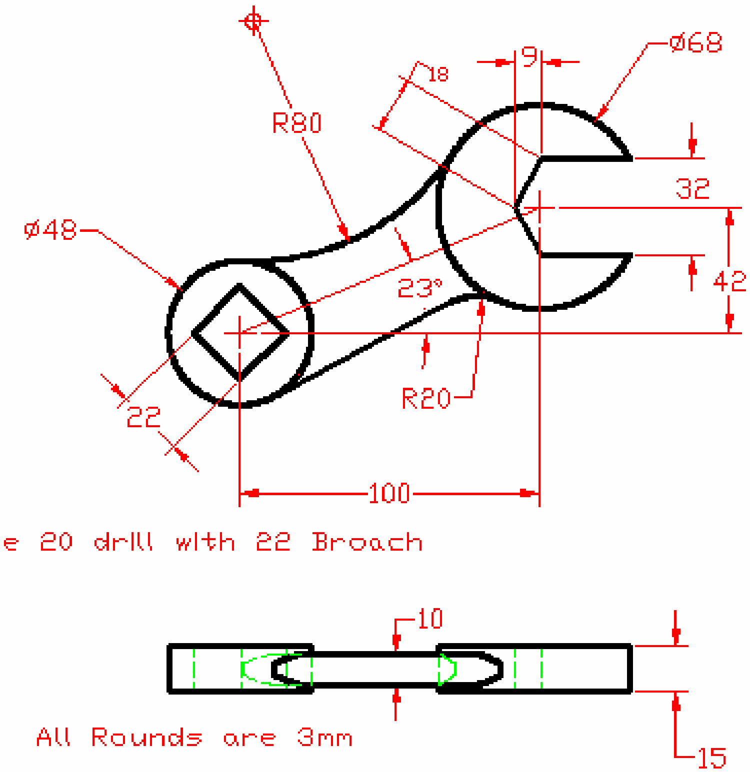
Further student graphic questions or learning issues:

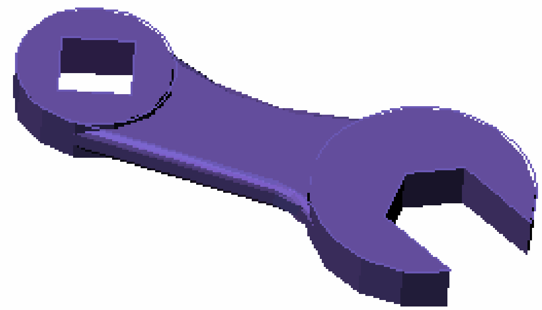
What font type should you use for the drawing, and what is the font size and alignment?

What type and thickness of pencil lead to use for each of the drawing lines, i.e. object, center, hidden, dimension lines and engineering notes?

What engineering geometry will you need to learn to complete the drawing to exact standards? All measurements are in Metric. Note where to place the dimensions in respect to the object.

Sketch and dimension the Stubby Wrench drawing.





NC STATE UNIVERSITY	SCALE: 1 : 1	MATERIAL: Cast	TITLE: Stubby Wrench
DRAWN BY: Name	DATE: Date	TOLERANCE INFO: ALL DIMENSIONS +/- 0.01 UNLESS OTHERWISE SPECIFIED	DWG NO: GC 120-001-001

WEEK FOUR

SCENARIO: Your job is to create the geometric drawing of the wrench and place any required notes and dimensions. Specifically your job is to prepare the drawing to ANSI - American drawing standards as the part will be manufactured in North America in Metric.

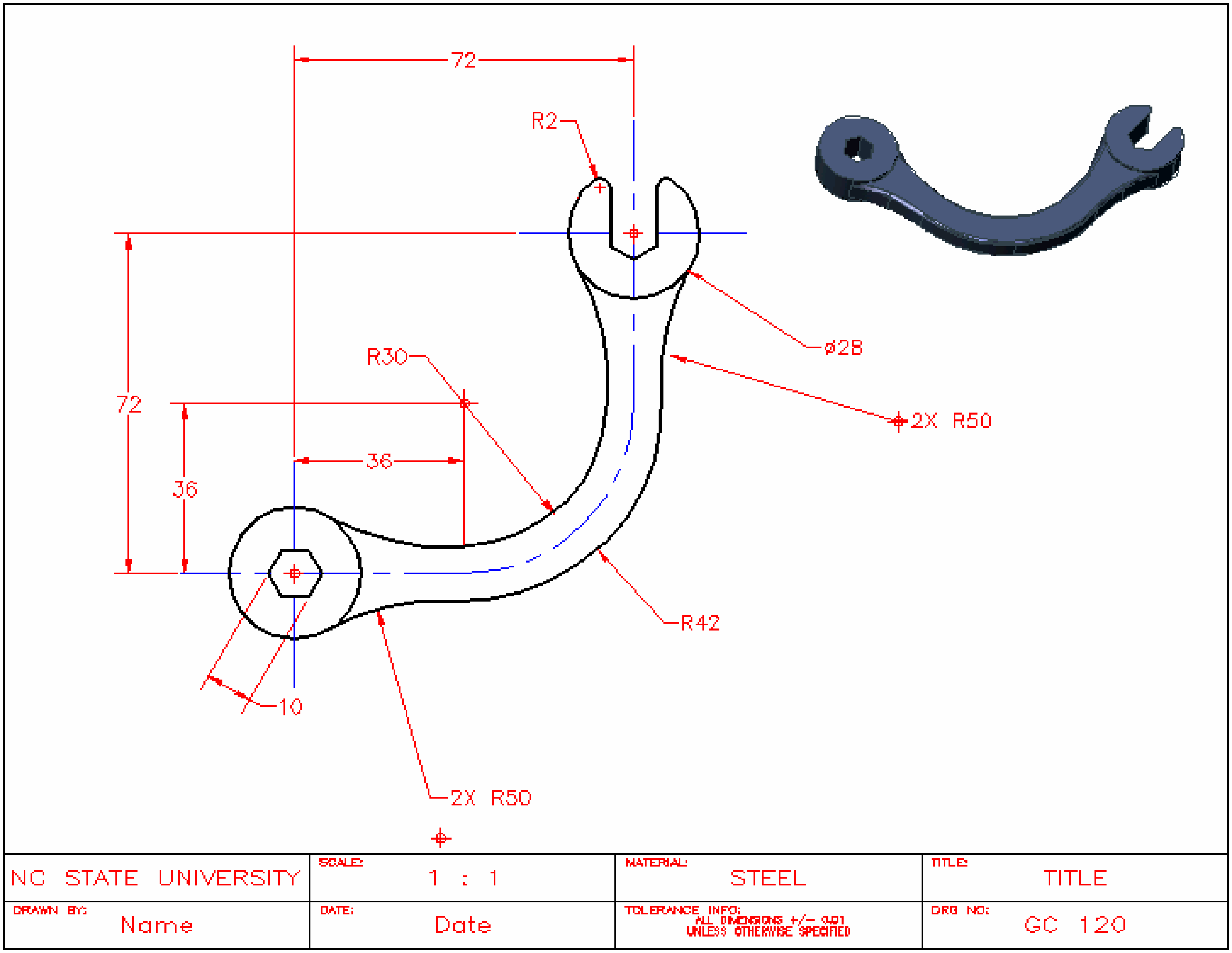
Problem instructions: The purpose of this problem unit is to learn simple engineering geometry. The drawing files consist of 2-D single views and a pictorial. In addition to creating the part in CAD, can you draw the part by hand, and sketch the steps needed to produce the part in CAD?

Further student graphic questions or learning issues:

What font type should you use for the drawing, and what is the font size and alignment?

What type and thickness of pencil lead to use for each of the drawing lines, i.e. object, center, hidden, dimension lines and engineering notes?

What engineering geometry will you need to learn to complete the drawing to exact standards? All measurements are in Metric. Note where to place the dimensions in respect to the object.



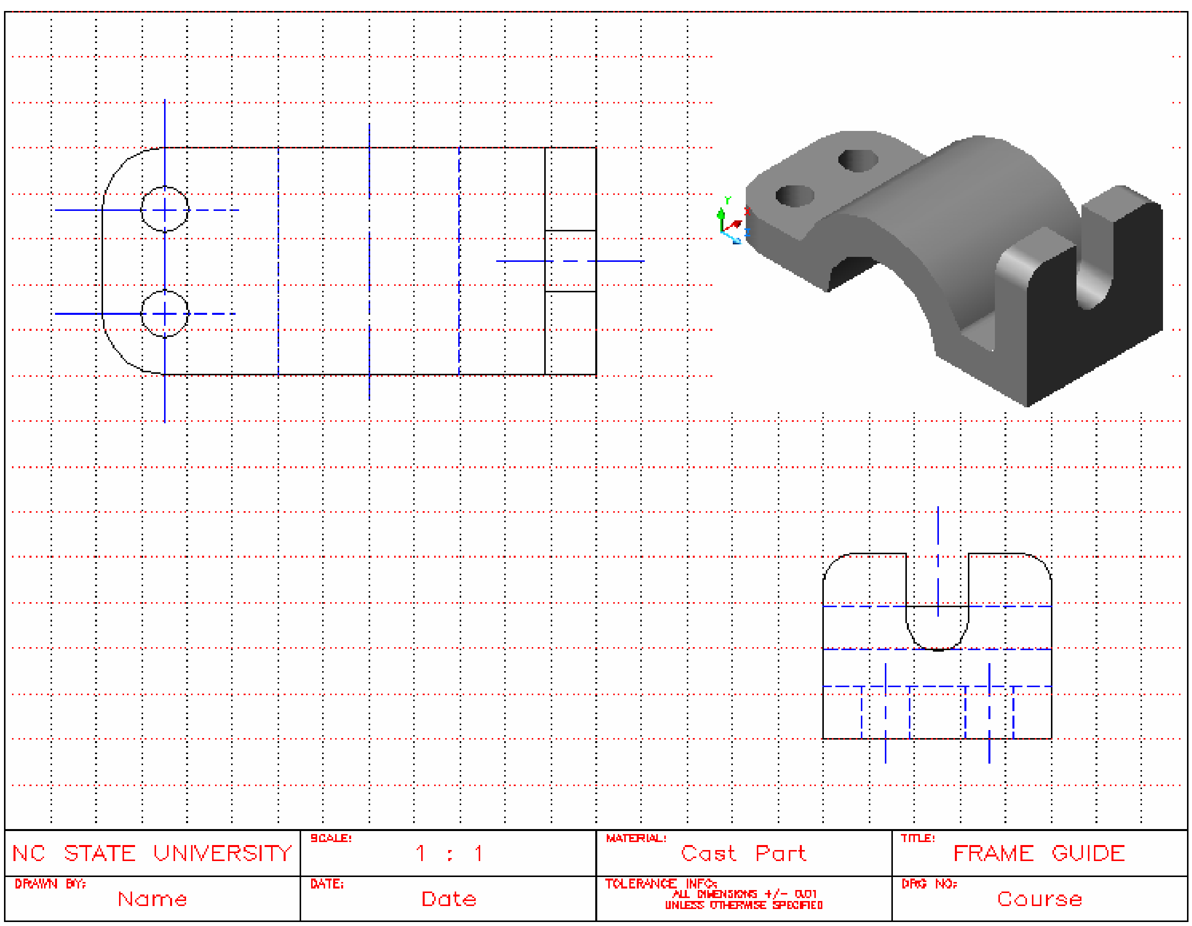
Sketch and dimension the Distributor Wrench drawing.

WEEK FOUR

SCENARIO: The senior engineer provides you with missing sketch files, which consist of missing views and scratch notes. Your job is to decipher the engineering notes and place the required dimensions on the detail drawing, and in CAD.

Problem instructions:
The sketch below has a missing Front View.
1. Sketch a correct profile in the correct multiview.
2. Dimension the part. Use a 1:1 scale (Grid = 10mm)

Student questions to reflect on and new learning issues:
Place the missing view in the correct location, show center-marks, center-lines, hidden-lines.
Do you have enough information/dimensions on the sketch to produce the drawing?
What lineweights are required to complete the sketches?
Dimension each part - as size, then location, then overall dimensions (10mm from the part).



WEEK FIVE

SCENARIO: The senior engineer provides you with missing sketch files, which consist of missing views and scratch notes. Your job is to decipher the engineering notes and place the required dimensions on the detail drawing.

Hand-drawn work and Missing Lines:

This exercise is designed to check if you can interpret 2-D & 3-D spatial sketches (views) and accurately produce missing views in a (top, front, or right-side) multiview format without assistance from the instructor, and place hidden lines, center-lines and center-marks.

Student questions to reflect on and new learning issues:

Place the missing views in the correct locations, and show center-marks, center-lines and hidden lines.

Do you have enough information/dimensions on the sketch to produce the drawing?

Remember to use the correct line weights to complete the sketches.

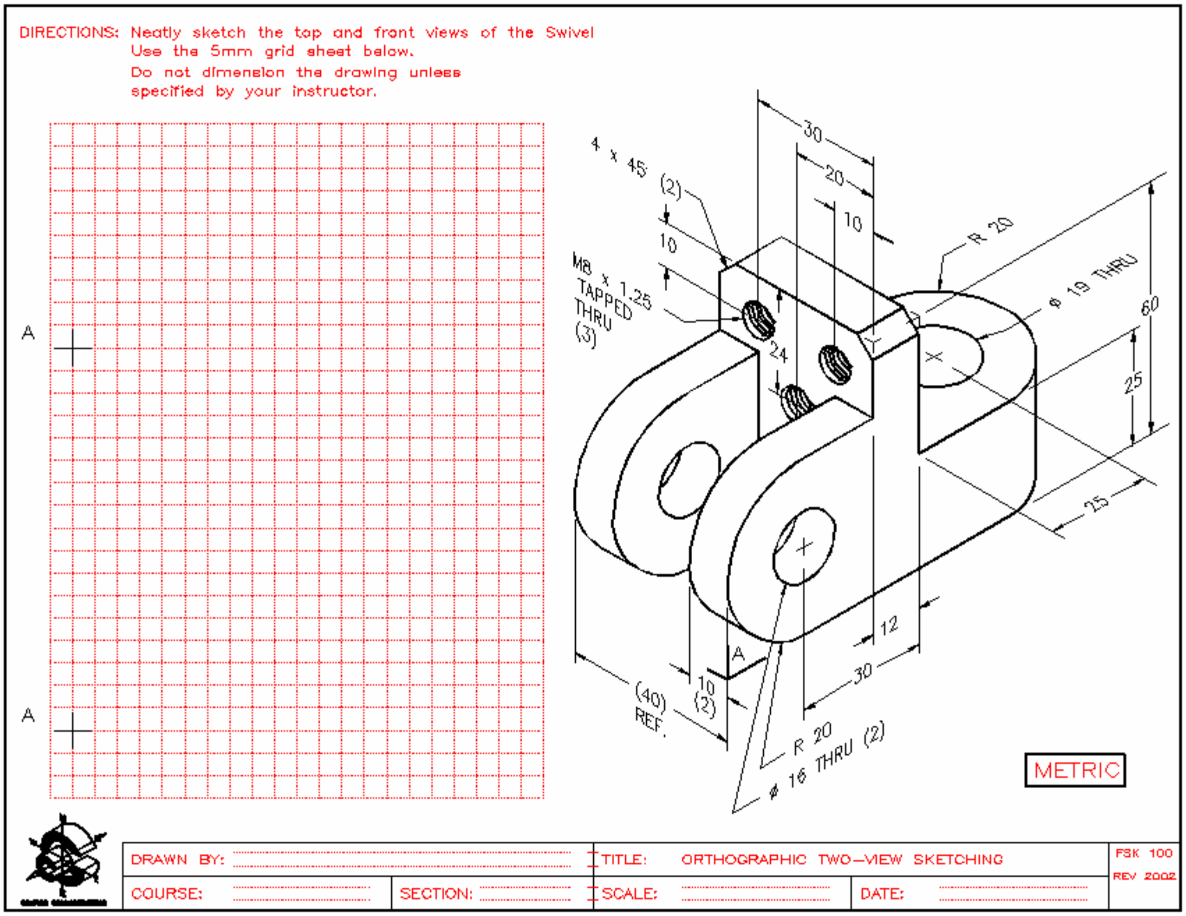
Dimension each part - as size, then location, then overall dimensions (10mm away from the part).

WEEK FIVE

Problem instructions:

The sketch below has either a missing Top View or Front View.

1. Sketch a correct profile in the correct multiviews location.
2. Dimension the part. Use a 1:1 scale (Grid = 10mm)



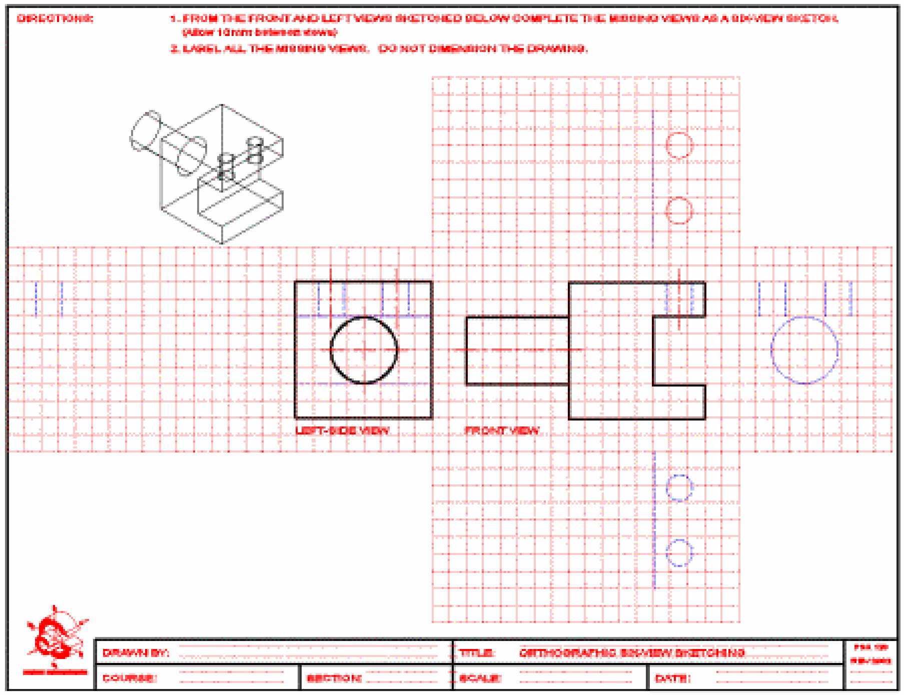
Complete the missing views of the Swivel and show dimensions.

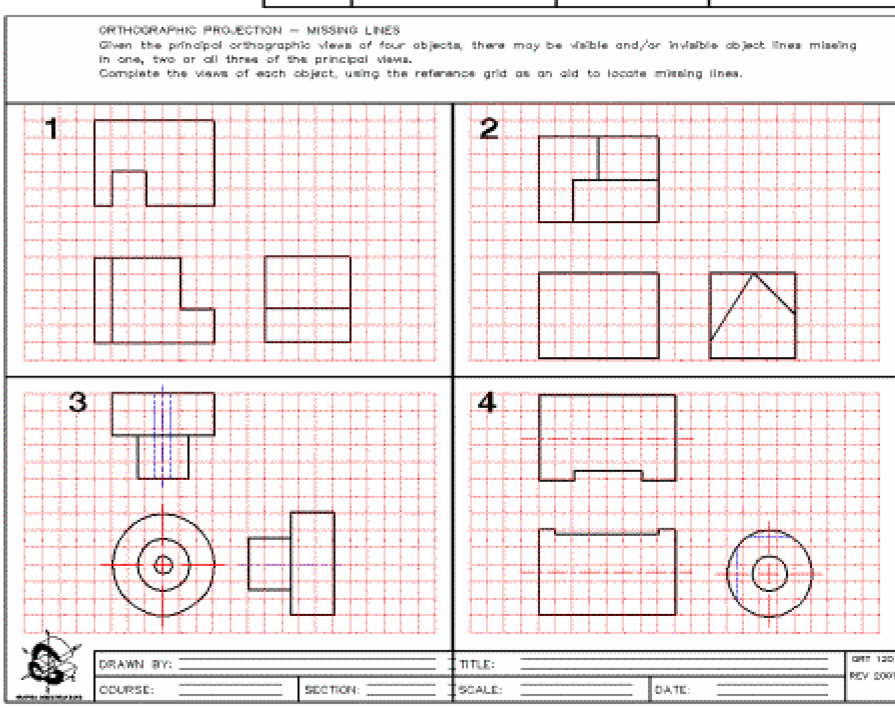
Sketch out the visualization steps and produce the part in CAD as a solid model.

WEEK FIVE

MISSING VIEWS AND LINES LAB.

SCENARIO: You are provided with two class exercise sheets which you have to complete. The scenario is that the senior engineer found these missing sketch files, which have missing views and scratch notes. Your job is to decipher the missing views and missing lines, and also place the required dimensions on the detail drawing.





WEEK SIX

SCENARIO: You are a junior CAD designer in a local ACME engineering company. Your old teacher asked if you could lead a group tour of the machine shop to a group of students from the local High School – (where you went as a student).

When you speak to the high school students in the machine shop what are the main manufacturing processes you could speak about?

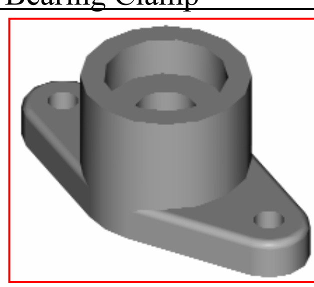
Questions: How will you explain about safety issues to the students, and why do they need to know about safety when they are only on a tour of the shop and not working in it?

What type of practical example(s) can you explain / show / demonstrate without actually have the students use the complex machines. How might you create the parts shown below?

How could you introduce CAD into the machining process and show where it is used in the overall picture?

Problem instructions: Your task is to explain how to produce or manufacture the manufactured parts shown:
Student instructions on practical and engineering theory issues: How would the Cross-Feed, Bearing-Clamp and Stubby-Wrench be made: drop forged, cast or machined? Which process is the strongest?
Sand Casting What are the different methods of casting? Name three parts, which could be cast. What are different types of casting sand? What is green casting sand? Why does a cast part need a radius around certain edges while it's in the casting mold?
Machining How can a part be machined from a casting? What is a machined face - on the part – as opposed to a cast face – and how does it differ?
Forging What are the different types of forging?
Sheet Metal Work What is cold working?
Welding What are the different forms of welding?
Engineering theory To what do the engineering terms: runout, fillet and round – refer? Where do the points of tangency occur on rounds, fillets and runouts? What is the difference between reaming a hole and boring / drilling / broaching a hole.

<u>Cross Feed</u> <u>Bearing Clamp</u> <u>Stubby Wrench</u>



Drilling Reaming Broaching

WEEK 6

SCENARIO: As a junior engineer in the engineering department of a local company you are asked to measure a 3-D Solid CAD sketch of a Toggle Clamp for the Casting Division of the Company. The original measurements of the CAD sketches are lost and an old paper set without measurements is provided by the senior designer of the company as shown below.

Problem instructions: Do NOT draw this part, just dimension it.

Your task is to produce a neat measured sketch of the dimensions, hidden and center lines at 1:1 scale for the manufacture of the Toggle Clamp.

Student questions to reflect on and new learning issues:

Can this part be created as a casting, and what are the different methods of casting production? What would be beneficial to you in order to learn about the casting process?

What is green sand, and what is it made of? Why is it called green sand?

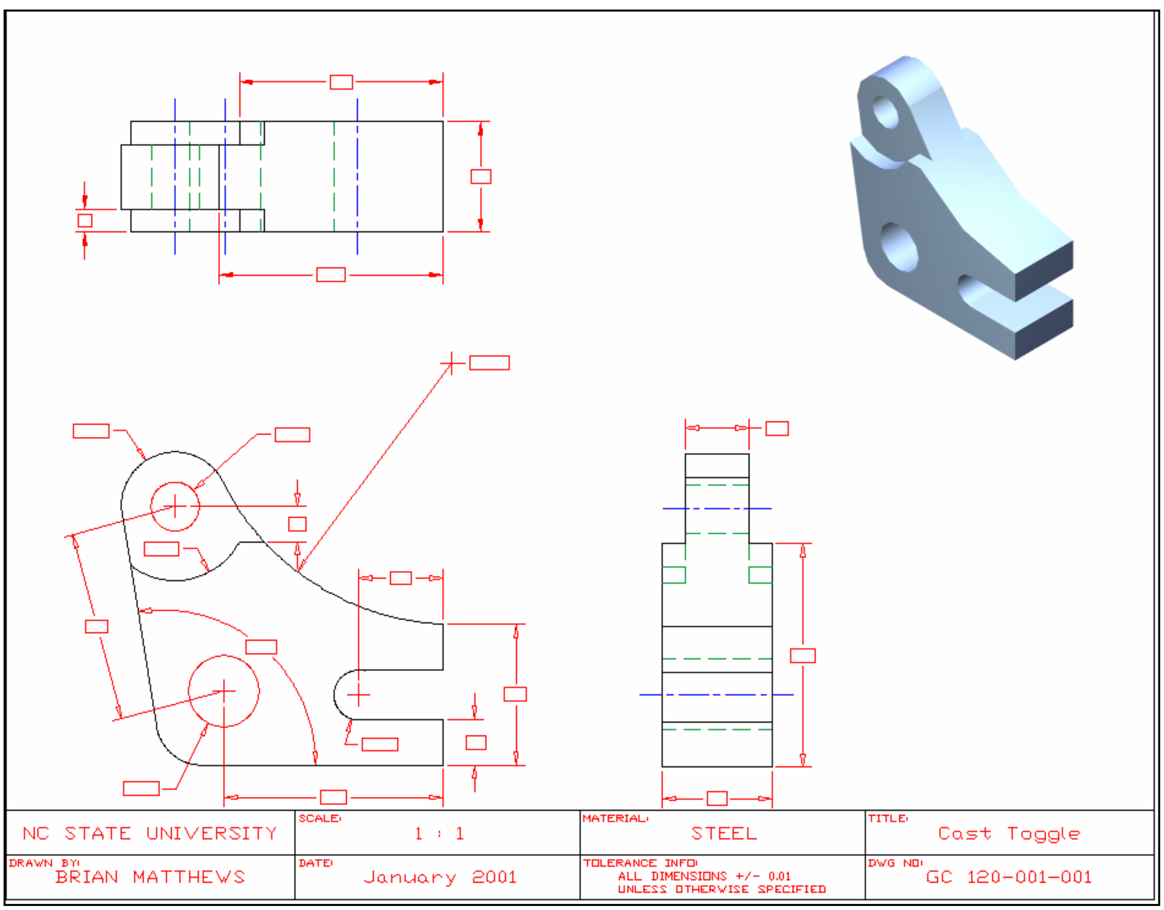
How would you indicate a machined face on the part – as opposed to a cast face?

Why does the cast part need a radius around certain edges?

What are the correct engineering names for creating an internal and external radius to a part?

Can you see where the point of tangency is applied to this particular sketch?

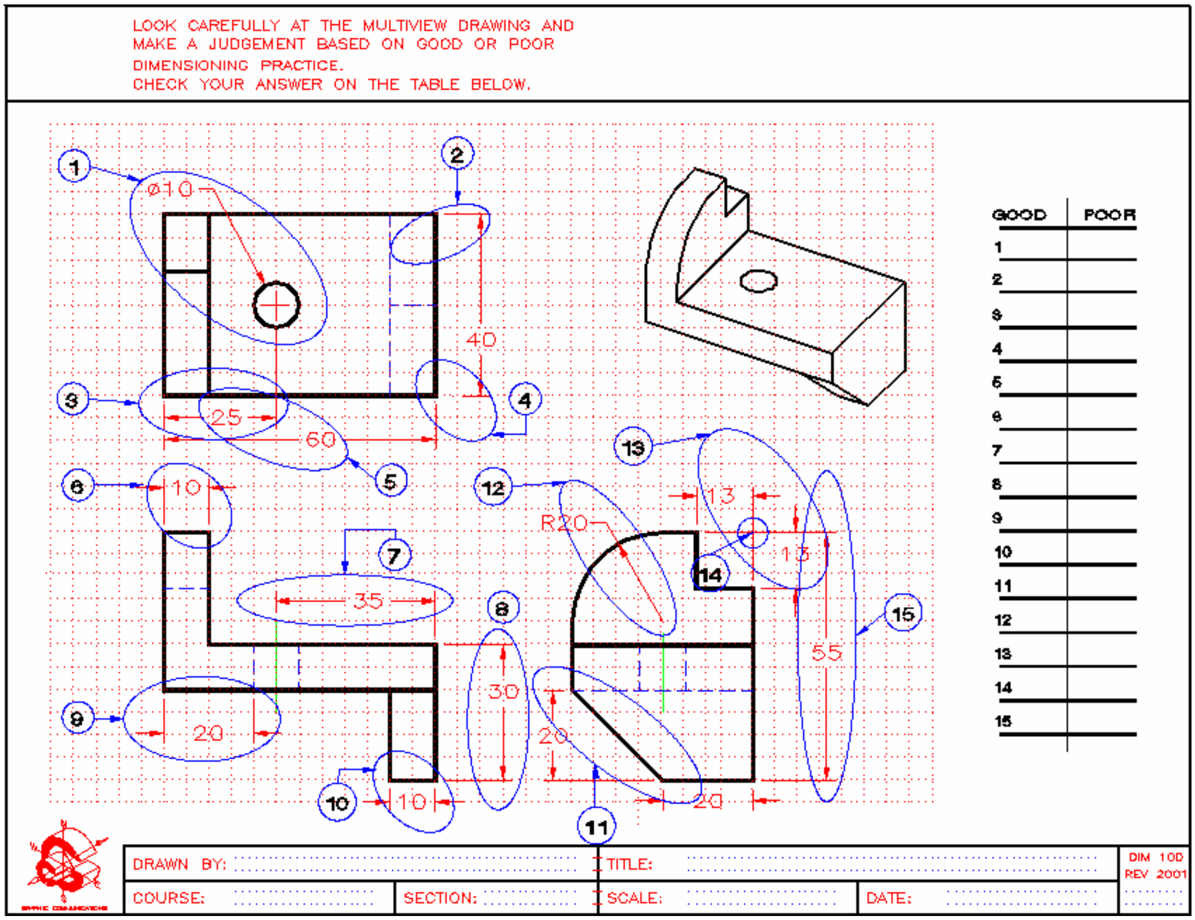
Can you sketch out the steps to create this drawing by CAD?



WEEK 7

Dimensioning Practice:

SCENARIO: In your groups, look carefully at the attached multiview drawing and make a judgement based on what you think are good or poor dimensioning practice. Check your answer in the table below. Then dimension the attached sheets.



From the table:

Make comments of what might be good or poor dimensioning practice from the dimensioning sheet above of listing 1 through 15.

WEEK 7

SCENARIO: As a junior engineer (summer intern) in the engineering department of a local company you are required to reproduce a 3-D Solid CAD sketch of a Link Bearing and Rocker Arm for the manufacturing division of the company. The original CAD drawings are lost and an old paper set with measurements is provided by the senior designer of the company. The original cast sketches are shown.

Problem instructions:

Produce a neat Metric sketch complete with dimensions at 1:1 scale, for the manufacture of the Link Bearing (ISO 050). Specifically, draw the part by hand and in CAD.

Student questions to reflect on and new learning issues:

How can the part be machined from a casting?

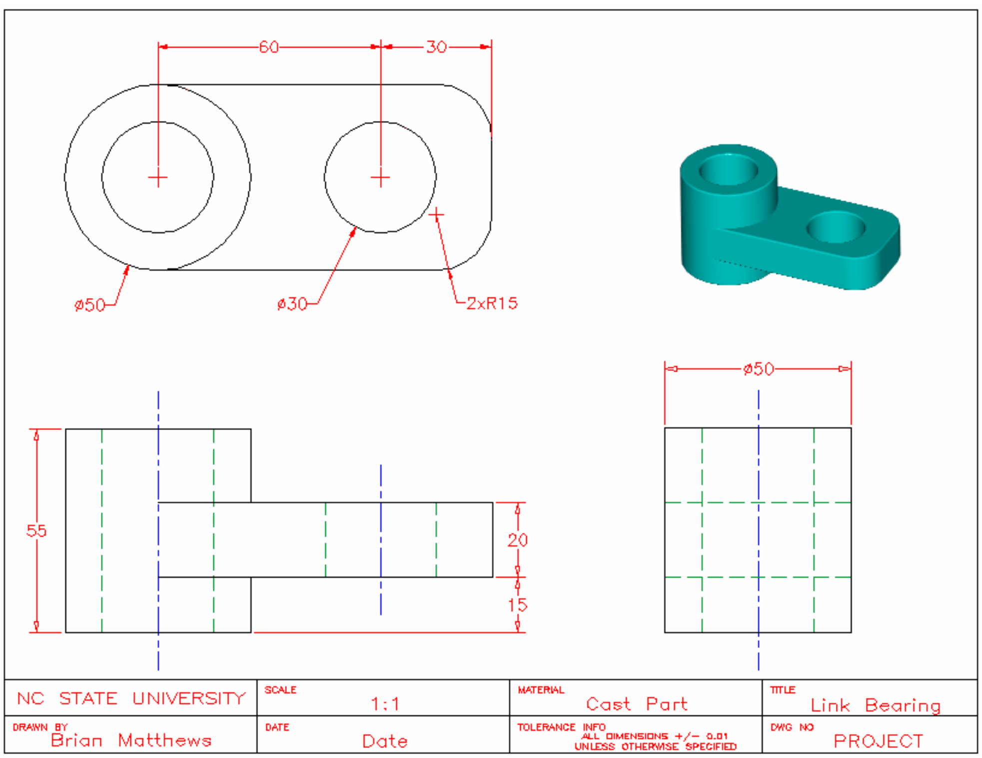
What would be useful to you in order to learn about engineering machine shop processes?

How would you indicate a reamed hole on the part – as opposed to a bored hole?

What is the difference between reaming a hole and boring/drilling/broaching a hole?

How would you indicate a machined face on the part – as opposed to a cast face?

Why would you need to machine a cast face of the part?



WEEK 8

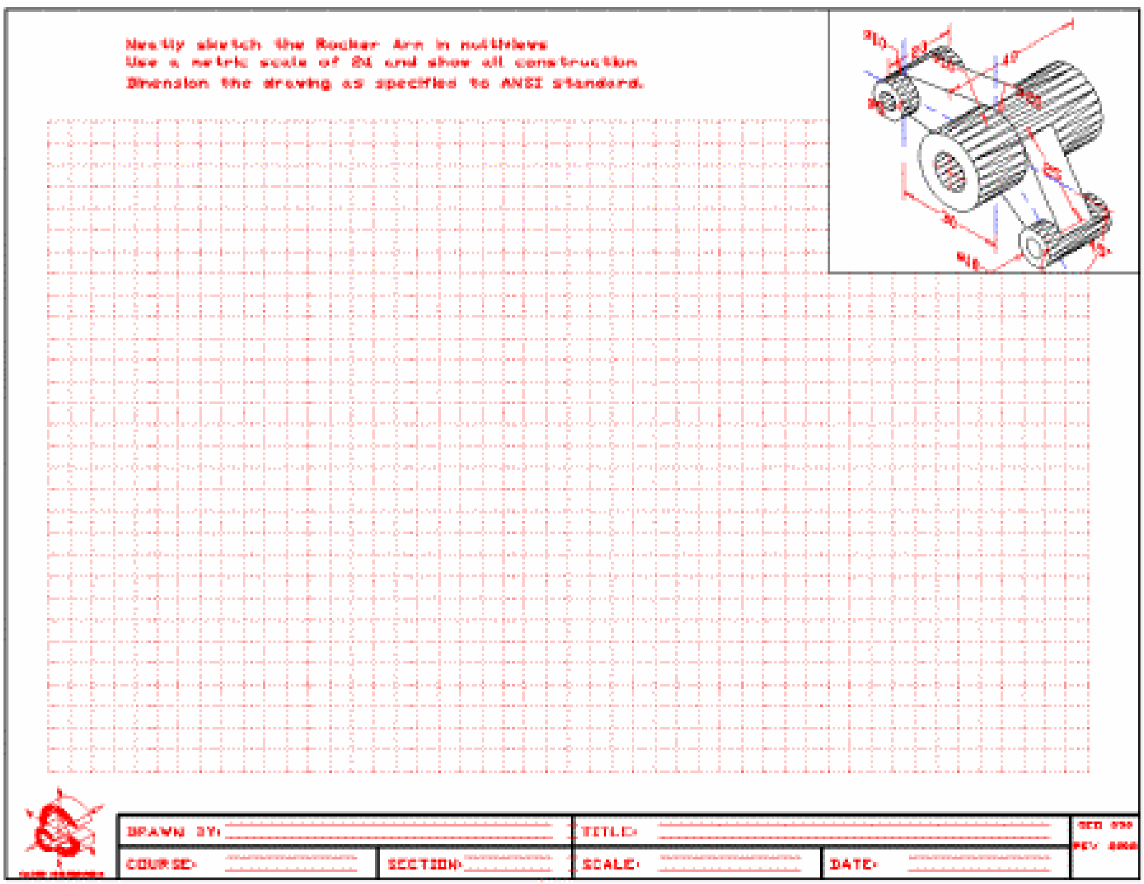
Problem instructions:

SCENARIO: Your task is to produce a neat Metric sketch complete with dimensions at 1:1 scale, for the manufacture of the Rocker Arm and show dimensions to Top and Front views. Sketch out the steps to produce the part in CAD, as a solid model.

Student questions to reflect on and new learning issues:

How would you create the toleranced hole on the shaft?

Would it be bored in one operation or two?



What is the difference between reaming a hole and broaching a hole?

Can you see where the different points of tangency are applied to this particular sketch?

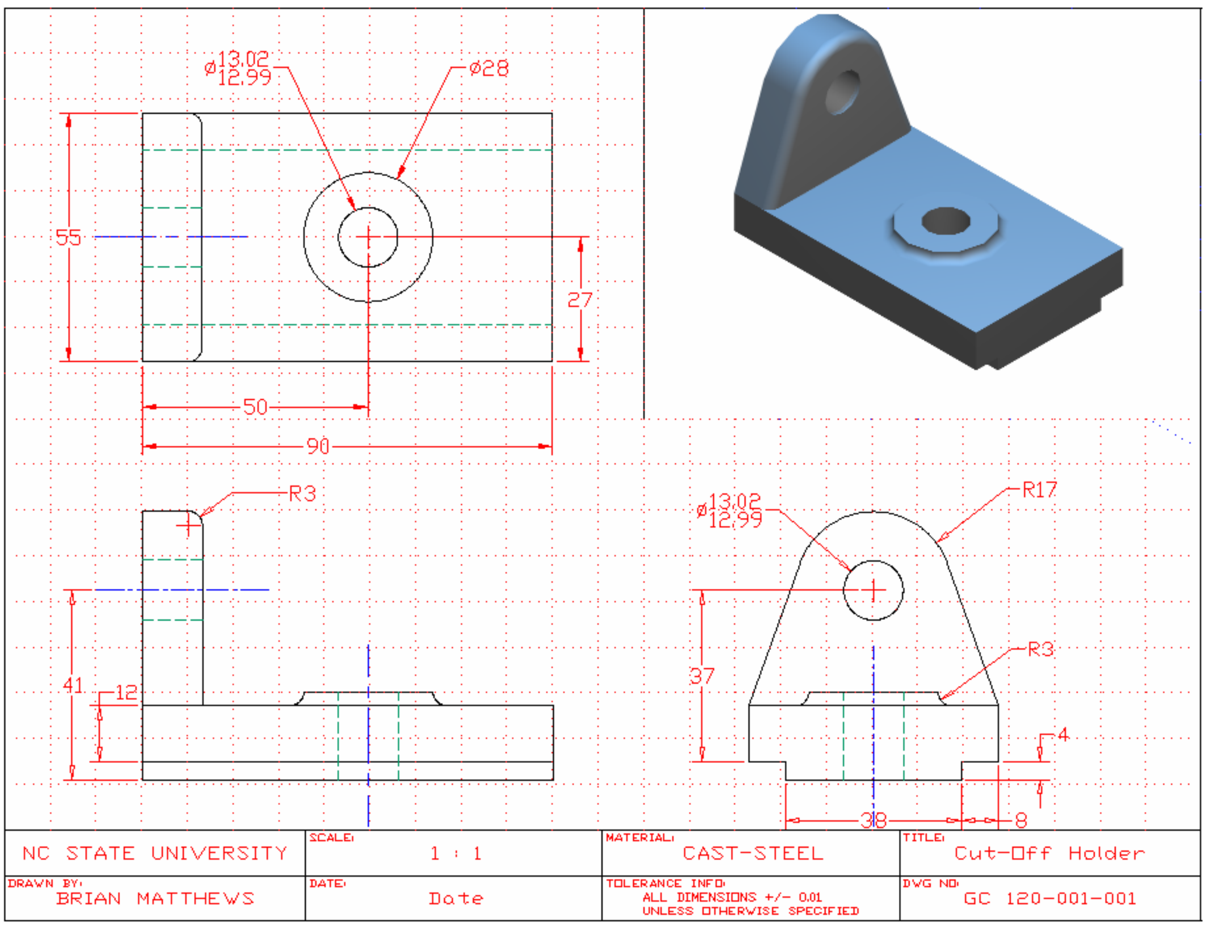
WEEK 8

SCENARIO: As a new engineering intern one of your tasks is to create measured working drawings for the part to be machined and determine the dimensions necessary for the manufacture of the part.

Problem instructions: Produce a CAD model for the manufacture of the Cut-Off Holder.

Questions to reflect on and new learning issues: What is the difference between reaming a hole and boring a hole? How might the Cut-Off Holder be made: drop forged, cast or machined? What do the 13.02 and 12.99 signify to the two-hole diameter dimensions?

Can you visualize and sketch out the steps needed to create the model in the CAD system?



WEEK 8

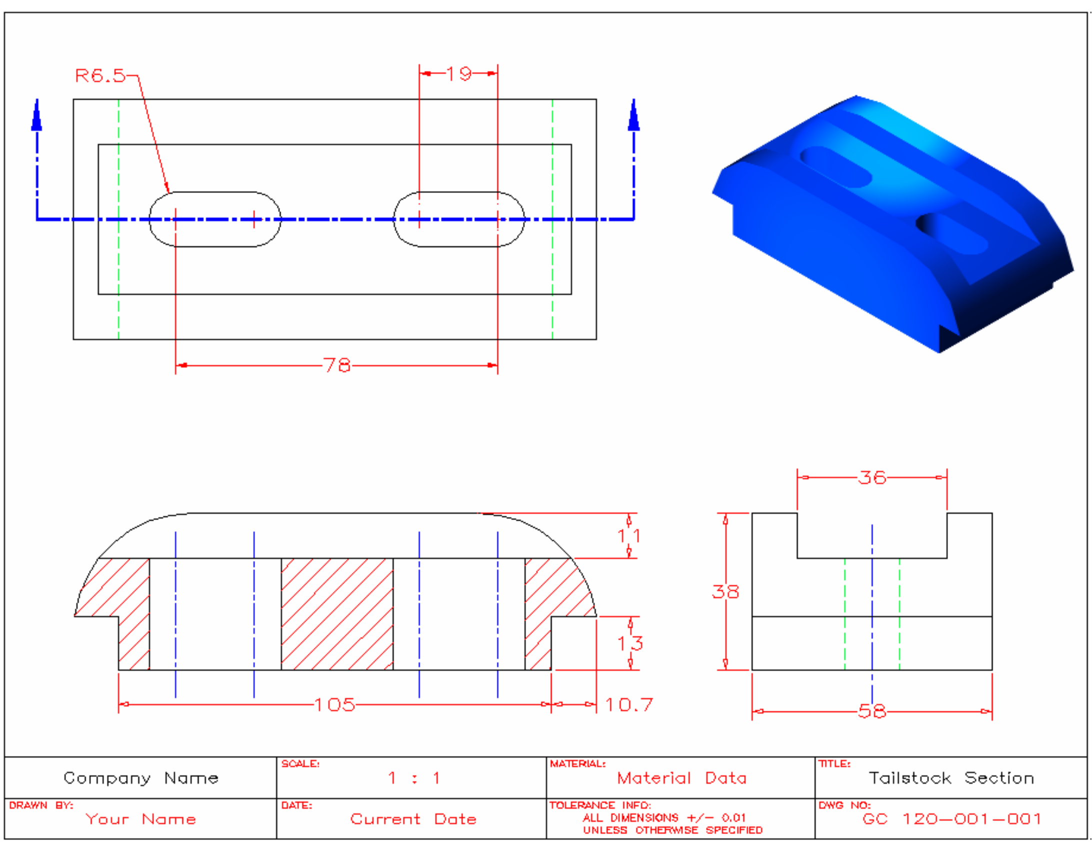
DRAWING FULL SECTION VIEWS

SCENARIO: As a junior engineer in the engineering department of a local company your task is to make sense of sketches provided by the senior designers of the company and produce specific section drawings complete with Metric dimensions at 1:1 scale, for the manufacture of a Tailstock section.

Problem instructions: Draw the part in CAD.
Answer the questions below, which relate to the 3-D machined part of the TAILSTOCK.DWG section.

Student questions to reflect on and new learning issues:

In which typical views can you place a section?
What is a section view used to describe?
Are there sufficient dimensions to describe the part below?
In the top-view below why do the arrows on the section cut line point away from the viewer?
In the front-view, what is the name of the section view shown?
The pictorial-view is a rendered view, is this required, or is a simple pictorial sufficient?
Is the right-side view required, or is it redundant?
What is the name of the hatch pattern used in the front section view?



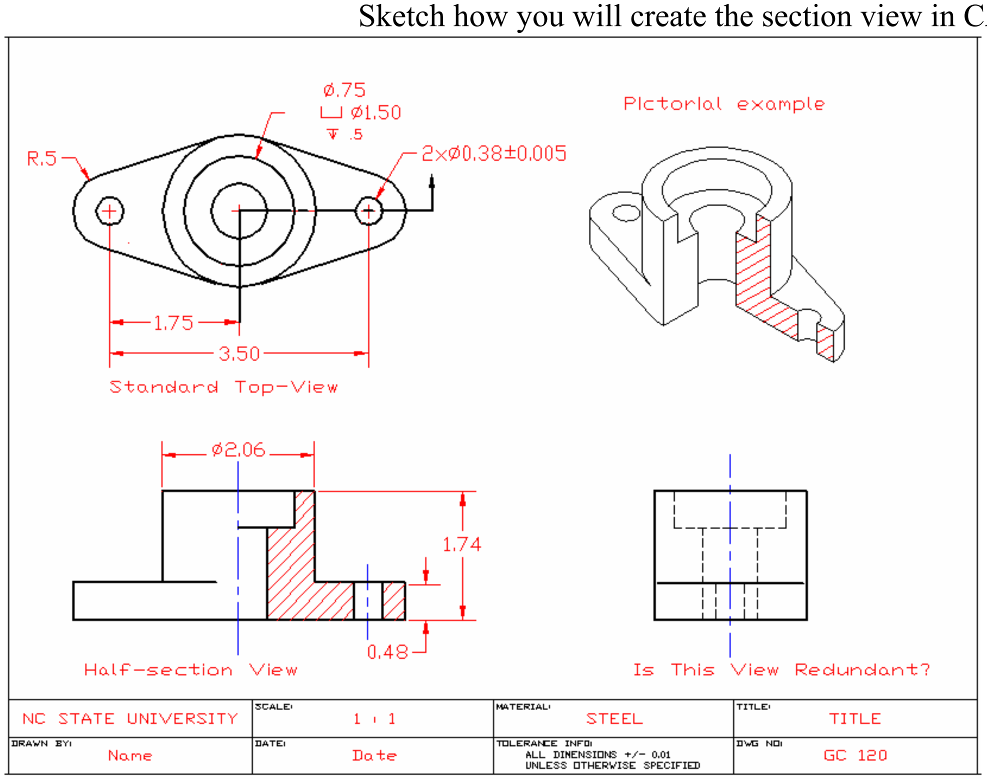
WEEK 9
DRAWING HALF-SECTION VIEWS

SCENARIO: As engineering intern your job to create drawings for the machinist and determine the dimensions necessary for the manufacture of a bearing part design. The engineer asks you to dimension, tolerance and section the part as a half-section.

Problem instructions: Do NOT draw this part to these non-metric dimensions. Answer the questions below, which relate to the BEARING CLAMP.DWG section.

Student questions to reflect on and new learning issues:

In which typical views can you place a section?
What is a section view used to describe?
In special situations can a section view be hatched in a pictorial view?
In the top-view, to what do the dimensions of .75, 1.5, and .75 refer?
In the front-view, what is the correct name of the section view shown?
In the front view, why do the left and right views appear different about the centerline?
In the pictorial-view, why does the hatching to the two cutting planes point toward the center?
Is the right-side view required, or is it redundant?
In the front view, to what does the 2.06 dimension refer? Why is it placed in this view?
What is the name of the hatch pattern used for section views?
Sketch how you will create the section view in CAD?

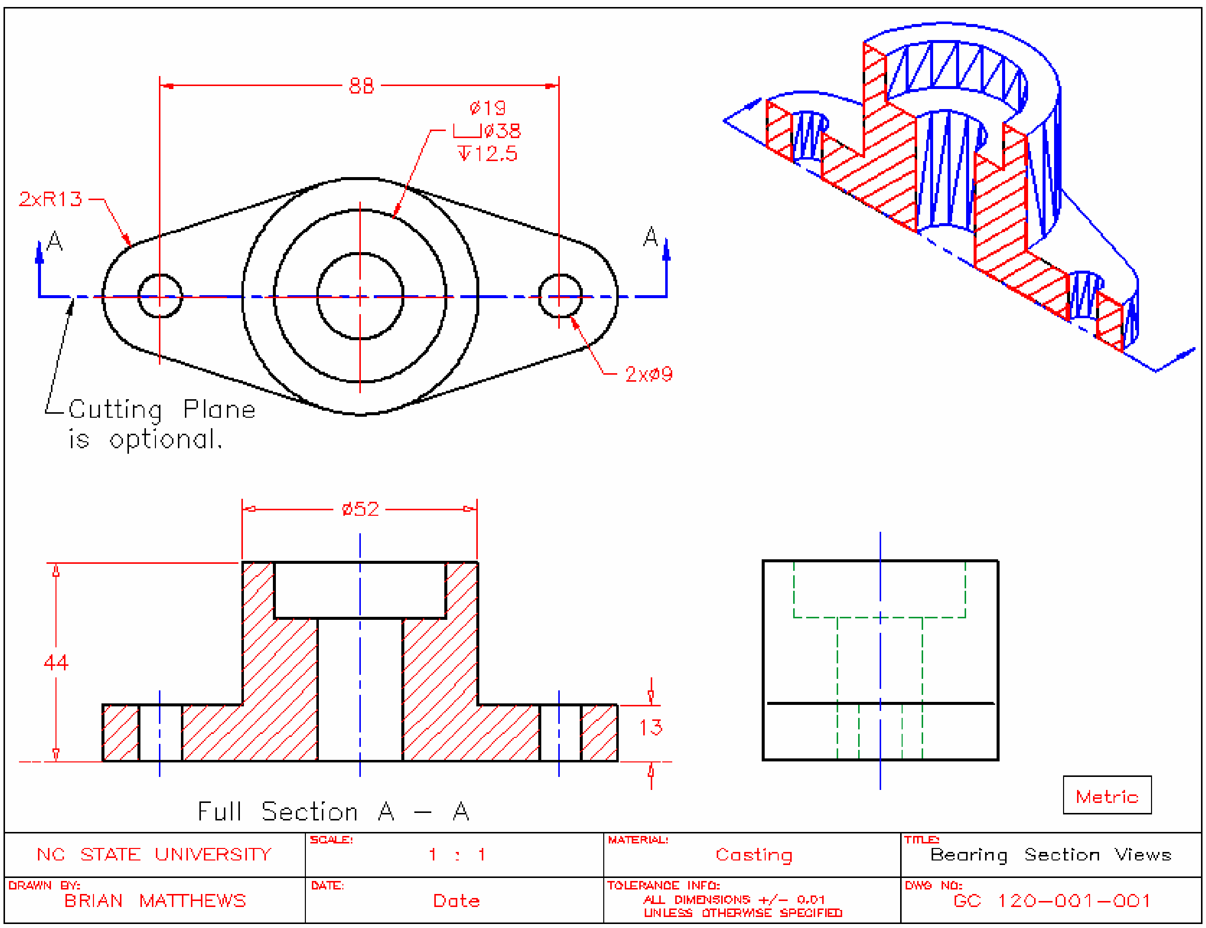


WEEK 9
DRAWING SECTION VIEWS

SCENARIO: As engineering intern your job to create drawings for the machinist and determine the dimensions necessary for the manufacture of a bearing part design. The engineer asks you to dimension, tolerance and section the part as a full-section.

Problem instructions: Draw the part in CAD.
(a) Produce a full-section of the drawing.
(b) Place dimensions on the detail drawing.
(c) Place counterbore dimensions on the simple part.
(d) Are any of the views shown below superfluous. If so, why and which one?

Student questions to reflect on and new learning issues:
What is a tolerance and what is its purpose?
The large bored hole is to have a F8/h7 fit with the shaft. What is F8/h7 fit?
Two holes that accept the hex head cap screws have a H9/d9 fit. What is H9/d9 fit?
The location dimensions for all holes could be basic dimensions. What are basic dimensions? Add the necessary notes (fillets and rounds, SI or metric, etc).

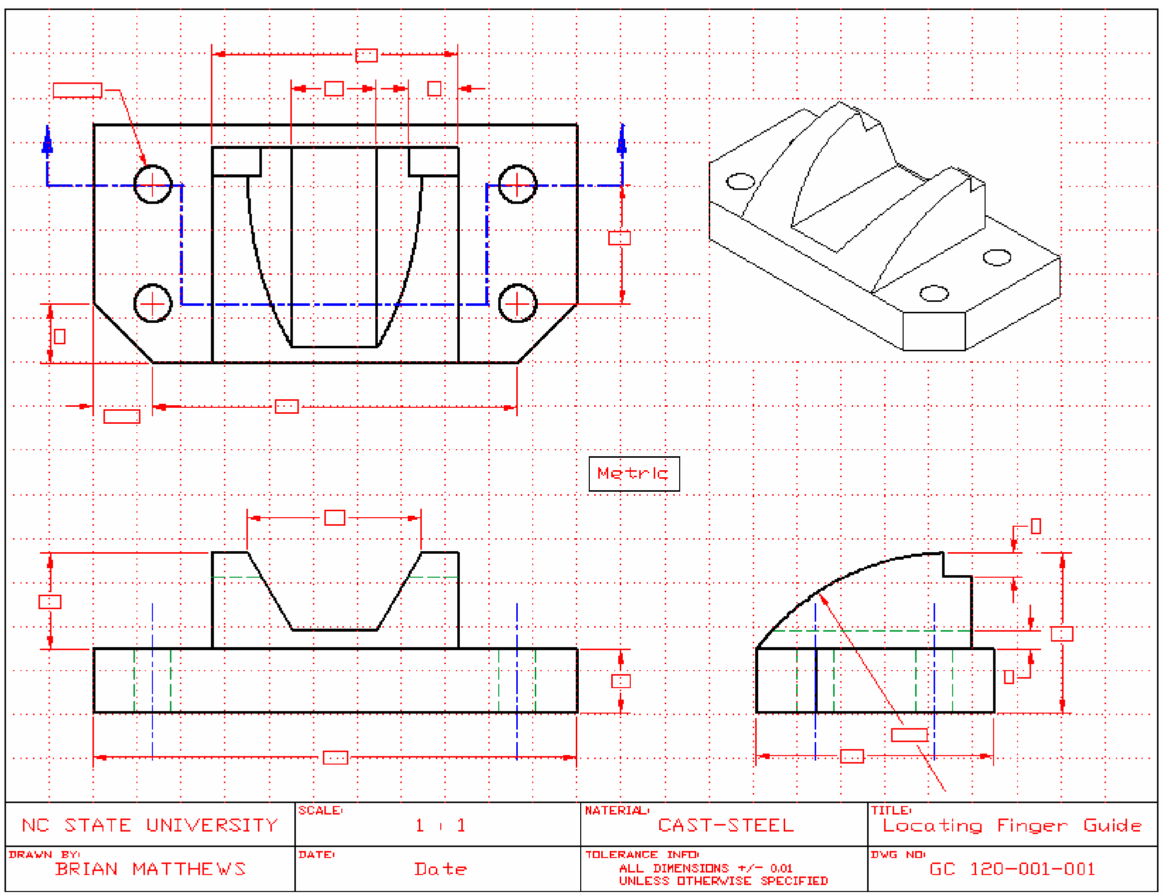


WEEK 10
GEOMETRIC DIMENSIONING AND SECTION – PROBLEM

SCENARIO: The Locating Finger Guide has to be machined for a client and the machinist requires working blueprints including an offset section view complete with dimensions for the part.

As an engineering intern your job is to determine the ANSI dimensions necessary for the manufacture of the Locating Finger Guide part design. A paper drawing is provided but not dimensioned.

Locating Finger Guide Drawing Instructions: Create and dimension the Locating Finger Guide drawing, and compare to the finished result. Dimension the drawing in the locations shown.



WEEK 10

AUXILIARY PROJECTION PROBLEM

Auxiliary views problem instructions:
SCENARIO: The company engineer needs you to setup standard views, dimension the part and produce an auxiliary view. The application view of how the SKULLY clamp fits onto its mating part is shown below.

The senior engineer expects you to:
(a) Produce standard views, plus an auxiliary view of the drawing.
(b) Place location, size and overall dimensions on the simple part – to ANSI standards.
(c) Place tolerance dimensions on the standard and auxiliary views of the detail drawing per the tolerance specifications given at the bottom of the page.

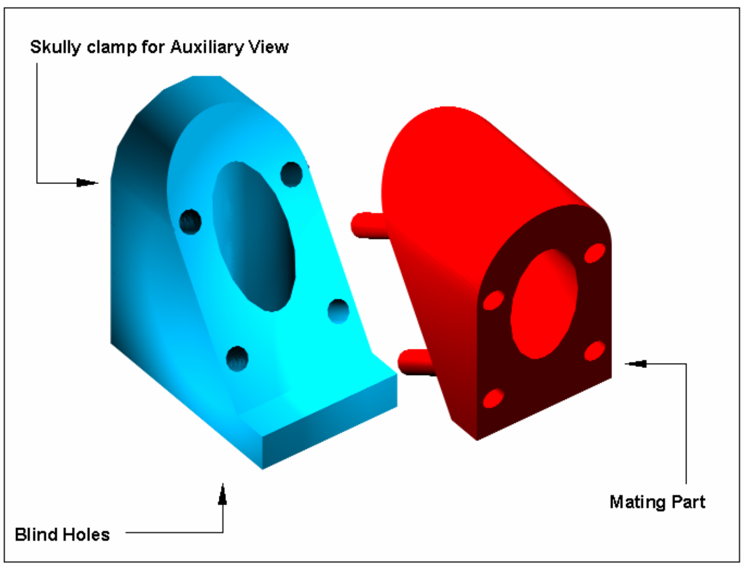


Figure 1: The sketch shows the SKULLY within the overall shaft and assembly.

WEEK 10

AUXILIARY PROJECTION – PROBLEM

SCENARIO: Auxiliary Views As an engineering graphics consultant your job is to take create an auxiliary view of the Skully clamp and determine the dimensions and views necessary for the manufacture of the clamp. You are provided with a drawing file (SKULLY.DWG – located in the GC120-001 locker).

Student questions to reflect on and new learning issues:

Why does this part need an auxiliary view in addition to the standard views?

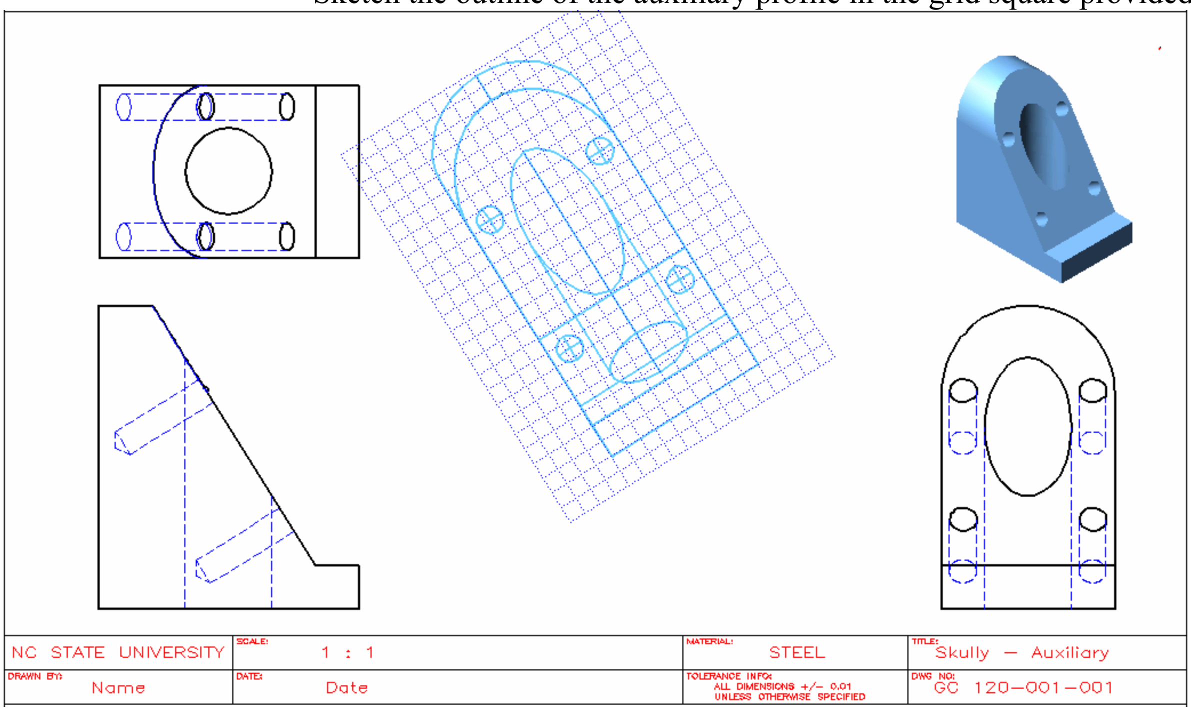
Indicate the large bored hole is to have a F8/h7 fit with the sister hole of the mating part.

Four blind holes that accept the hex head cap screws have a H9/d9 fit with the locating screws.

Place the location dimensions for all holes as basic dimensions. What is a basic dimension?

Add the necessary notes (fillets and rounds, metric, etc).

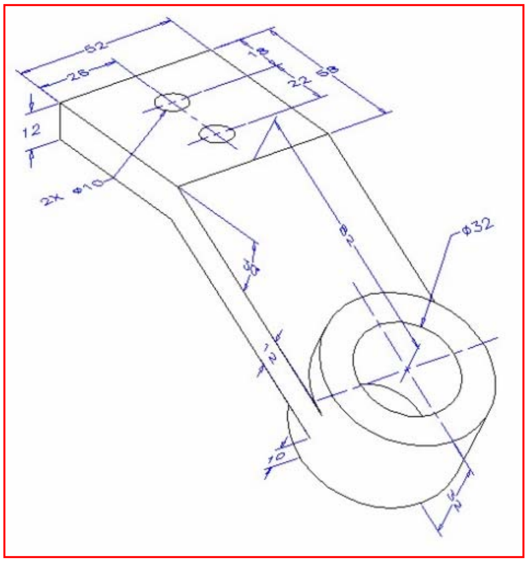
Sketch the outline of the auxiliary profile in the grid square provided.



WEEK 10

AUXILIARY PROJECTION PROBLEM

SCENARIO: As an engineering graphics intern your job is to take specifications provided by senior designers and determine the dimensions and views necessary for the manufacture of an Offset Bearing clamp. Create the part and document all views - as below.



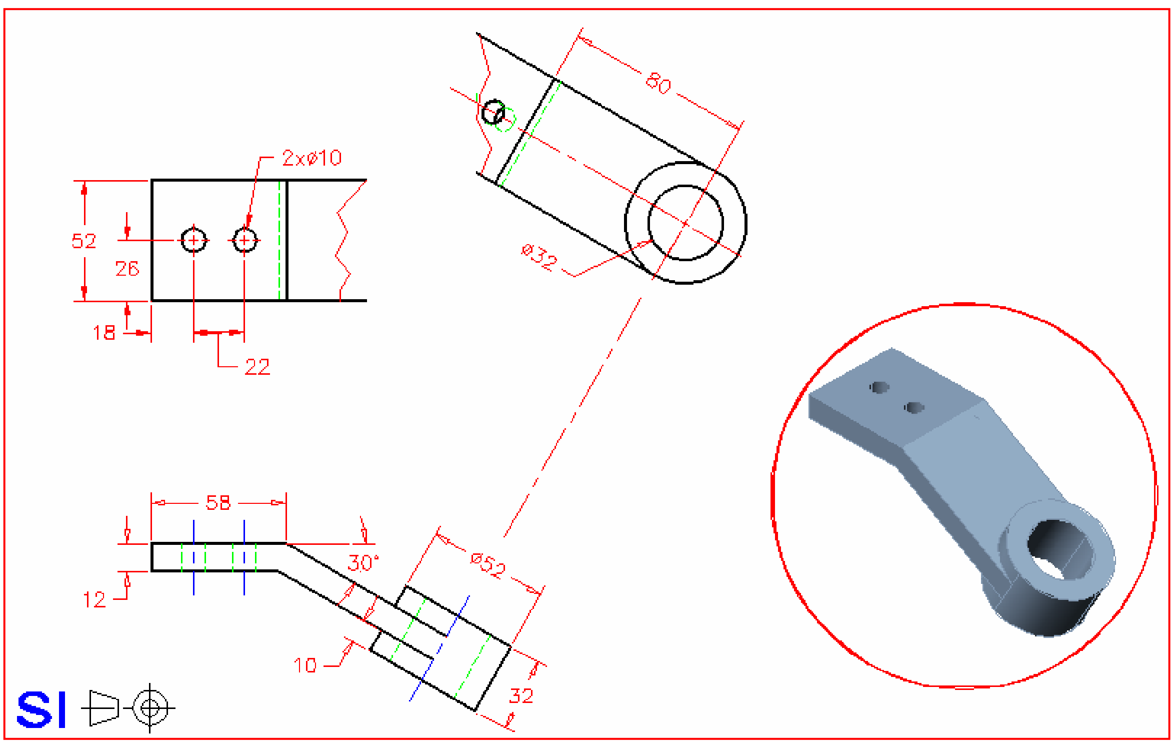
Problem instructions:

The company needs you to setup standard views, dimension the part and produce an auxiliary view. You are expected to:

(a) Produce standard views, plus an auxiliary view of the drawing.

(b) Place location, size and overall dimensions on the simple part – to ANSI standards.

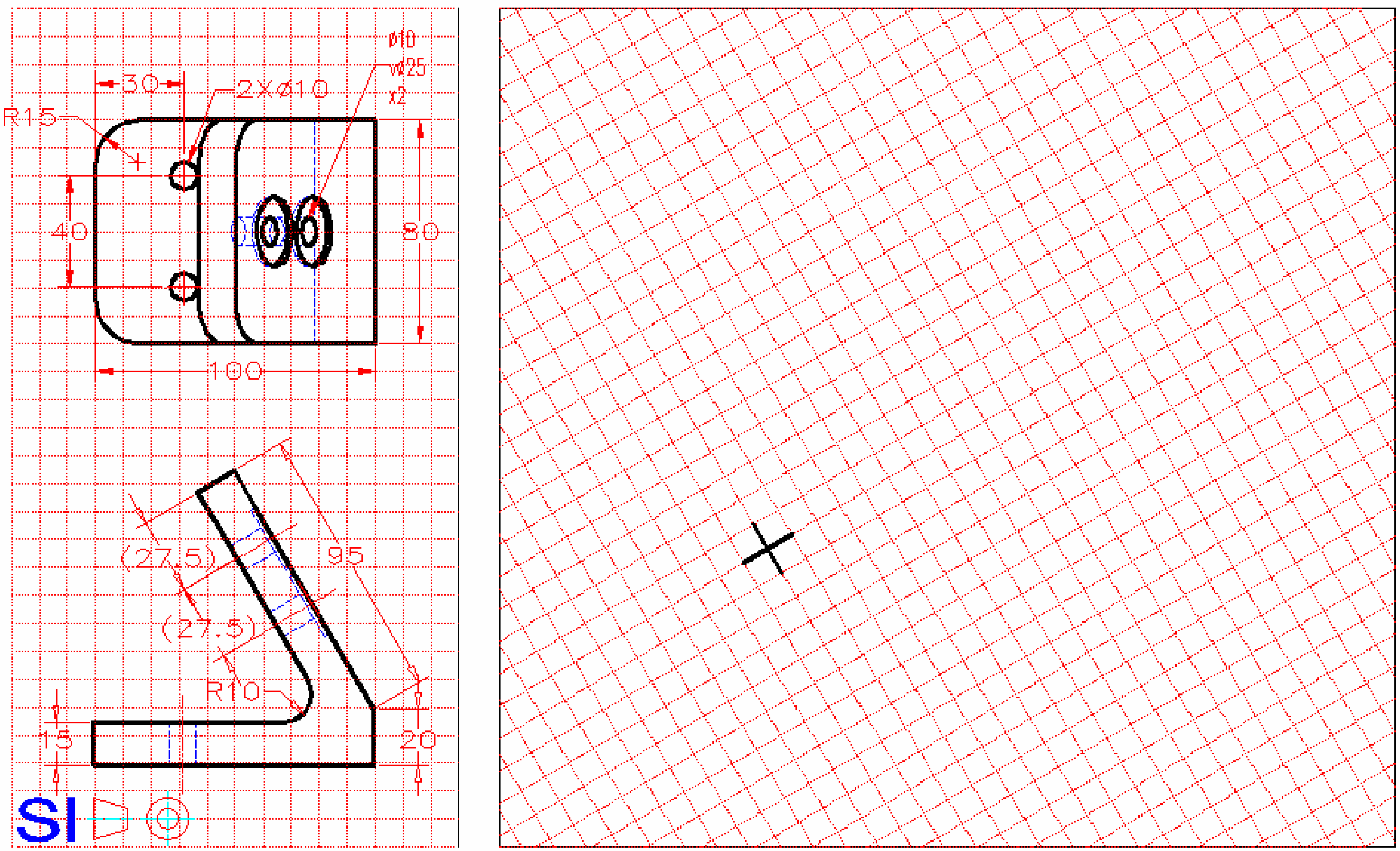
(c) Place tolerance dimensions on the standard and auxiliary views of the detail drawing per the tolerance specifications given at the bottom of the page.



The large bored hole is to have a F8/h7 fit with the sister hole of the mating part.

Two blind holes for the hex head cap screws have a H9/d9 fit with the locating screws.

NEATLY SKETCH THE AUXILIARY VIEW OF THE INCLINED PLANE
USE THE SAME METRIC SCALE AS SHOWN – SHOW ALL CONSTRUCTION.
DIMENSION AND LABEL THE DRAWING VIEWS/PLANES
CAN YOU VISUALIZE THE STEPS TO PRODUCE THE PART IN CAD



DRAWN BY:		TITLE: AUXILIARY VIEW	Rev. 2002
COURSE:	SECTION:	SCALE: 1:1	DATE: MARCH 2002

WEEK 12 TO WEEK 14
EXAMPLE OF FINAL PROJECT

Problem instructions: Draw all the parts in CAD.
Answer the questions below, which relate to the Air Cylinder Assembly.

Student questions to reflect on and new learning issues:

In the upper left corner – what is the purpose of the list, and what is its engineering term? Throughout the drawing – what are the purpose of the bubbles and numbers within them?

In the upper view of the Air Cylinder – what is the drawing termed?

In the upper view – what is the purpose of the lines connecting the bolts to the holes?

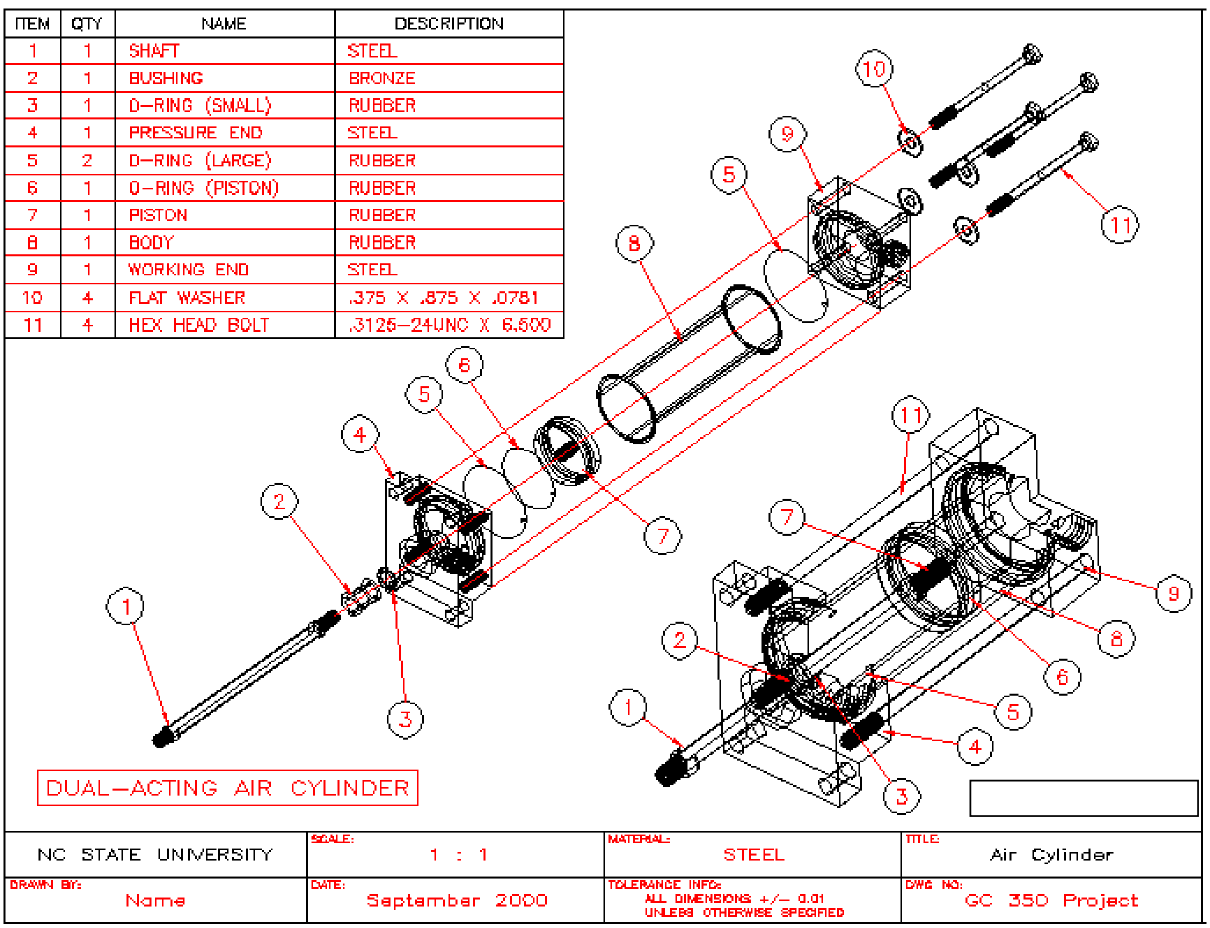
In the upper view – why are all the parts not connected – what is the purpose of this type of drawing?

In the lower right view of the Air Cylinder – what is the drawing called?

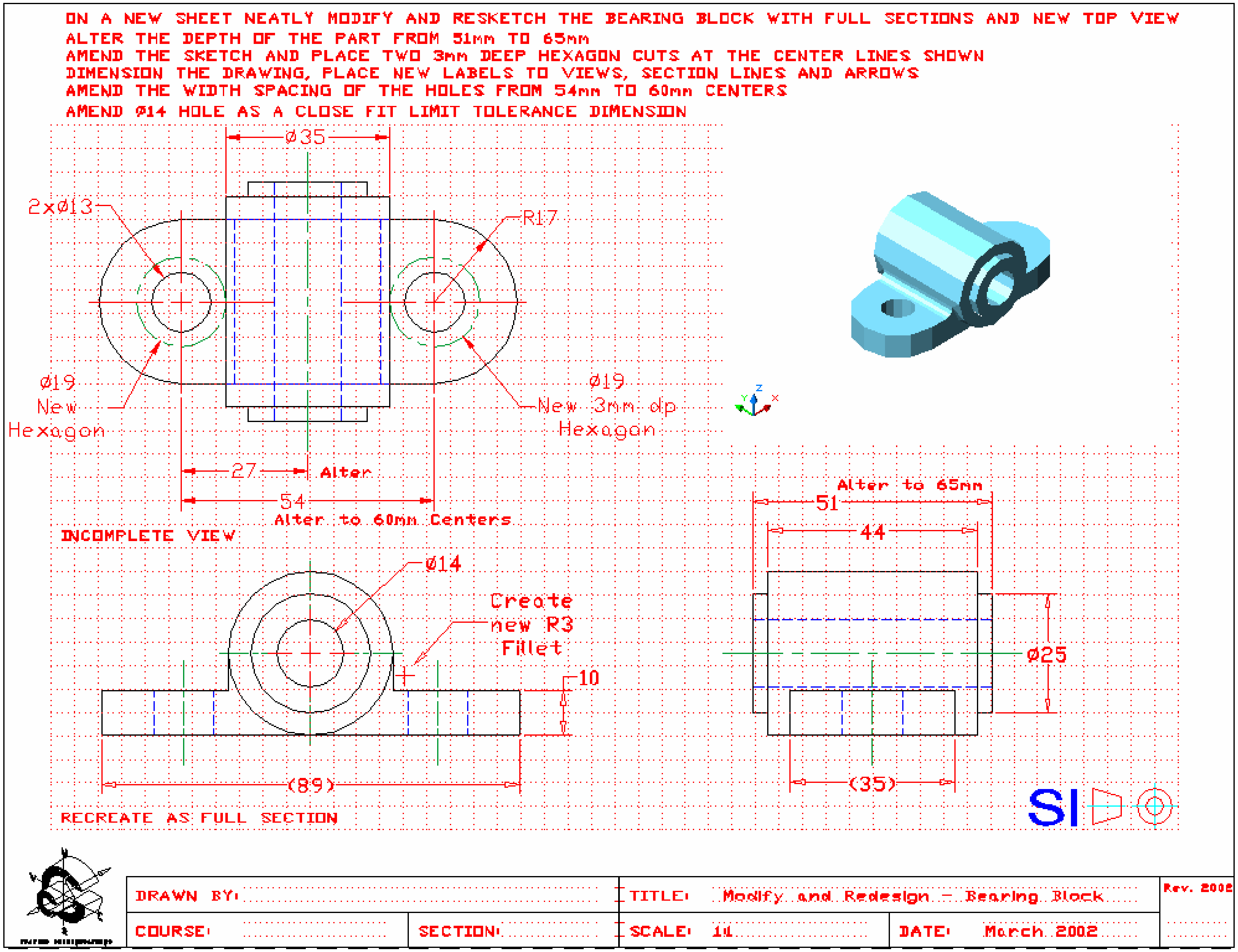
In the lower right view – what does the section view describe?

In the lower right view – what type of section is shown?

Which ANSI hatch pattern is used for a section?

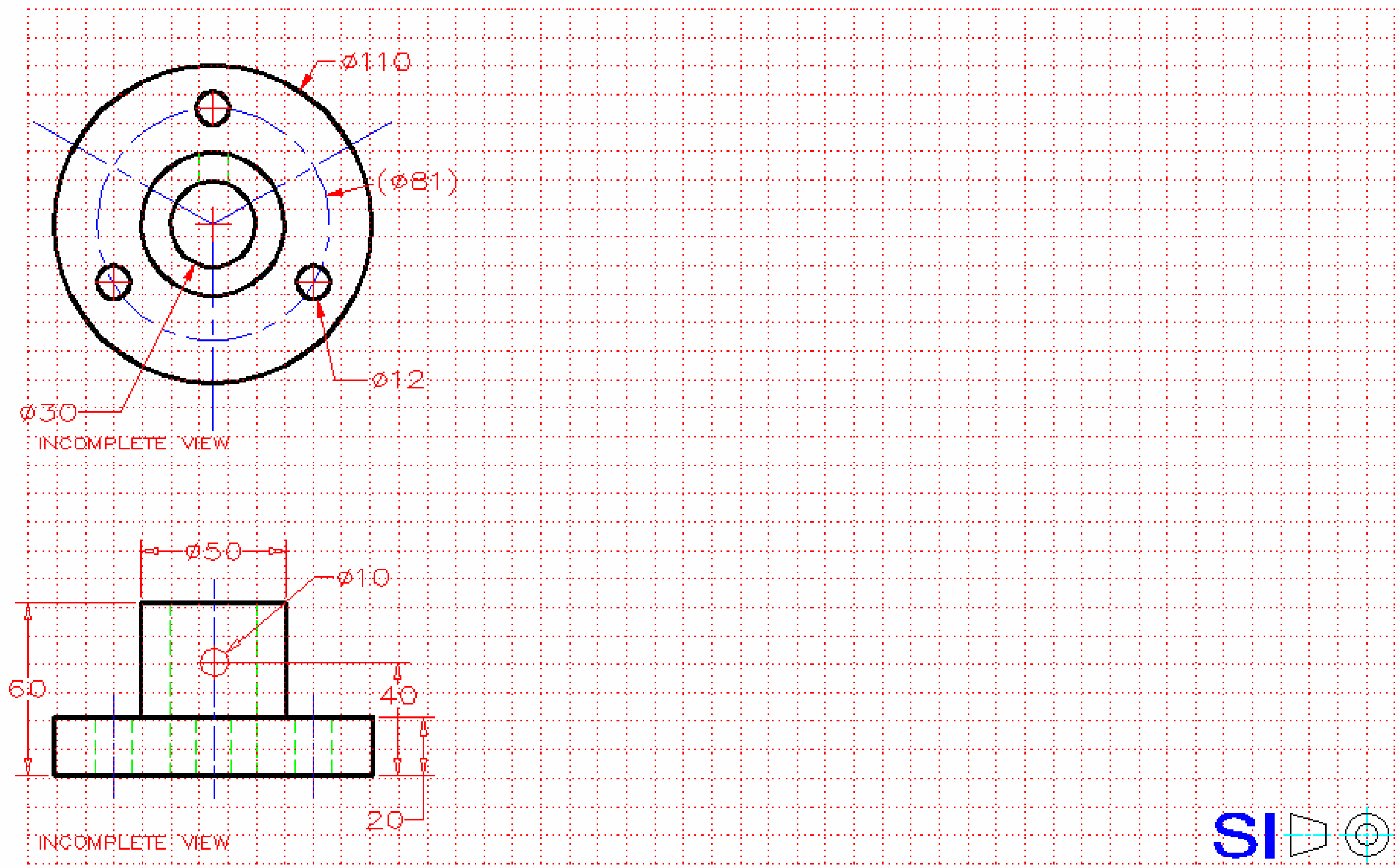


ITEM	QTY	NAME	DESCRIPTION
1	1	SHAFT	STEEL
2	1	BUSHING	BRONZE
3	1	O–RING (SMALL)	RUBBER
4	1	PRESSURE END	STEEL
5	2	O–RING (LARGE)	RUBBER
6	1	O–RING (PISTON)	RUBBER
7	1	PISTON	RUBBER
8	1	BODY	RUBBER
9	1	WORKING END	STEEL
10	4	FLAT WASHER	.375 X .875 X .0781
11	4	HEX HEAD BOLT	.3125–24UNC X 6.500


ON A NEW SHEET NEATLY MODIFY AND RESKETCH THE BEARING BLOCK WITH FULL SECTIONS AND NEW TOP VIEW
ALTER THE DEPTH OF THE PART FROM 51mm TO 65mm
AMEND THE SKETCH AND PLACE TWO 3mm DEEP HEXAGON CUTS AT THE CENTER LINES SHOWN
DIMENSION THE DRAWING, PLACE NEW LABELS TO VIEWS, SECTION LINES AND ARROWS
AMEND THE WIDTH SPACING OF THE HOLES FROM 54mm TO 60mm CENTERS
AMEND Ø14 HOLE AS A CLOSE FIT LIMIT TOLERANCE DIMENSION
Ø35
2xØ13
R17
Ø19
New
Hexagon
Ø19
New 3mm dp
Hexagon
27
Alter
54
Alter to 60mm Centers
INCOMPLETE VIEW
Alter to 65mm
51
44
Ø14
Create
new R3
Fillet
10
Ø25
(89)
(35)
RECREATE AS FULL SECTION
SI
DRAWN BY:
TITLE: Modify and Redesign - Bearing Block
Rev. 2002
COURSE:
SECTION:
SCALE: 1:1
DATE: March 2002

TYPICAL CLASS PROBLEM

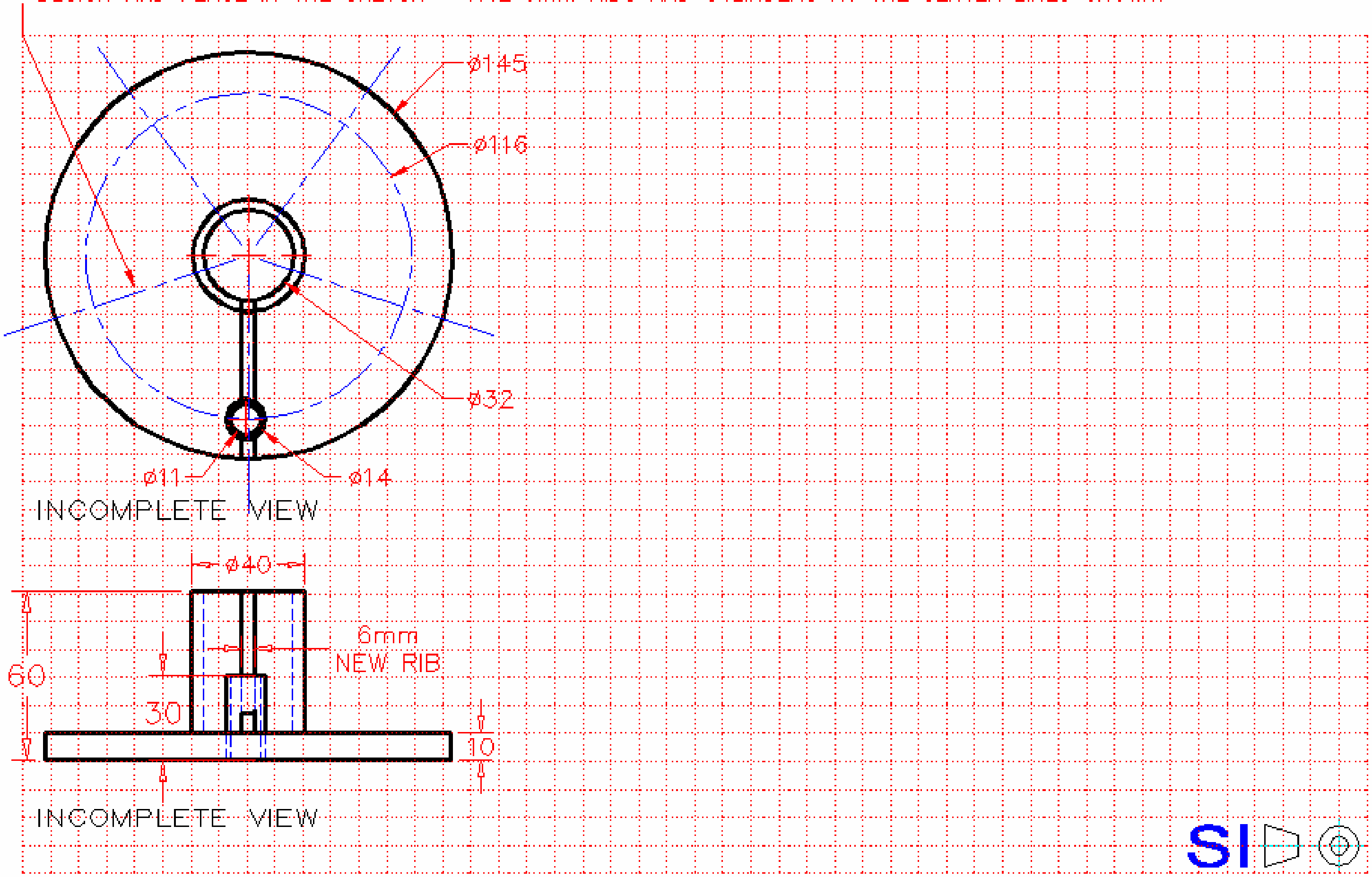
ON THE RIGHT-HAND SIDE NEATLY MODIFY AND SKETCH THE SHAFT RETAINER WITH A FULL SECTION AND TOP VIEW
ADD AND PLACE IN THE SKETCH THREE 10mm RIBS AT THE CENTER LINES SHOWN
DIMENSION THE DRAWING, PLACE LABEL VIEWS & SECTION LINE & ARROWS
USE A METRIC SCALE AND SHOW ALL CONSTRUCTION.



DRAWN BY:		TITLE: Modify and Redesign – Shaft Retainer		Rev. 2002
COURSE:	SECTION:	SCALE: 1:2	DATE: March 2002	

GRAPHIC COMMUNICATIONS

IN THE RIGHT–HAND SPACE NEATLY MODIFY AND RESKETCH THE 3D–SHAFT RETAINER AS A FULL SECTION AND TOP VIEW
USE SAME METRIC SCALE – SHOW CONSTRUCTION LINES AND MISSING RIBS IN A NEW SECTION AND TOP VIEW
DIMENSION THE DRAWING, PLACE LABELS TO VIEWS, SECTION LINE, & ARROWS WHERE NEEDED.
DESIGN AND PLACE IN THE SKETCH – FIVE 6mm RIBS AND CYLINDERS AT THE CENTER LINES SHOWN.



DRAWN BY:		TITLE: Modify and Redesign – 3D–Shaft Retainer	Rev. 2002
COURSE:	SECTION:	SCALE:	DATE: March 2002

WEEK 11
TYPICAL CLASS PROBLEM

APPENDIX D
Skill Test & Post-Test

SKILL TEST - (WEEK TEN)

In the time available – 1.5 hours
Create as much as possible of the part in CAD.

You need to produce two specific views of the V Pulley, (as shown below) complete with dimensions, section & center lines.

Create the profile, revolve the profile 360 degrees - then create the 7mm dia. Hole.

Create the views as shown.

Figure 1: Pictorial view of the V-Pulley

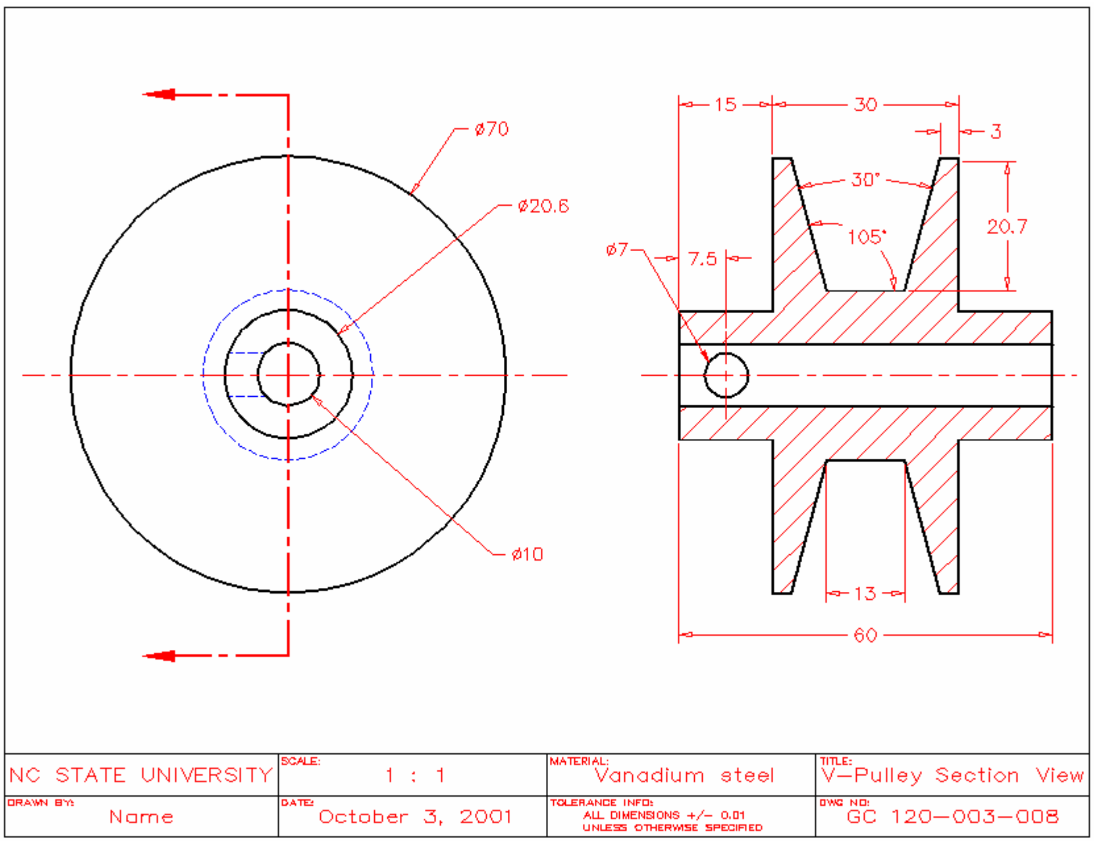


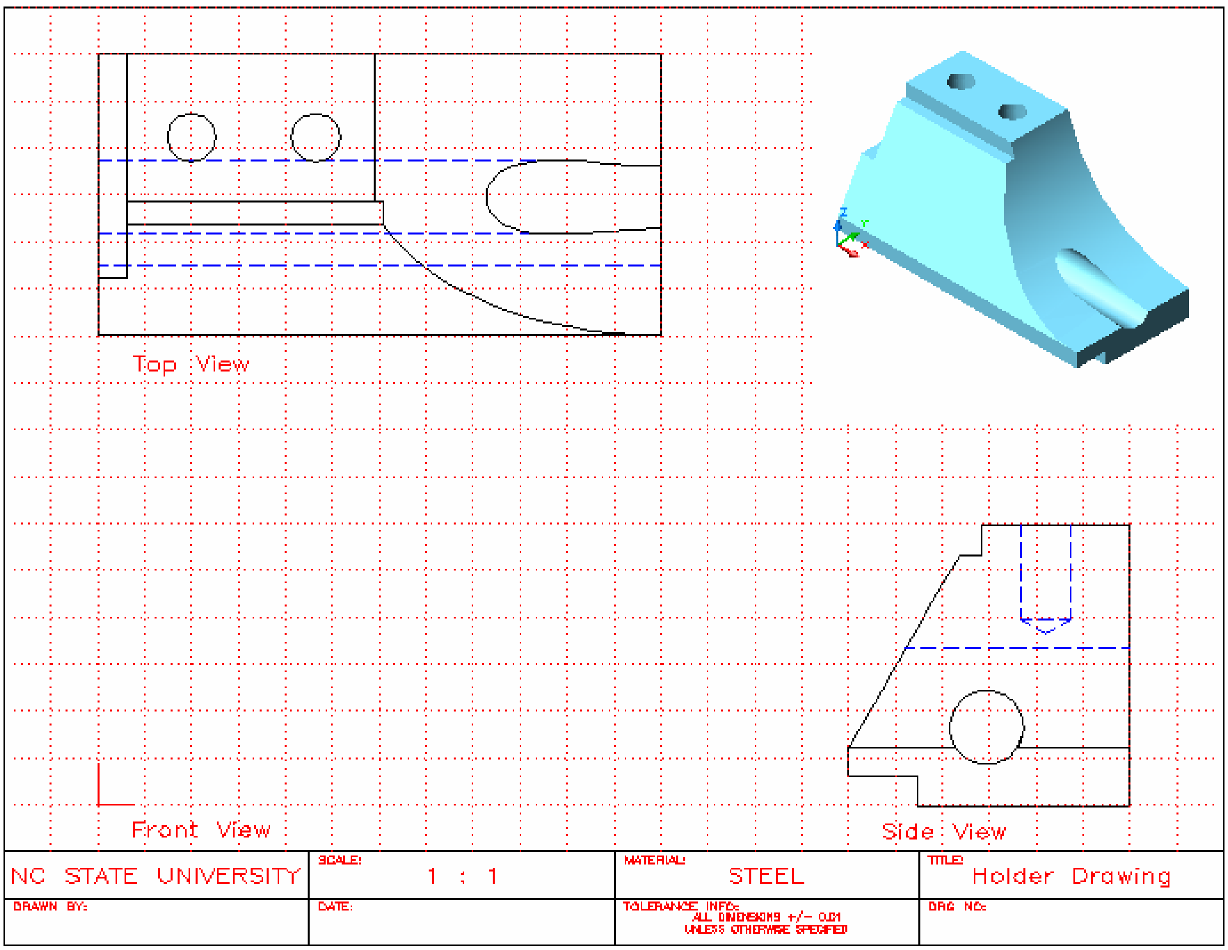
Figure 2: Front and full-section view to show required views.
In the time available – 1.5 hour – Create and document as much as possible of the part in CAD.

POST-TEST-1 (WEEK ELEVEN)

SCENARIO: You have interviewed for a position as a junior engineer at a local engineering company. One of your first tasks is to complete the drawing below, which has a missing view, lines and dimensions. Complete it to the best of your ability.

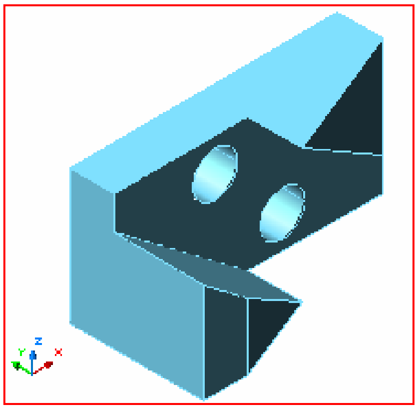
Interview Candidate Instructions: The drawing is missing a Front View. Complete the missing sketch and missing lines, and dimension it to the best of your ability.

Do you need any more information to complete the missing view of the single part?



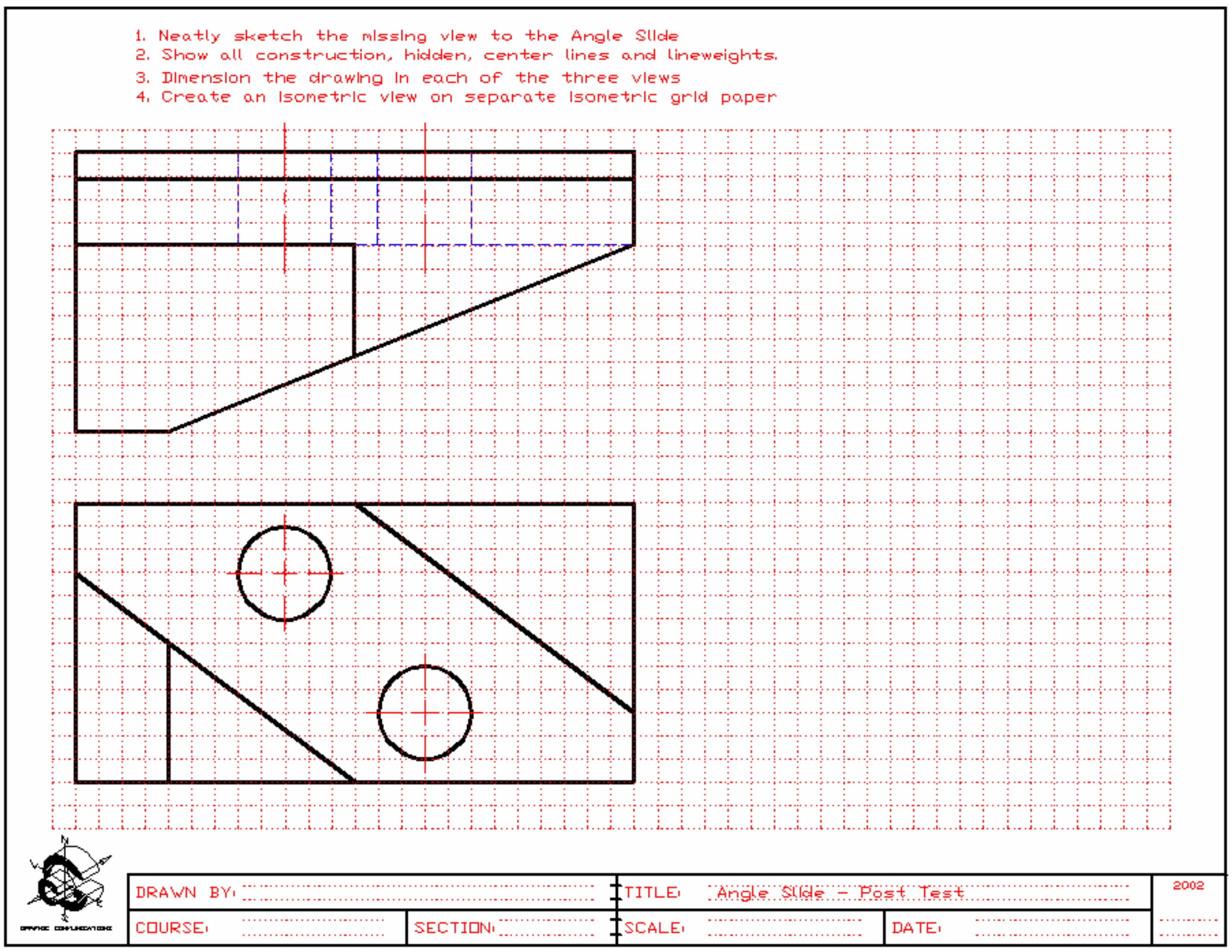
POST-TEST-2 (WEEK ELEVEN)

SCENARIO: You have interviewed for a position as a junior engineer at a local engineering company. One of your first tasks is to complete the drawing below, which is missing some views. Complete it to the best of your ability.



Interview Candidate Instructions: The drawing is missing a Right-Side View and Pictorial View. Complete the missing sketches to the best of your ability.

Do you need any more information to complete the missing views of the single part?



APPENDIX E
MSLQ & Demographic Information Questionnaire

NC STATE UNIVERSITY

MSLQ - WEEK TWELVE

MOTIVATED STRATEGIES FOR LEARNING PROFILE – SHORT VERSION

Demographic Information

Please complete the demographic information below before completing the Motivation Strategies for Learning Profile. The information is used to benchmark your data against other respondents. ALL RESULTS ARE CONFIDENTIAL.

(This data is for research purposes only at NCSU. There are no right or wrong answers.)

THIS IS NOT A TEST. IT IS NOT RELATED IN ANY WAY TO YOUR CLASS GRADE.

Contact Information - CONFIDENTIAL

Your Name ______________________________

Current GC course (Check which apply)

GC 120 - GC 210 - GC 211 - GC 250 - GC 320 - GC 350 - GC 350 - GC 420 - GC 450

High school attended ______________________________

I understand my participation is voluntary in this research: **Yes** ___ **No** ___

Personal - CONFIDENTIAL

(Check which apply)

Age -	Under 20	19-20	21-22	23-24	25-30+
Academic level - Freshman – Sophomore – Junior – Senior – Graduate - PBS					
Gender - Male - Female					
Ethnicity – Caucasian – African American - Asian – Hispanic - Native American - Other					
Are you Left or Right handed	Left handed	Right handed			
Is this your first drawing course	Yes	No			
I have work experience of engineering drawings	Yes	No			

What drawing or shop courses have you taken

(Check which apply)

Art courses	High school	Voc/Tech School	Comm. College	University
Architectural drafting	High school	Voc/Tech School	Comm. College	University
Mechanical drafting	High school	Voc/Tech School	Comm. College	University
Technology education	High school	Voc/Tech School	Comm. College	University
Shop classes	High school	Voc/Tech School	Comm. College	University
Scientific visualization	High school	Voc/Tech School	Comm. College	University

Descriptive geometry	High school	Voc/Tech School	Comm. College	University
Blueprint reading	High school	Voc/Tech School	Comm. College	University

Reasons for taking this class - CONFIDENTIAL (Check which apply)		
a. It fulfills distribution requirement	Yes	No
b. The content seems interesting	Yes	No
c. It is required of all students at college	Yes	No
d. It will be useful to me in other courses	Yes	No
e. It's an easy or required elective	Yes	No
f. It will help improve my academic skills	Yes	No
g. It's a required course for my major (program)	Yes	No
h. It was recommended by a friend	Yes	No
i. It was recommended by a counselor	Yes	No
j. It will improve my career prospects	Yes	No
k. It fits into my schedule	Yes	No
l. This is my first GC course	Yes	No

Motivated Strategies for Learning profile

Directions:

The following questions ask about your motivation for and attitudes about this class.

Remember there are NO right or wrong answers - just answer as accurately as possible.

Use the scale below to answer the questions.

If a statement is very true of you, choose 7; if you think a statement is not true, choose 1.

If the answer is more or less true, choose a number between 1 and 7.

MOTIVATED STRATEGIES QUESTIONNAIRE – Short Version
The MSLQ cannot be shown due to copyright by Pintrich, et al. (1993).
The test is available from Pintrich, P. R., Smith, D. A., Garcia, T. G. & McKeachie, W. J. (1991). Motivated Strategies Learning Questionnaire. Center for Research to Improve Post secondary Teaching and Learning (NCRIPTAL). University of Michigan.

Additional Information attached to MSLQ

Please complete the additional information form below. This information is used for research purposes to determine the relationship between personality and other criteria. Your responses are optional in this section but are greatly appreciated. Thank you for your time and input.

How do you learn best:

Please answer the following questions as they apply to you.

Directions: Please place a "check mark" beside each statement that applies to you.

1. I learn best by seeing through pictures?	Yes	No
2. Have you had any formal CAD training?	Yes	No
3. Have you taken any CAD courses before?	Yes	No
4. Have you ever used modeling software?	Yes	No
5. Did you take a geometry course in high school?	Yes	No
6. Did you ever use any of the following activities?	(Check which applies)	

Lincoln Logs	Legos	Puzzles	Sewing	Model Building	Rubic Cube

General Comments: - CONFIDENTIAL

Take a moment to inform us about anything you would like to share, or what we may have missed. Please be brief.

APPENDIX F
Class Rubrics & Forms

PRE/POST-TEST RUBRIC

Department of Public Instruction – amended drafting rubric for pre- / post-tests.

Concepts and principles of orthographic projection

Views are not aligned or in projection. A view is missing. Numerous lines are misplaced or missing. Precedence of lines not followed.	Features are aligned or correctly projected between the views. Some visible or hidden lines are missing. Precedence of lines followed for most lines.	The views (visible & hidden edges) correctly describe the shape of the object. The views are oriented correctly. Features are aligned or correctly projected between the views. Precedence of lines correctly followed.	Total Points
0-35 points	*36-45 points*	*46-50 points*	

Accuracy and measurement

Numerous errors in measurements. Inappropriate scale used.	Some errors in measurement.	When measured, the sizes of features and their locations closely agree with the given problem. Scale is correct.	Total Points
0-14 points	*15-18 points*	*19-20 points*	

Lineweight technique and neatness

Line weights not uniform. Numerous double lines. Intersections not correctly formed. Construction lines too dark. ANSI standards for thickness and darkness not followed. Missing or improperly placed centerlines.	Some lines are not uniform. Some intersections are not formed correctly. Some lines do not meet ANSI standards. Some intersections for hidden lines not correct. Few misplaced or missing center lines.	Line quality is neat, clean, well-formed, and meets ANSI standards for thickness, darkness, and coding. Correct practices for hidden lines and center lines followed. Center lines are properly placed.	Total Points
0-14 points	*15-18 points*	*19-20 points*	

Layout & balance

The sketch is not centered vertically or horizontally.	The sketch is centered vertically but not horizontally (or horizontally but not vertically).	The sketch is centered within the working space.	Total Points
0 points	*3 points*	*5 points*	

Dimensioning Text and Notes

Text style and size does not meet accepted standards. More than one spelling error.	No more than one spelling error.	Text style and size meets accepted standards. Spelling is correct.	Total Points
0 points	*3 points*	*5 points*	

Total Score 100 __________

PBL CLASS RUBRIC FORM

Group Assessment Chart - Rubric

Class ______________________ Activity or Project ______________________________

Directions. Rate each individual's performance as 4, 3, 2, 1, or 0 on each of the criteria listed below.
(4 = Excellent, 3 = Good, 2 = Fair, 1 = Poor, 0 = Unscore-able)
(See Holistic scoring rubric for complete explanation of this Likert scale)

Student NAMES											
Criteria											
Participates in group work											
Contributes to project success											
Listens to others											
Asks and answers questions											
Stays on task											
Cooperates with others											
Offers positive suggestions											
Exhibits leadership											
Compliments and encourages others											
Overall Rating											

SELF-ASSESSMENT RUBRIC

Name ________________________________ Date _______________

Activity or Project ____

1. What did you do in this activity or project?

____
____
____
____
__

2. What parts of the activity or project did you do well?

____
____
____
____
__

3. What could you do better next time to improve your work?

____
____
____
____
__

4. What did you learn from this activity or project?

____
____
____
____
__

5. What did you like best about this activity or project?

____
____
____
____
__

PEER-ASSESSMENT RUBRIC

Name ___________________________________ Date ________________

Activity or Project ____

1. What did your classmate do in this activity or project?

2. If you worked with your classmate on this activity, indicate what parts you did.

3. What was the best thing your classmate did?

4. How would you rate your classmate's work? (In confidence)
   (4 = Excellent, 3 = Good, 2 = Fair, 1 = Poor, 0 = Needs Improvement)

5. What suggestions would you make to help your classmate do better in future?

HOLISTIC LIKERT SCALE RUBRIC

CATEGORY 4: EXCELLENT

The student completes all the important components of the task and communicates ideas clearly.

The student demonstrates in-depth understanding of the relevant concepts and/or processes

The student chooses (where appropriate), more efficient and/or sophisticated processes.

The student chooses (where appropriate), to offer insightful interpretations or extensions (generalizations, applications, analogies).

CATEGORY 3: GOOD

The student chooses (where appropriate) to complete most of the important components of the task and to communicate clearly.

The response demonstrates an understanding of major concepts even though the student overlooks or misunderstands some less important ideas or concepts.

CATEGORY 2: FAIR

The student chooses (where appropriate) to complete some important components of the task and communicate those clearly.

Gaps in the student's conceptual understanding are evident.

CATEGORY 1: POOR

The student chooses (where appropriate) shows minimum understanding.

The student completes only a small portion of the required task.

The student is unable to generate strategy or the answer may display only recall effect.

The student's answer lacks clear communication.

The student's answer may be totally incorrect or irrelevant.

CATEGORY 0: UNSCOREABLE

The student is blank or has no response.

The student's answer is completely wrong or irrelevant.

The student does not participate in any group discussions.

The student does not participate in any work or tasks.

OVERALL-ASSESSMENT GRADE RUBRIC FORM

Name ____________________________________ Date ________________

Activity or Project ____

Assessment Measures		Scoring Levels			Score		Date		Comment
Performance								
Processes								
Comprehension								
Other:								
Final Grade								

Participation Rubric Form

GC120 PBL Participation Rubric	5-point Likert Scale					Group No.		Weekly Topic Notes: Date:
Name	0	1	2	3	4			

GC120 Classroom & desk layout of groups					
Group 1		Group 3		Group 5	
Group2		Group 4		Group 6	

APPENDIX G
GC 120 Course Syllabus

COURSE SYLLABUS

GC 120 - Foundations of Graphics
Revised for fall 2002

INSTRUCTOR: Brian Matthews Phone: 919-515-1751
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COURSE DESCRIPTION:

Foundations of Graphics is an introductory course providing orientation to the language of engineering graphics for students majoring in any field. The course is designed to help students develop and refine their ability to use this universal technical language. Emphasis will be placed on: (1) Selection of the appropriate methods and tools; (2) Enhanced visualization of 3-dimensional objects through studies of orthographic projection; and (3) Applied uses of engineering graphics. Also included will be an overview of the emerging field of computer graphics and applied computer aided drafting/design.

OBJECTIVES:

Having completed Foundations of Graphics, students should be able to:

1. Correctly select, use, and maintain the required drawing instruments for this course.
2. Apply the principles of geometric construction and orthographic projection to produce complete, legible, and accurate drawings or sketches of 2 and 3-dimensional objects.
3. Visualize, interpret, and critique orthographic drawings equal in complexity to those experienced in this course.
4. Apply dimensions and notes to multiview drawings in accordance with the practices set forth in the ANSI (American National Standards Institute) standards.
5. Construct the appropriate auxiliary and sectional views necessary to further clarify the interpretation of drawings of 3-dimensional objects.
6. Apply appropriate graphic conventions to drawings as needed to simplify the construction and/or the interpretation of drawings.
7. Describe the organization, function, and operation of an applied computer aided drafting/design system and the integration of engineering graphics into this emerging technology.
8. Demonstrate overall competence with the topics, tools, and concepts covered by developing a set of detailed working drawings or illustrations. Where practical, this exercise may reflect the student's major area of study or interest.

APPENDIX H
GC 211 - Course Outline & Syllabus

GC211 Course Outline & Class Syllabus WebPage

Week-by-week Control Group Procedure *nate_hartman@ncsu.edu*

Date	**Topic**	**Reading Assignment** **Homework/Laboratory**
Week 1 August 19	**Orientation** Importance of Graphics in the Design Process Future trends Standards & Conventions **Assignment:** Test your Unity login in Poe 414 before the next class. In your sketchbook, produce (2) pictorial sketches of a manufactured object.	Bertoline/Wiebe Chapter 1: 1.1-1.5, 1.11 Answer the following *Questions for Review*: page 59: 1-10. • Read Syllabus • Email Assignment. Send me an email with a brief statement describing your goals for this course (why are you taking it, what do you hope to learn, etc.). nate_hartman@ncsu.edu • Buy the required materials for the course (textbook, voucher, sketchpad, calipers, pencil and eraser).
Week 1 August 21	**Introduction to SolidWorks - Lab 1** Open an existing Part, Drawing and Assembly and show how they are all linked. Model simple parts (widgets). Emphasize modeling procedure (select plane, sketch profile, create feature). **Assignment:** Finish modeling problems from the back of Bertoline/Wiebe: Chapter 6, pages 364-369: 5, 8, 22, 46, and 60.	Online Constraint-based Modeling Tutorial Bring textbook to class. • Work on problems from the back of Bertoline/Wiebe: Chapter 6, pages 364-369: 5, 8, 22, 46, and 60.
Week 2 August 26	**Sketching** Alphabet of lines. Types of sketches. Sketching technique. Proportions and construction lines.	Bertoline/Wiebe Chapter 1: 1.13-1:18 Answer the following *Questions for Review*: page 59: 13-21.

	Lettering and text. **Assignment:** Revise the pictorial sketches according to feedback. In your sketchbooks, create (2) pictorial sketches of each of the following objects on pages 364-367: 11, 15, 33, 47. Also, sketch (1) pictorial of an object of your choice.	• Two pictorial sketches of manufactured part are due. These are to be completed in your sketchbooks.
Week 2 August 28	**Engineering Design Process** **2D & 3D Geometry** Ideation, Refinement, Implementation. Drawing control & product data management. Shape description. Geometric elements (Figure 3.15). **Assignment:** Sketch the ROD GUIDE (Figure 3.86, p. 183) and identify the geometric relationships present. Plan a modeling procedure for the STOP BASE (Figure 6.111, p. 376). Identify the geometric relationships present for each sketch.	Bertoline/Wiebe Chapters 2 & 3 Answer the following *Questions for Review*: page 123: 1-25. page 176-177: 1-4, 6-10, 16-18. • Solid models of problems from the back of Bertoline/Wiebe: Chapter 6, pages 364-369: 5, 8, 22, 46, and 60 are due. Copy the files to the homework directory. • (2) pictorial sketches of each of the following objects on pages 364-367: 11, 15, 33, 47 due. Also, pictorial of an object of your choice due.
September 2	LABOR DAY HOLIDAY	Review Readings
Week 3 September 4	**SolidWorks Lab 2 - Constraints/Relations and Dimensions** Create simple models in SolidWorks, but models are required to be fully constrained. **Assignment:** Finish modeling the ROD GUIDE and the STOP BASE.	Bertoline/Wiebe Chapter 5 Answer the following *Questions for Review*: page 283: 1-12. • Sketch of the ROD GUIDE (Figure 3.86, p. 183) due. Modeling procedure for the STOP BASE (Figure 6.111, p. 376) due.
Week 3	**2D & 3D Geometry**	

September 9	**3D Solid Modeling** Model definition. Primitive, CSG, B-Rep, Hybrid, Constraint-based modeling. Feature analysis & definition. Editing features. **Assignment:** Modeling procedures of the TOOL HOLDER (Figure 6.112, page 376) and the BEARING BLOCK (Figure 6.117, page 377) due next time.	Bertoline/Wiebe Chapters 3 & 5 • Work on Modeling procedures of the TOOL HOLDER (Figure 6.112, page 376) and the BEARING BLOCK (Figure 6.117, page 377)
Week 3 September 11	**Projection Theory** Projection methods. Multiview projection planes. Six principal views. Multiview sketches. View selection. Types of pictorials. Sketching pictorials. **Assignment:** Finish ORT 040, ISO 020 & ISO 030.	Bertoline/Wiebe Chapters 6 & 7 • Solid models of the ROD GUIDE and the STOP BASE due. • Furniture Design Project: (6) designs due.
Week 4 September 16	**SolidWorks Lab 3** Revolving Profiles Fillets and Chamfers **Assignment:** Model the HEAVY DUTY V-PULLEY (Figure 8.64, page 474).	Bertoline/Wiebe Chapter 5 SolidWorks *Getting Started Manual*: Chapter 7 (Revolve and Sweep Features) • ORT 040, ISO 020 & ISO 030 due.
Week 4 September 18	**Multiviews and Pictorials** Sketching circles and ellipses. Sketching multiviews and pictorials with cylindrical features. **Assignment:** Finish ORT 050 and ISO 040.	Bertoline/Wiebe Chapters 6 & 7 • Work on ORT 050 and ISO 040.
Week 5 September 23	**Multiviews and Pictorials** Inclined and oblique surfaces. **Assignment:** Sketch	Bertoline/Wiebe Chapters 6 & 7 • HEAVY DUTY V-PULLEY (Figure 8.64, page 474) due.

	multiviews and pictorials of problems 18 & 22 on the handout. Multiview and pictorial sketches of problems 15, 16, 21 & 22 will be graded.	• ORT 050 and ISO 040 due.
Week 5 September 25	**SolidWorks Lab 4 - Symmetric Features** Mirroring features and mirroring sketch entities (lines and circles). **Assignment:** Finish the solid model of the BEARING.	Bertoline/Wiebe Chapter 5: Pay close attention to material in section 5.8.6 concerning symmetry. • Steps 3 & 4 of the Furniture Design Project due
Week 6 September 30	**Multiviews & Pictorials** Fillets, rounds, runouts, and cylinder intersections. Reverse engineering. **Assignment:** Study for Midterm.	Bertoline/Wiebe Chapters 6 & 7 • Multiview and pictorial sketches of problems 15, 16, 21 & 22 due.
October 2	**MIDTERM EXAM**	Review Sheet
Week 6 October 7	**SolidWorks Lab 5 - Pattern Features** Rectangular and circular patterns of features and sketch entities. **Assignment:** Finish solid models of the Lego and the PISTON CAP (Problem 2, p. 476).	SolidWorks Getting Started Manual: Chapter 9 (Pattern Features) .
Week 7 October 9	**Dimensioning** Size & location dimensions. Detail dimensioning (dimensioning machined holes). Dimensioning technique. ASME Y14.5M standards. Examine how individual parts function within an assembly	Bertoline/Wiebe Chapter 9: 9.1-9.4 • Work on solid models of Lego and PISTON CAP.

	before dimensioning. **Assignment:** Work on Step 5 of the Furniture Design Project.	
Week 7 October 14	FALL BREAK	Review readings Jot down questions you have about solid modeling in SolidWorks
Week 8 October 16	**Sectional Views** Sectioning basics. Cutting-plane lines. Section line practices. Sectional view types. Conventional practices. CAD techniques. **Assignment:** Finish SEC 010-050.	Bertoline/Wiebe Chapter 8 • Solid models of the Lego and the PISTON CAP (Problem 2, p. 476) due.
Week 8 October 21	**SolidWorks Lab 6 - Introduction to Drawings in SolidWorks** Drawing templates. Tools-Options settings related to dimensions and drawing formats. Inserting views and projecting new views. Inserting model items (dimensions). Editing titleblocks. Modifying and moving dimensions. **Assignment:** Finish drawing of TAILSTOCK CLAMP.	SolidWorks *Getting Started Manual*: Chapter 5 (Drawing Basics) • Step 5 of the Furniture Design Project due
Week 9 October 23	**Metals Laboratory Tour** *Poe 104 (on the first floor near the double elevators).* Machining, Welding, Forging, Sand Casting, Sheet Metal Work.	Review websites concerning materials and processes.

	Assignment: Finish TAILSTOCK CLAMP and SEC 010-050.	
Week 9 October 28	***No Class*** ***Engineering Design Graphics Division of American Society for Engineering Education Midyear Conference***	Review Readings
Week 10 October 30	**Working Drawings, Assemblies** Basic concepts. Working drawings. **Assignment:** Work on Furniture Design Project. **Final Project Requirements**	Bertoline/Wiebe Chapter 10: 10.1-10.2. • SolidWorks drawing of TAILSTOCK CLAMP due.SEC 010-050 due.
Week 10 November 4	**SolidWorks Lab 7 - Assemblies** Assembly constraints (mates). Exploded assemblies. Applying color to individual parts.	SolidWorks *Getting Started Manual*: Chapters 4 (Assembly Basics) & 11 (Assembly Mates)
Week 11 November 6	**Auxiliary Views** **Assignment:** Work on projects.	Bertoline/Wiebe Chapter 4: 4.5-4.6
Week 11 November 11	**SolidWorks Lab 8 - Sweeps, Lofts and Rendering** **Assignment:** Work on projects.	SolidWorks *Getting Started Manual*: Chapter 8 (Loft Features) & Advanced Functionality (Photoworks) Step 6 of the Furniture Design Project due.
November	**Technical Data Presentation** Visualization of analysis data. Data types. Visualizations for one or two independent variables. Visualizations for functional relationships.	Work on final project

	Tools for visualization. Graphic representations beyond CAD. Graphics used for problem-solving and teamwork.	
November	Work on Final Projects	Work on final projects.
November	Thanksgiving Holiday	Study for Exam
November	No more late assignments can be handed in.	All solid models to be finished
December	Final Projects Due	Final Projects Due
December	FINAL EXAM 9:00-12:00am	Study for Exam