

Redesigning Engineering Graphics to Include CAD and Sketching Exercises

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Abstract

Computer-aided design (CAD) software is changing the way Engineering Graphics (EG) is taught. Many schools and professors question how best to prepare students for the manufacturing world. Several years ago, St. Ambrose University changed its approach to teaching EG. We removed drawing tables and introduced computer-aided design software as a major course component. In a one-semester course, both EG theory and CAD was taught. However, we learned that CAD was making many EG topics obsolete and that the course needed revision again.

These ideas were shared with engineering graphics professionals at the 2001 ASEE conference. It stimulated much discussion. One issue that seemed particularly disturbing was how to help EG students improve visualization skills. It was postulated that mastering CAD might not help, and that sketching should remain a major EG component.

The EG course at St. Ambrose University was redesigned again with ideas from ASEE2001. It now emphasizes sketching, drawing interpretation, and CAD. Two newly selected textbooks help students connect the topics. This paper reviews the progress teaching the course under the new format. We believe that product visualization, drawing interpretation, and CAD are effectively learned in the one-semester course.

I. Introduction

It has always been a belief that engineers should be able to communicate effectively. Since engineering graphics is the engineer's language for communicating product ideas, our faculty never doubted the need for training in EG. St. Ambrose's Industrial Engineering program has always included a one-semester course in engineering graphics - IE110.

The course has two objectives: 1) to have students understand how engineering designs are communicated visually in industry, and 2) to have students learn to use advanced modeling computer-aided design software. The first objective has existed since day one. The second objective was added four years ago based upon both industry and student demand.

I shared my ideas for teaching EG with other professionals at the 2001 ASEE conference¹. My hypothesis was that much of the traditional EG theory was becoming obsolete by the power and capability of modern CAD products. This hypothesis stimulated much discussion about what should be included in an EG course.

One issue that seemed particularly interesting was how to help EG students improve visualization skills. It was postulated that mastering CAD might not help, and that sketching should remain a major EG component. Some studies have found no improvement in visualization skills with the use of CAD². The argument to include some form of visualization skills was convincing, and I set out to change our EG course the following semester and concentrate on visualization skills and CAD.

II. Historical Perspective

St. Ambrose University is not the only university attempting to teach both EG theory and CAD in a one-semester course. Western Washington University, for example, is another university that recently reported similar course design³. We recognize that students can have excellent CAD skills but may lack visualization skills. An analogy to this would be a student who possesses good word processing skills but lacks the ability to write. The problem between CAD and visualization is not quite as dramatic, however, because CAD does improve visualization and an understanding of some EG concepts.

In 1997, the Society of Manufacturing Engineers (SME) studied industry needs and reported these in its "Manufacturing Education Plan⁴." This was a joint endeavor between the SME and SME Education Foundation (SME-EF) with an objective to establish a process that would motivate the academic community to help improve the manufacturing workforce competency over the next five years. They surveyed many companies within many industries about their employee educational needs. The most identified competency gaps concerning EG included: CAD/CAM, geometric dimensioning and tolerancing, and blueprint reading. The report makes a strong argument for engineering education to improve students' blueprint reading skills, and to tie blueprint reading to CAD, to include solids modeling, and to improve shape visualization.

The National Coalition for Advanced Manufacturing (NACFAM) has also set forth some CADD Skills Standards, which are part of their National Skill Standards Project for Advanced High Performance Manufacturing. NACFAM believes that students should have both CADD skills and blueprint reading skills.

While teaching CAD and engineering graphics concepts, I discovered that with our CAD product, Solidworks⁵, more than half the engineering graphics textbook⁶ information became obsolete. Among these topics are:

- Use of instruments for drawing
- Geometric construction
- Descriptive Geometry
- Oblique projection
- Lettering and lines
- Multiview drawing construction

Traditional textbooks on EG focus too much on manual drafting. CAD makes engineering drawing faster and more accurate. When hand drawing concepts are eliminated, engineering students can concentrate more on the drawing features, why they exist, their relationships to each

other and on the assembled product, the effect on manufacture, and the effect on the product cost.

III. Current Pedagogy

The course objectives for IE110 remain the same: 1) to have students understand how engineering designs are communicated visually in industry, and 2) to have students learn to use advanced modeling computer-aided design software. The newly designed course now uses sketching and drawing interpretation along with the CAD to teach and reinforce EG concepts.

The two textbooks that were being used, “Engineering Graphics⁶” by Giesecke, and “Designing Parts With SolidWorks⁷” by Wysack were abandoned. The first textbook did not support an emphasis on sketching, blueprint reading, and visualization. The Solidworks book did not include drawing (blueprint) creation and it seemed too focused on part modeling.

Finding textbooks to support a new pedagogy is always challenging. Many EG textbooks, like Giesecke’s, do not cover sketching and blueprint reading thoroughly. These textbooks also lack ample student exercises. Conversely, many textbooks on blueprint reading do not cover EG concepts adequately. One book that was found, “Graphics Concepts with Pro/Engineer⁸” recognizes the connection between visualization and CAD skills. It states, “Visual thinking is the foundation of engineering.” Although this textbook appeared to address the desired topics, it did not seem to provide enough sketching and visualization exercises, and its CAD product was not the one St. Ambrose University selected.

After an exhaustive search, the book “Interpreting Engineering Drawings⁹” by Jensen was selected because it appeared to be the best (and possibly the only) textbook focused on sketching and blueprint reading. This book contains far more information than what can be taught in a one-semester course. An instructor can select units of instruction that best suits the students’ needs. Of the 52 textbook units, I have selected 21 of these to be included in IE110. Among the topics are: working drawings, inclined and circular features, drawings to scale, surface texture, tolerances and allowances, inch and metric fits, sectioning and auxiliary views. Some topics that are not included are: manufacturing material, welding drawings, gears and cams, pin fasteners, and structural steel shapes.

The Jensen textbook goes from simple concepts to more complex. By the end of the semester, students are struggling with assignments. Figure 1 shows a simple sketching exercise. This is only one of eighteen problems that students must complete from Unit 1, Sketching and Third-Angle Projection. Figure 2 is a more complex sketching exercise from Unit 2 that includes dimensions. Figure 3, taken from Unit 4, introduces slanted surfaces. In Unit 4 students have 15 problems of various difficulties similar to this one concerning slanted surfaces. Figure 4 (an excerpt), also from Unit 4, illustrates the beginning of drawing interpretation. This type of drawing interpretation problem is difficult to find in other engineering graphics textbooks.

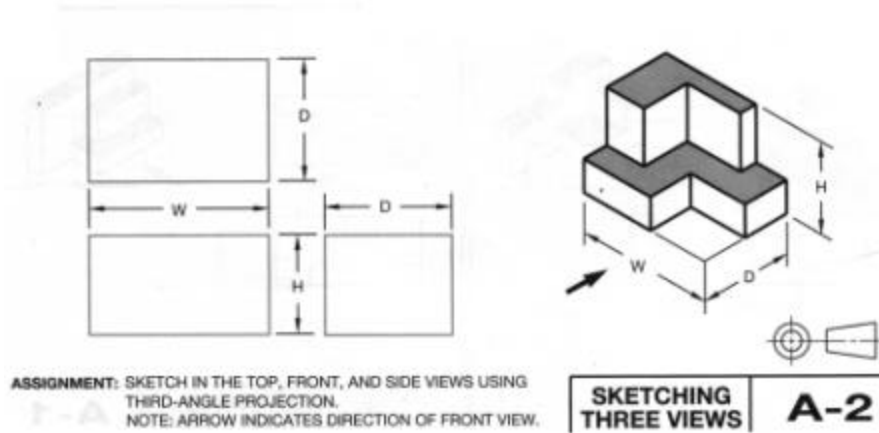


Figure 1. A Simple Sketching Three Views Exercise

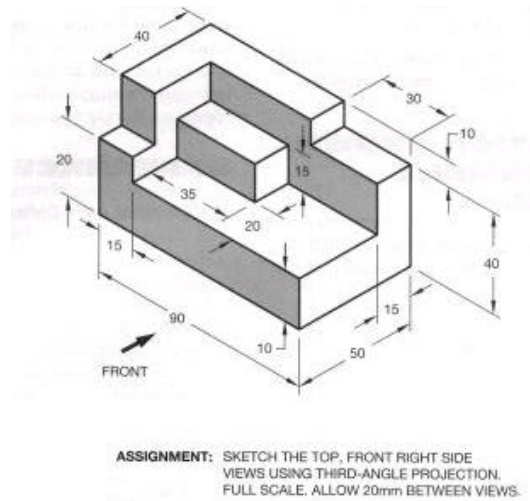


Figure 2. A More Complex Sketching Three Views Exercise

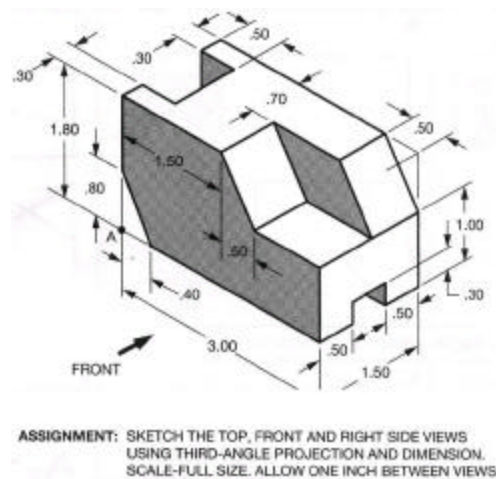


Figure 3. A Sketching Exercise with Slanted Surfaces

After finding a good book on sketching and drawing interpretation, my next challenge was finding a SolidWorks book. The book was chosen with three goals in mind: 1) the topics should be coordinated as much as possible with the Jensen textbook, 2) the book should teach Solidworks 2001, and 3) it should include exercises on creating models, drawings, and assemblies. The textbook “Engineering Design with SolidWorks 2001¹⁰,” by the Planchards satisfied these desires.

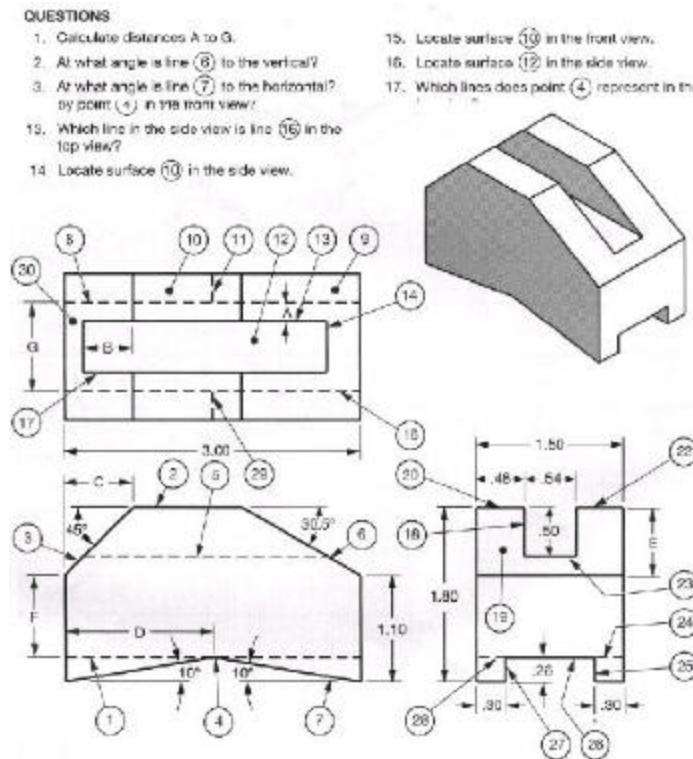


Figure 4. A Drawing Interpretation Exercise

This book focuses on providing a solid foundation in SolidWorks using competency-based projects. The learning process is explored through a series of design situations, industry scenarios, projects and objectives. Its chapters include: Fundamentals of 3D Solid Modeling in SolidWorks, Fundamentals of Assembly modeling, Fundamentals of Drawing, Extrude and Revolve Features, Sweep and Loft Features, Top Down Assembly, and Injection Molded Plastic Part Design Basics.

Figure 5, a guide-rod assembly, illustrates the results of two projects. In the first project students learn to model the individual components of the guide-rod assembly and begin to understand solids-modeling fundamentals. In the second unit, students create an assembly from the previously designed individual components. In this assembly exercise, they learn how to bring components together and to constrain their relationships, similar to what one does in the physical assembly. They download a CAD file from a parts supplier (SMC USA - www.smcusa.com) over the Internet and incorporate this component product into their own assembly. They also learn to use the SolidWorks “components library” to add standard bolts. In a third project, students take the “guide” component and learn to create an engineering drawing (see Figure 6.)

They create an orthographic view and then add dimensions, an auxiliary view, various section views, and an isometric view. The remaining exercises challenge students to complete other design projects and to learn more SolidWorks features.

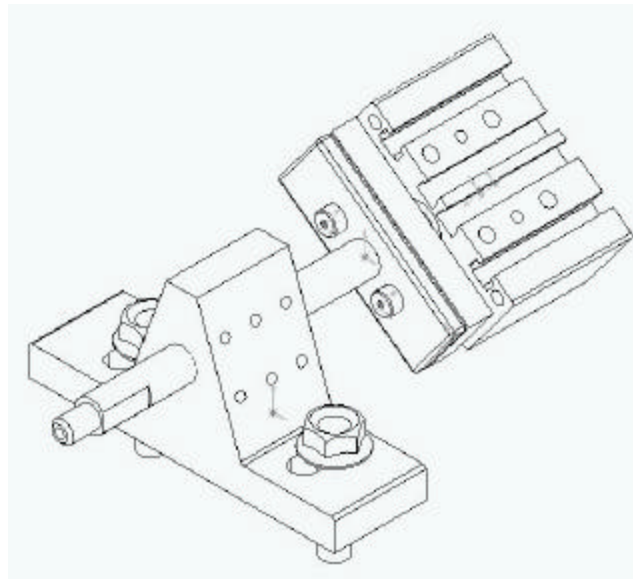


Figure 5. Guide-Rod Assembly Project in SolidWorks.

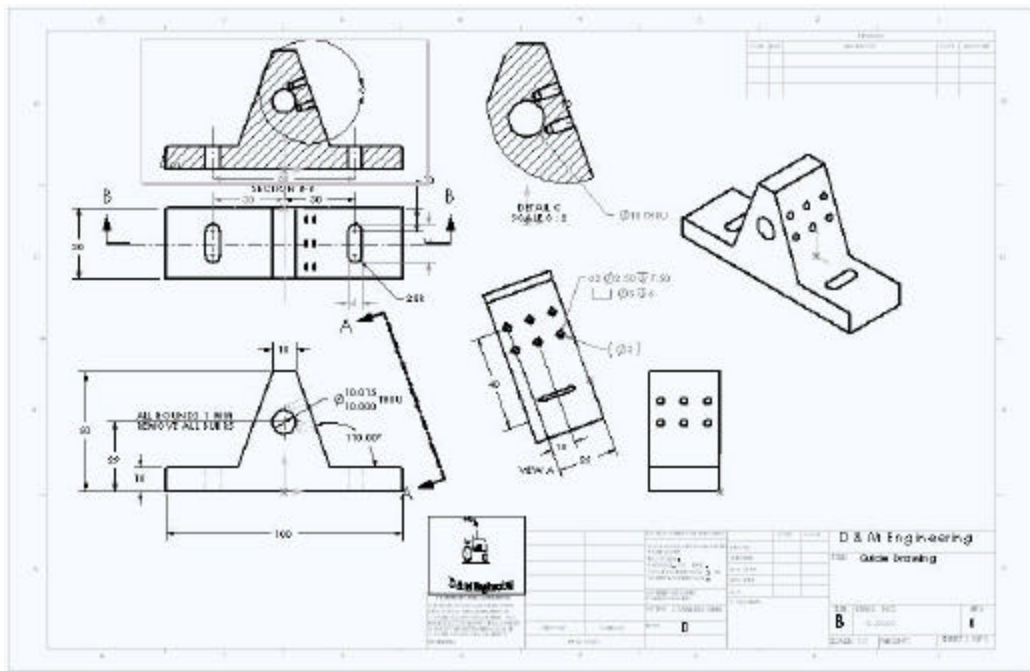


Figure 6. Engineering Drawing Exercise in SolidWorks.

Using two books allows the course to be naturally divided into components – interpreting engineering drawings and CAD. While each book has its own focus, many topics appear in both books, which allow the instructor a chance to coordinate and reinforce learning. Each

SolidWorks project lasts approximately two weeks. The drawing interpretation exercises become progressively more difficult. I illustrate how to use SolidWorks to obtain the answers to these exercises, and I suggest that they do the same. You can view the course syllabus at <http://web.sau.edu/rjerz/Ambrose/IE110/ie110.htm>.

The exercises for this class are fairly rigorous. The SolidWorks projects take the instructor approximately two hours to complete. It is easy to triple this time for the students. The Jensen exercises take the instructor approximately five to fifteen minutes to complete. In Jensen's study guide, he suggests that the exercises should take the student between 40 and 60 minutes to complete. I am always sensitive to creating the proper amount of student work for a normal semester load.

With seven Solidworks projects and approximately fifty assignments from the Jensen textbook, I was unsure how to test students' knowledge throughout the semester. I decided not to quiz students during the semester, and to administer a final exam that included a sketching problem, a drawing interpretation problem, and a SolidWorks design problem. On the final exam, some student did not do well. It was evident that these students probably did not work through the exercises on their own. Intermittent quizzes would probably catch these problems earlier.

IV. Future Course Improvements

Fall2001 was the first semester this course was offered under this new format. As such, it was somewhat experimental. Several improvements are planned for the Spring2002 semester.

To improve student learning, multimedia (AVI) courseware will be developed so that students can see the professors completing some assignments, especially the SolidWorks assignments. Using multimedia support should increase student success, and it should allow the instructor to cover more topics. From the Jensen textbook, I am considering including chapters on geometric tolerancing. My goal is to help students gain as much EG knowledge as possible in this one-semester long course.

During the Fall2001 semester, I was trying to gauge homework and I chose not to give quizzes. For the Spring2002 semester, I want to administer several quizzes and a final exam. Both textbooks provide Instructors Guides with tests.

V. Conclusions

The new content for IE110 appears to be achieving the goals for this course. IE110 now needs to be slightly improved, adding student aids, quizzes, and a little more content. The textbooks work well together. I believe that the Jensen textbook is the best for introducing students to sketching and blueprint reading. It delivers information in small and concise chapters. It includes many assignments for students to complete. The project-based approach of the Planchards book seems to present assignments in real life scenarios.

The first time through this new course structure was very demanding for both students and the professor. The seven Solidworks projects and approximately fifty assignments from the Jensen

textbook caused a little exhaustion for everyone¹. The challenge remains to help students learn as much as possible within the semester. Discussions about setting standards for EG knowledge from both academia and industry should continue.

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¹ As of this writing, student feedback was not received. I anticipate some negative comments from students relative to the quantity of work in this course.