# Freshman Engineering Drawing and Visualization at Youngstown State University

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## Introduction

The first year engineering curriculum at Youngstown State University is a two-semester sequence of courses taken by qualified first year students of all engineering majors. Part of this freshman experience involves an exposure to engineering graphics including 2D drafting with AutoCAD and Solid Modeling with Solid Works. One problem encountered in teaching the graphics sequence is the lack of preparation our students have from high school in basic engineering drawing skills. This includes visualizing objects described by traditional three view drawings and understanding basic information typically shown on engineering drawings. This paper outlines the development of a non degree credit course which was instituted to solve this problem.

## Background Information

Entering engineering students typically take a college prep sequence of courses in high school which generally gives at best very little exposure to engineering drawing. In the distant past at Youngstown State we had a non credit course which was used to develop student skills in engineering graphics. This course was required of students who had not completed two years of high school drafting. After completing this non credit course a rigorous advanced course in engineering drawing was taken which developed the necessary background for successful entry into the engineering field. Both courses used drafting instruments and T-Squares.

As we moved into the computer graphics realm, the engineering dean decided that only computer graphics could be maintained in the engineering college; no paper/pencil work was to be continued. At this point the non credit course used to bring under prepared students up to speed was dropped with the logic that the needed background could be developed during the computer graphics portion of the curriculum.

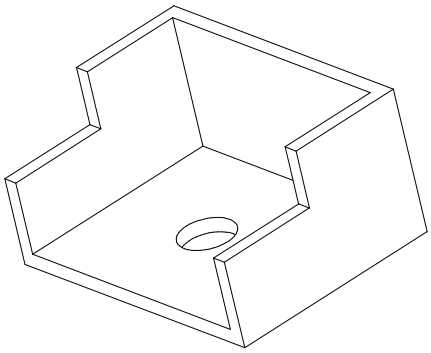
At this point the computer graphics courses tried to teach 2-D drafting with AutoCAD and Solid Modeling with Solid Works. The time allotted was approximately 6 weeks of AutoCAD and 4 weeks of Solid Works. Each week had 5 contact hours of a mix of lecture and lab time in a computer lab with the instructor having a work station and computer projection system. It was very ineffective since with little understanding of traditional 3 view drafting, it is difficult to use the computer to draw something that is not understood. Dimensioning was a complete disaster since the students did not understand proper dimensioning standards and the AutoCAD text just showed how to develop the dimensions, not how and where they should be placed. Similar problems arose with section and auxiliary views. The solid modeling went a bit better as long as an isometric was given to describe the geometry to be developed. In addition design projects were required of the students and to document them required making 3 view drawings. Faculty and students were in a no win situation since the students were not given a proper chance to learn the material and the faculty were placed into a difficult situation with under prepared students trying to achieve a good level of engineering graphics competence.

Faculty began holding after class help session to help students with background deficiencies. Some students took advantage of these sessions, but many did not. As a means of helping with the problem, a 3 contact hour per week, non degree credit, lab session was added. Students took this lab concurrently with the computer graphics course. Students were required to take this course if they could not pass the proficiency test shown in Figure 1. This was a step in the right direction, but two new problems surfaced. First it was difficult to cover the background material quickly enough in the lab before it was needed in the class. Also, the total amount of time in the lab was a bit short for good coverage.

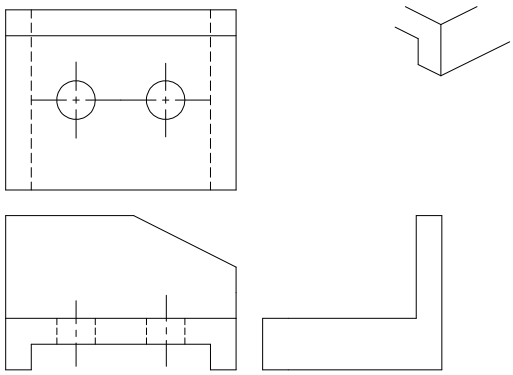
This led to the development of the course ENGR 1555 – Engineering Drawing and Visualization which is the main focus of this paper. This class is given 2 semester hours of credit; however the credit is not applicable to the engineering degree. Only sketching is used to do the work; no instruments or T-squares! The course meets 4 hours per week of combined lab and lecture. It is typically scheduled 4 days per week, 1 hour per day. Students may take the course concurrently with the computer graphics course, but are encouraged to take the course in a semester prior to taking the computer graphics course. Instead of having all freshman take the proficiency exam as in the past, all freshmen engineering students are enrolled in the course, unless they individually ask to take the proficiency exam, again shown in Figure 1. This change in the proficiency exam procedure was instituted since so few students actually passed the exam.

**Youngstown State University**
**College of Engineering and Technology**
**ENGR 1555—Engineering Drawings and Visualization Proficiency Exam**

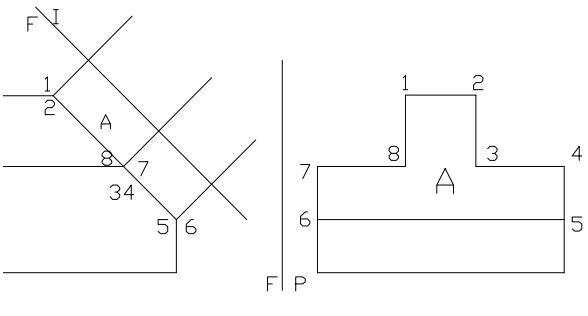
Base
Sketch
front, top
and right
side views



Bracket
Sketch isometric and
complete the views.



Control Block for Fixture
Sketch auxiliary
view of surface A




Roller Support
Draw full
section AA

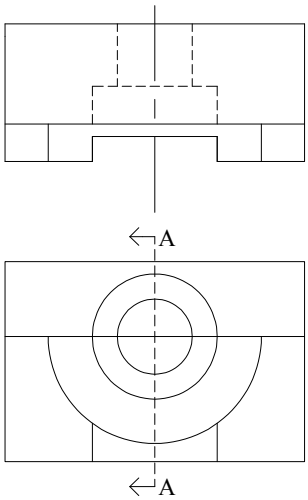



Figure 1. Proficiency Exam

Current Course Structure of Freshman Engineering.

ENGR 1550 Basic Engineering Concepts (3 SH)
The first course in the current sequence at Youngstown State University is ENGR 1550 Basic Engineering Concepts, offered only in the Fall Semester. The three semester hour course is comprised of two lecture hours and three laboratory hours per week. Prerequisite/concurrent requirement for this course is a math course of pre-calculus or higher level.

There are several distinct sub-goals of this first course; however they are all intertwined when focusing on the main goal of successfully transitioning the first year student to becoming part of the YSU engineering community. While presenting and teaching several engineering/technical skills, the course effectively introduces the student to engineering and to the university, and finally helps to develop survival skills needed to be a successful engineering student. Students are introduced to the different engineering majors available via invited speakers and laboratory tours. The engineering design process is introduced and simple designs are accomplished in a group mode where technical report writing is begun. Various laboratory projects are done and the lab assistants are upper level engineering students. For textbooks an electronic book is made from McGraw Hill with topics from Excel, MathCAD, and PowerPoint. Supplemental handout materials are used for other topics.

ENGR 1560 Engineering Computing (3 SH)
The second course in the sequence is ENGR 1560 Engineering Computing. It is offered only in the Spring Semester. The course meets for an equivalent two hours lecture and three hours of lab per week. It is scheduled as a combined lecture/lab course typically three days per week at one and a half hours per day. This class is limited to thirty students and is conducted in a computer lab classroom where each student has a computer. Prerequisite is ENGR 1550 and concurrent Calculus I.

The goal of this course is somewhat different than the ENGR 1550. Most of the students that continue with this second class of the series have decided that they would like to pursue the field of engineering. Therefore, the focus is turned away from introducing the engineering profession and turned more toward imparting important computer skills. It is expected that this class will help the students become somewhat proficient with computer programming, CAD 2D drafting, and CAD Solid Modeling. The computer programming language currently used is Visual Basic which is covered for about six weeks of the course. For CAD 2D drafting, AutoCAD is used and this exposure lasts about five weeks. This is followed by about four weeks of solid modeling using Solid Works. For text books "AutoCAD Companion" by Leach is used along with internally developed handout materials for Visual Basic and Solid Works. There is a minimum of one design project required. More details of these courses can be obtained in Suchora and Pierson, 2004 [1].

ENGR 1555 Engineering Drawing and Visualization (2 SH)
As noted previously, this course meets 1 hour of lecture and 3 hours of lab per week. It is typically scheduled as combined lecture and lab for 1 hour per day 4 days per week. This class is held in an auditorium with a visual presenter and computer connected to a projection system and

students have tables as a work space. Only sketching is used by the instructor and the students to present work. Class size varies with each offering enrolling up to 70 students per class. There is approximately 1 lab assistant per every 25 students. There is no prerequisite and the course does not count towards the engineering degree.

The goal of this course is to develop the students' ability to visualize a part given the traditional 3 view drawing and to understand the standard drafting conventions used in engineering to document engineering designs. The class is conducted by generally beginning each session with a 5 to 15 minute lecture followed by an assignment which is to be done by the end of class. The instructor and lab assistants circulate in the room to assist the students. Homework is returned almost daily to keep the class moving and quizzes are given every two weeks to keep students progress monitored.

A text and combined workbook is used for the course. The current text is "Engineering Graphics Text and Workbook" by Craig and Craig [2]. In order to be able to cover material quickly and have the students focus on the visualization concepts, it was felt that a workbook was essential. The concept of a combined workbook and text was chosen to keep the cost of text books down. Supplemental materials are used in addition to this text for topics we feel are important and are not included in the text in enough detail. This format has worked out well for us.

The class is graded as A, B, C or No Entry to make the class as non threatening as possible. The mix of weighting between homework and exams has evolved since the course was instituted. Initially homework was weighted up to 70% of the grade with the exams only counting 30%. Again this was done to make the course as non threatening as possible. This did not work as some students were able to get help with all the homework and not really learn the material. Our current mix is about 65% weighting on exams and 35% on the homework assignments. A web site used to support a recent offering of the course which includes policies and assignments is located at http://www.eng.ysu.edu/~dhsuchor/ENGR1555.htm

This course is offered fall, spring, and summer semesters. Students are encouraged to take this course in the summer or fall semester prior to taking ENGR 1560 in the spring semester. Students have had a good experience taking the course in the summer session prior to the typical first semester in college. This aided the transition from high school to the university, aided the students with adapting to university life, and facilitated the early faculty-student contact.

Topics and Timeline Used in ENGR 1555

1. Given the isometric and requiring the standard 3 view drawing. Weeks 1 and 2.

The first class begins by describing the idea of visualizing the shape of a 3 dimensional object on 2 dimensional planes of projection. The logic for lines on a drawing are explained, i.e. edge view of a plane, intersection of planes, or the extreme of a contour shape. The concept of placing the object inside a glass box and projecting the shape to the sides of the box and unfolding the box is emphasized. An actual glass box is brought to class to reinforce this concept, Figure 2.

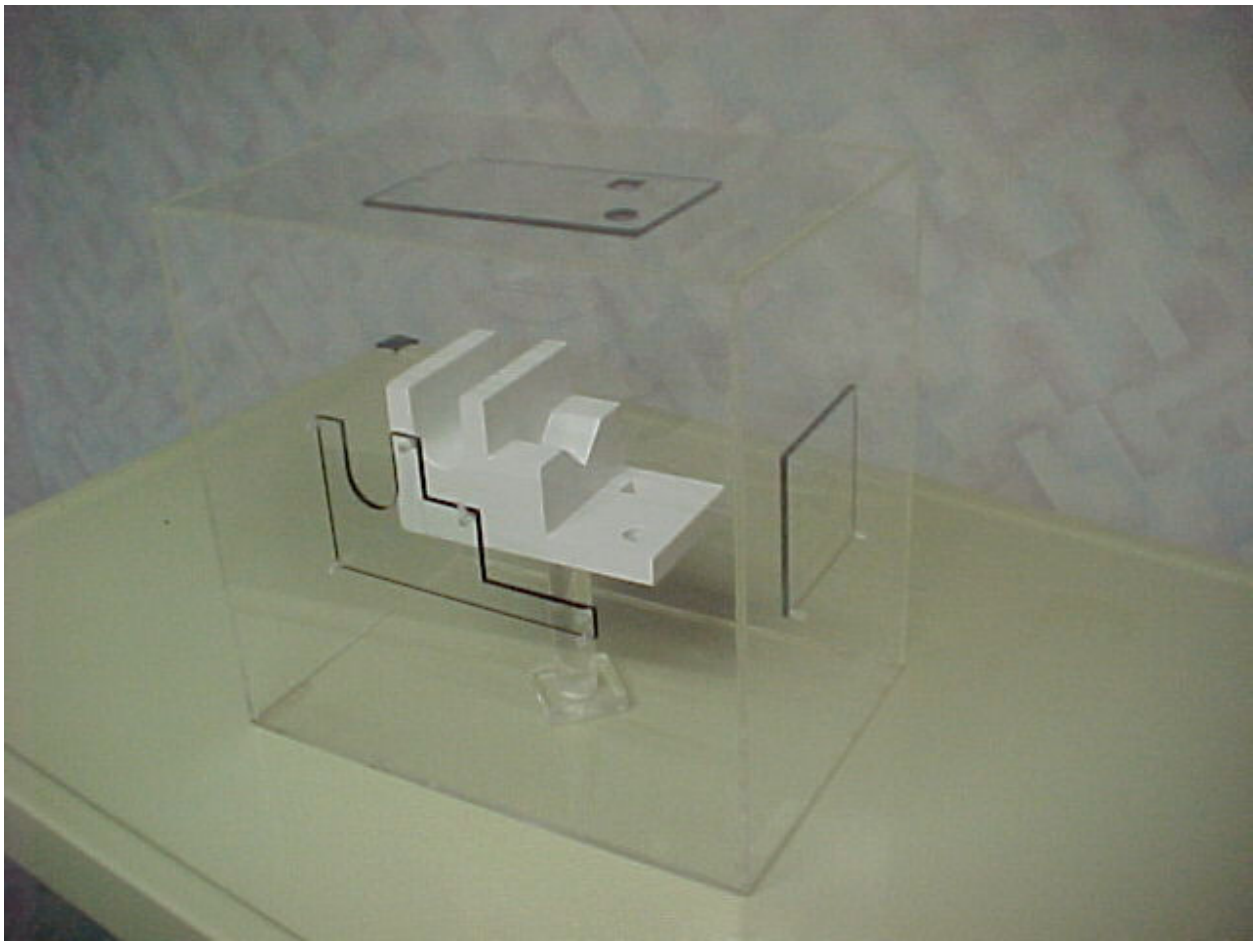


Figure 2- Glass Box for 3 View Drawings.

Since the majority of students rarely have the text the first day of class, a worksheet is passed out and done with the help of the instructor. See figure 3.

Each class is conducted with the instructor presenting, via the visual presenter, a brief discussion of the material to be covered for the day. This is followed by the students working on the assignment for the day. The instructor and lab assistants actively walk around the class and view the student work and assist as needed. By the end of the class an appropriate part of the assignment is collected with the remainder due at the beginning of the next class session. This is important since student typically will leave class as soon as they have done what is due that day. If a student needs additional help, which often occurs, appointments are made to meet prior to the next class with either the instructor or one of the lab assistants.

Each class session the assignments get more challenging and further develop the students' ability to see how increasingly complex features are represented in 3 view drawings. The assignments begin with simple blocks with holes in which all planes and holes are parallel or perpendicular to the projection planes. This is followed by inclined surfaces and cylindrical parts with inclined holes. See course site at http://www.eng.ysu.edu/~dhsuchor/ENGR1555.htm for daily schedule.

Draw or complete the three orthographic views of each
of the parts as shown as isometric pictorials. Label the Views.

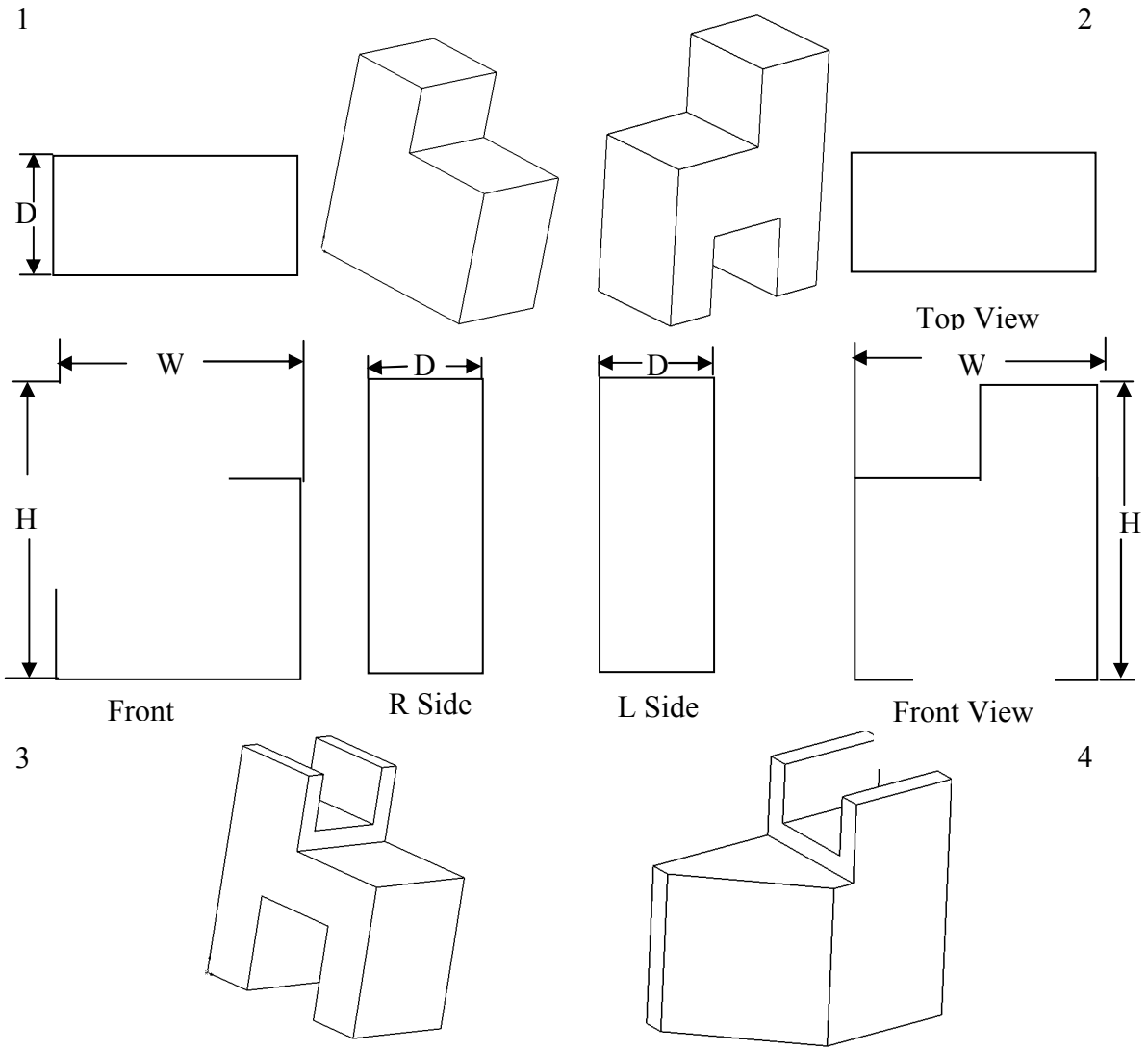



Figure 3 – First Day Assignment

Occasionally in the lecture section the 3 view drawing is shown and the student is asked to visualize the part since this is the more difficult challenge. However, the assignments to be turned in are all with the isometric given, requiring the student to supply the 3 view drawing to help them gain confidence.

Collected material is graded and returned by the next class period. This is an important feature in the class so problems that arise can be addressed quickly.

2. Given the 3 view drawing and the isometric is required. Weeks 3, 4, 5, and 6.
This phase begins with very simple blocks with all faces parallel and perpendicular to the standard projection planes. This is followed with more complex objects with holes and inclined surfaces. Various standard features and how they are represented in 3 view drawings are emphasized. This includes analyzing how normal, inclined, and oblique surfaces look in 3 view drawings so they can be identified easily. This is followed with a similar analysis of cylindrical surfaces.

This is a challenging 4 week period. Some students have extreme difficulty in visualizing more complex shapes. Students having problems are encouraged to start with a sketch of a block of proper height, width, and depth. Using one given view they cut parts of the block away to agree with the given view. This is continued with the other views until the block agrees with all the given views. In many cases with students having difficulty, extra help sessions are scheduled with the instructor and lab assistants.

To give reassurance to students that these skills are necessary, example drawings from local companies they are familiar with are brought into the class. This is extremely important since the students need reassurance that even in the computer age they need to be able to understand the shape of parts when only given the 3 view drawing.

3. Auxiliary Views. Week 7.
The concept of projecting a shape on to a surface that is inclined to the primary orthogonal projection planes is introduced. The reason that this is done is emphasized, i.e. to show the true shape of an inclined surface. This is needed since at times the students need reassurance that what they are doing, even though a bit difficult, is necessary. Again the parts considered are simple and progress to the more complex including holes and cylindrical surfaces. Figure 4 shows a box used as an aid to student understanding of auxiliary views.

4. Section Views. Weeks 8 and 9.
The need to clearly view internal features is explained as the reason that section views are needed. Again the parts considered begin as simple parts and develop into the more complex. Full, half, revolved, aligned, and broken out sections are considered. The standard conventions used to represent treads and fasteners with simplified representation is done along with other simplifications which violate the strict rules of projection, but are much easier to draw and easily understood.

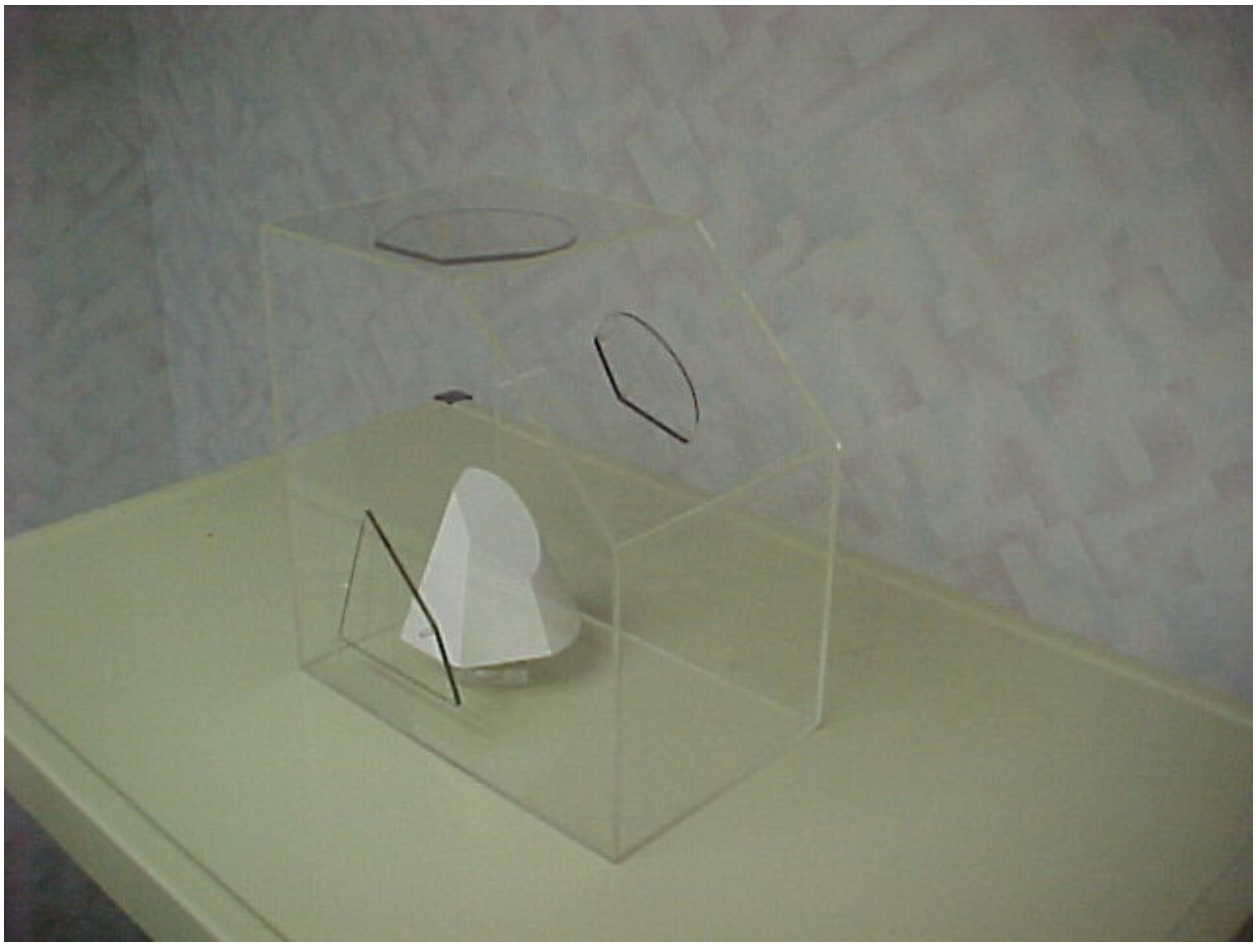


Figure 4 – Glass Box Used for Auxiliary Views

5. Dimensioning. Weeks 10 and 11.

The standard dimensions techniques are covered with emphasis on the way that standard features are dimensioned. This begins with dimensioning blocks properly so that the features such as a cut out are dimensioned in the view that shows each feature most clearly. This is followed by dimensioning cylindrical shapes and locating holes. Notes to dimension some standard features, i.e. threaded holes, counter bored holes, chamfers etc, are then considered. Again typical "real" drawings are brought in from local companies to give examples which reinforce the material and give the students good reason to learn the material.

6. Threads and Fasteners. Week 12.

Standard fasteners and how to represent them on a drawing are covered next. Actual fasteners are brought into class and the students get to measure the threads etc and then write the proper description of the fastener on the drawing. Both English and metric threads and fasteners are covered.

At this point in the class a session is held in the Engineering Machine Shop. A machinist gives demonstrations of actual cutting of metal with milling machines, lathes, and grinders. The importance of good dimensioned drawings is emphasized and the concept of tolerances and cost introduced. Both internal and external threads are cut. Actual drawings are viewed. This tour serves as another way of showing the students that the material they are learning has real and important application.

7. Tolerancing. Week 13.
The impossible concept of making a part to an exact dimension is discussed along with the cost of making parts with dimensions of high tolerance. Typical methods of listing tolerances on a drawing are covered including general tolerance notes implying a particular tolerance by the number of decimal points in a dimension or a particular common fraction or angle measurement. The use of tolerance tables for interference and clearance fits is introduced.

8. Assembly Drawings. Week 14.
A complete set of an assembly drawing, bill of material, and detail drawings of a machine assembly is given. Students are asked a set of questions which require them to use the drawings to understand how the machine is assembled, tolerances developed, and information on function of the assembly. This assignment is complex enough to encompass most of the topics previously covered in the class.

9. Design Project. Week 15.
A simple design project is assigned. Students are required to develop detail drawings, a bill of material, and an assembly drawing to document their design. Again most of the material covered in the class is needed. Emphasis is on completely documenting a design to current engineering standards. Students see the need to be able to clearly sketch designs so that they can be communicated to the engineering world.

## Conclusions

The results of ENGR 1555, Engineering Drawing and Visualization, are generally very favorable. Almost all students that attend the class on a regular basis pass the course. Concerns include trying to reach some students who seem to have great difficulty in visualizing even after completion of the course. It seems that some students, even with hard work, still cannot visualize more complex objects given the traditional 3 view drawing. In the future one possibility being explored is to have a solid modeling package available for the instructor and students to aid in developing good visualization skills.

As a means of assessing the results of the course, the Proficiency Exam of Figure 1 was given to all freshmen engineering students for a period of 2 years prior to taking this course. The average score achieved over this period was 31% out of a possible 100%. This past year, the final exam in the course included problems more difficult that those of the Proficiency Exam of Figure 1, and the average grade achieved on the final exam was 81% out of a possible 100%.

An anonymous survey was conducted in the Spring 2005 semester of all students taking ENGR 1560 – the computer graphics course. This course has students who have completed ENGR 1555 and those taking it concurrent with the computer graphics course. After completion of the first 5 weeks of the course which covered AutoCAD, the survey was administered. This survey was intended to measure not only the effectiveness of the 1555 course, but also if 1555 should be taken prior to rather than concurrent with 1560. The response scale ranged from strongly disagree at 1 to strongly agree at 5.

One question asked of the group who had already completed taking ENGR 1555 prior to ENGR 1560 was if ENGR 1555 helped them to understand drawing conventions and make AutoCAD drawings. The average response was 4.7. In the comments section one student stated "I knew nothing about technical drawing before 1555, and would have been lost in 1560 if I didn't have 1555 first".

The same question asked of the second group who were taking ENGR 1555 concurrently with ENGR 1560 i.e. if ENGR 1555 helped them to understand drawing conventions and make AutoCAD drawings. The average response was 3.9. This lower response is interpreted to imply that taking 1555 before 1560 better prepares the students than when taken concurrently with 1560. In the comments section one student stated "ENGR 1555 helps me but I am learning now what I needed to know last week. If I would have taken 1555 before 1560, I would have been better prepared."

These results show the effectiveness of ENGR 1555 – Engineering Graphics and Visualization, especially if it is taken prior to ENGR 1560. It appears that one change that should be pursued is to require students to take ENGR 1555 prior to taking ENGR 1560 rather than allowing it to be taken concurrently, even though this will cause some scheduling problems. All in all ENGR 1555 is doing an excellent job of preparing students for the computer graphics course.

Those interested in more detailed information about the course may contact the first author at dhsuchora@ysu.edu or visit the course web site at www.eng.ysu.edu/~dhsuchor/ENGR1555.htm

Bibliography

1. Suchora and Pierson. (2004), *First Year Engineering Curriculum at Youngstown State University*, Presented at ASEE 2004 Annual Conference, Session 1353.

2. Craig, Jerry W. and Craig, Orval B. (2003), *Engineering Graphics Text and Workbook,* Mission, Kansas: Schroff Development Corporation, 2003.

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