Engineering Graphics:
The Fate of Pencil, Paper, and the 2-D Drawing

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Abstract

The Engineering Technology (ET) department at UNC Charlotte began offering the first two years of its BSET curriculum in the fall semester 2004, having previously been exclusively a "two plus two" program. Although much of the first two years includes basic studies outside the department, a major portion of the new curriculum delivered by the department is the study of engineering graphics.

Developing the new curriculum from scratch allowed a fresh examination of engineering graphics education in the context of today's computer driven society. One advantage was avoiding the "we've always done it this way" mantra. An additional advantage was the opportunity to examine today's computer based drawing, modeling, and design tools, and to plan a curriculum around them, rather than integrating them into an existing course sequence.

Significant thought and planning went into the effort, and included input from several sources. Major decisions were made on several key issues such as: Should any work be done with manual instruments on the board? Is hand sketching an appropriate topic? Should some level of hand work (board or sketching) precede work on the computer? Should 2-D drawing practices, such as orthographic views and dimensioning, be stressed? Should the focus now be on design and parametric modeling rather than traditional 2-D drawing?

This paper details the issues faced in developing an engineering graphics course sequence for today's engineering technology students. It examines the current role, if any, of board drafting and hand sketching. It includes discussion of the merits of studying 2-D drawing techniques, and how 2-D drawings dovetail with 3-D models. Parametric modeling is also discussed, including its role in the design process.

Introduction

Prior to the fall of 2004, the Engineering Technology (ET) department at UNC Charlotte was exclusively a "two plus two" program, offering only the junior and senior years of the BSET curriculum. All students entered with an associate's degree, predominately from two-year community college programs. In order to facilitate growth and to bring its structure inline with current trends, the department is now offering all four years of its degree programs and has recently welcomed its first freshman class to campus.

As part of admitting freshmen students, the department had to develop curricula for the first two years of its programs, which include civil, computer/electrical, fire safety, and mechanical engineering technology. Referred to as the "lower division," this new curriculum includes basic studies outside the department, such as English, math, and physics, and also several courses taught within the department. For mechanical and civil students, the most significant lower division coursework within the department is in the area of engineering graphics.

Though creating an engineering graphics course sequence from scratch obviously entailed a great amount of work, it did have distinct advantages. First off, the old mantra of "we've always done it that way" was completely avoided. Secondly, today's computer based tools could be carefully examined, and their role in the curriculum decided up front, rather than attempting to integrate them into an existing course sequence. Finally, the shift from computer aided drawing to computer aided design could be addressed, along with the role of the design process as it now relates to graphics communication.

Approach

Significant thought and planning went into the effort, and included input from several sources. Best practices were studied at the community colleges that supply our transfer students, at other four-year ET programs, and at the engineering programs within our own college. Past experiences of current faculty were also considered, as were opinions from our industrial advisory committee, made up of representatives from employers in our region. An additional valuable source of information was Clarke's recent informal survey of two and four-year engineering technology programs (1).

After collecting all the data, major decisions had to be made on several key issues regarding engineering graphics education in today's computer-driven world. Questions included: Should any work be done with manual instruments on the board? Is hand sketching an appropriate topic? Should some level of hand work (board or sketching) precede work on the computer? Should 2-D drawing practices, such as orthographic views and dimensioning, be stressed? Should the focus now be on design and parametric modeling rather than traditional 2-D drawing?

Though there are certainly no "correct" answers to these questions, informed decisions were made on all of the above issues. The result is a three semester course sequence that gives thorough preparation in engineering graphics. Once complete, the student should possess the skills necessary to succeed in upper division coursework and ultimately in the workplace.

Pencil & Paper – Instrument Drawing and the Hand Sketch

Although the vast majority of drawing work in today's industry is performed on the computer, skills involving the use of pencil and paper should not be ignored. This view appears to be widely supported, as noted in references 1-5. What is widely debated, however, is whether the pencil and paper work should be in the form of instrument drawing and/or hand sketching.

Instrument drawing, by use of T-squares, triangles, compasses, etc., is how this author learned the subject of engineering graphics. Indeed, most of today's engineering educators, as well as many current engineers and managers in industry, learned engineering graphics the same way. It is interesting to note that a significant number of educational institutions continue to teach some amount of instrument drawing, even though the practice has all but disappeared in today's industry (6).

According to a recent informal survey of two and four-year engineering technology programs (1), 39 of 77 responding institutions (~51%) still teach some form of instrument drawing. Reasons given in support of this approach varied widely, but some central themes do emerge from the data. They are broadly summarized as follows:

- Can introduce fundamentals without simultaneously teaching software commands
- Students with only CAD training lack visualization skills
- Learning instrument drawing first eases later instruction in CAD
- Concepts such as orthographic projection and tangency are best learned manually
- Manual drawing teaches the thought process necessary to produce working drawings
- Knowledge of hand drafting is necessary to use CAD correctly
- Some amount of board drafting still exists in the workplace
- Starting with CAD is equivalent to first graders learning math with calculators

Respondents were also given the opportunity to provide comments against including instrument drawing. A broad summary of the reasons given:

- Little to no demand from industry or advisory boards
- Cost and space requirements of maintaining drafting boards
- Sketching followed by CAD is how engineers work today
- Sketching concepts are more important that formal board drawings

While there does not appear to be a consensus on the value of instrument drawing, there is strong evidence in support of the inclusion of hand sketching in the engineering graphics curriculum (7). In the same survey, 40 of 77 responding institutions (~52%) include hand sketching in their engineering graphics coursework. A broad summary of the reasons given:

- A necessary skill for communicating thoughts/ideas without access to a computer
- Effective method of teaching technical drawing concepts (views, dimensioning, etc.)
- Necessary prerequisite to drawing in CAD
- Isometric hand sketches provide great visual insight

- Helps students' visualization skills
- Necessary skill for field sketches and drawings created when no computer is available
- Effective vehicle for introducing geometric relationships
- Sketching is how engineers think through a problem
- Is a vital skill for the professional success of today's students

Respondents were also given the opportunity to provide comments against the inclusion of hand sketching. None were received. It should be noted that only 7 of 77 responding institutions (~9%) use CAD for 100% of their engineering graphics instruction, and the majority of those have only a single semester of course work. Where multiple courses are taught, nearly all programs include some form of pencil and paper drawing work, either sketching or instrument drawing.

Based on all collected data, it was decided that the new engineering graphics course sequence would include significant work in hand sketching before the introduction of CAD. The course would not include any work with formal drawing instruments. The primary reason for this decision is that nearly all identified advantages of board apply equally to hand sketching. Basic concepts, such as views, orthographic projection, dimensioning, etc. would be introduced in the context of hand sketching before using the computer. In addition, pictorial sketching, including isometric and perspective, would also be introduced.

The 2-D Drawing

After tackling the issue of hand drawing, the next major decision in developing the engineering graphics course sequence was the issue of the 2-D drawing. When CAD systems came of age in the early to mid 1980s, they were initially used as drafting tools. They greatly enhanced the productivity and quality of drawing work, but they were primarily a replacement for the drafting board. They were used to create two-dimensional drawings, but had not yet found much utility as a design tool. During this period, there was little doubt that engineers needed to know how to generate 2-D drawings, align views, place dimensions, etc., whether the work was done by hand or on the computer.

Today, even the simplest CAD systems support three-dimensional solid modeling, and most will generate 2-D drawings from 3-D geometry. The more advanced systems are fully parametric, establishing a link between the 3-D model and the 2-D drawing, and are a great aid in the design process. Some may argue that today's engineering graduate need only know the ins and outs of these modeling programs, and can let the computer handle the details of the 2-D drawing.

The consensus amongst our faculty and advisory committee on this issue is quite different. The computer has become a fantastic modeling and drawing tool, but current software has yet to master the intricacies of the 2-D drawing. Packages such as PTC's Pro/Engineer and Autodesk's Inventor are quite good at generating correctly placed views with accurate visible and hidden lines. But these packages do not as yet possess the ability to automatically produce a finished drawing, including view selection, center lines, notes, bill of material, and in particular, dimensional information that is clearly and accurately displayed, so that a drawing would be suitable for turnover to shop personnel (8, 9).

And even if these packages could automatically generate finished, ready to go 2-D drawings, which they may some day do, it is believed that there is great value in knowing how to create them, even if one doesn't do so daily in their jobs. An analogy would be deciding not to teach strength of materials to mechanical students, with the reasoning that finite element packages can now perform virtually any needed analysis. Clearly, the engineer needs a good and thorough understand of the process, even if the computer does the dirty work for them.

For these reasons, the new engineering graphics course sequence includes significant work in the fundamentals of 2-D drawing before the introduction of 3-D modeling. Basic concepts include placement of views, transferring distances, hidden and center lines, sections, auxiliary views, dimension placement, etc. Students learn to develop these two-dimensionally before 3-D computer models are introduced.

3-D Parametric Modeling & Design

In the time since mainstream use of CAD packages began in the mid 1980s, the definition of CAD has evolved from Computer Aided Drafting to Computer Aided Drafting and Design (CADD) to simply Computer Aided Design. Along the way, CAD programs have evolved from simple 2-D drawing tools into to 3-D design tools (10).

When using today's feature based parametric modeling software, the engineer first creates the 3-D solid model, complete with holes, cuts, rounds, etc. The 3-D model is then used to generate the 2-D drawing, which, as mentioned earlier, will still require some amount of clean-up work.

In working on the design of a product with multiple parts, each element of the product is created individually, with its own 3-D model and associated 2-D drawing. The individual 3-D models are assembled in their functional positions, and can even be "joined" by connections such as fixed fasteners, pins, and sliders. Moving assemblies can even be animated, if desired.

In true feature based parametric modeling software, the 3-D model and the 2-D drawing are linked, meaning that a change in one generates the same change in the other. For example, if a hole's diameter is changed in the solid model, the 2-D drawing's circle and hidden lines, depending on the view, are also updated. The diameter dimension is updated as well. The process also works in reverse, as changes to dimensions in the 2-D drawing are reflected in the 2-D views and the 3-D model.

In teaching graphics communication, this relatively new capability requires some treatment of the design process earlier in the curriculum than it might traditionally appear. For that reason, the new engineering graphics course sequence includes a thorough introduction to the design process.

Course Content

The result of this work is a three semester course sequence in engineering graphics, with each course carrying two credit hours. The courses are summarized below. Additional details are included in the appendix.

The first course, ETGR 1103, Technical Drawing I, is taken by students in the mechanical, civil, construction, and fire safety engineering technology programs. The course begins with five weeks of hand sketching. Topics include sketching techniques, orthographic projection, multiview drawing, pictorial sketching, and dimensioning. Hand sketching is used to introduce and reinforce these basic drafting principals before any work on the computer is undertaken. The hand work is followed by ten weeks of 2-D CAD work using Autodesk's AutoCAD software. Topics include constructions, object properties, multiview drawings, dimensioning, templates, layouts, plotting, auxiliary views, section views, working drawings, and assemblies. This course is taught in a classroom equipped with workstations that include desktop space for hand sketching as well as a CAD workstation.

The second course, ETGR 1104, Technical Drawing II, is taken by mechanical, civil, and construction engineering technology students. It introduces 3-D drawing and modeling using Autodesk's AutoCAD software. Topics include the generation of wireframe, surface, and solid models. Various construction techniques are introduced, including primitives, extrusions, sweeps, and Booleans. A review of 2-D drawing concepts is followed by the creation of 2-D drawings from 3-D models. Final work includes photo-rendering and an individual end-of-semester project and student presentation.

The final course in the sequence, ETME 2202, Introduction to Mechanical Design, is geared towards students in mechanical engineering technology. It introduces the design process, utilizing Autodesk's parametric modeling software Inventor. Topics include the fundamentals of parametric modeling, solid geometry concepts, model history, constraints, construction tools, Parent/Child relationships, part drawings, and associative functionality. The course concludes with a comprehensive group design project and presentation.

Conclusion

Today's computer based tools have radically changed the landscape of engineering graphics. This paper details the issues faced in developing an engineering graphics course sequence for today's engineering technology students.

It concludes that board drafting with instruments need not be included in today's curriculum, but that hand sketching is still a vital skill that should be thoughtfully addressed. It also concludes that teaching 2-D drawing techniques is still extremely important, even though many software programs generate 2-D views automatically. Finally, this paper concludes that teaching today's parametric modeling software requires an introduction to the design process, and that design as a topic appears earlier in the curriculum than in traditional models.

References

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Biography

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Gregory Watkins received a B.S. in Mechanical Engineering from North Carolina State University, a Master of Engineering Management from Old Dominion University, and a Ph.D. in Mechanical Engineering from UNC Charlotte. He has taught in the Engineering Technology department at UNC Charlotte for the past 2.5 years. He taught in the Engineering Technologies Division at Central Piedmont Community College for 8 years and has 9 years of industrial work experience.

Appendix 1 – ETGR 1103, Technical Drawing I

Texts: Giesecke, et al., *Modern Graphics Communication*, 3rd Edition, Prentice Hall, 2004
Shih, *AutoCAD 2004 Tutorial, First Level: 2D Fundamentals*, SDC Publications, 2003

Course Website: http://www.coe.uncc.edu/~gkwatkin/ETGR1103/

This course carries two semester credit hours, and is taught with one lecture and three lab hours per week.

Week	Topic
1	Design and Graphic Communication, Freehand Sketching
2	Multiview Sketching and Projection
3	Multiview Sketching and Projection (cont'd)
4	Pictorial Sketching
5	Dimensioning
6	Getting Started in AutoCAD, Geometric Construction Basics
7	Geometric Construction and Editing Tools
8	Object Properties & Organization
9	Orthographic Views in Multiview Drawings
10	Basic Dimensioning & Notes
11	Templates & Plotting
12	Auxiliary Views and Grip Editing
13	Section Views
14	Working Drawings
15	Review / Catch-up
16	Performance Exam

Further details about this course, including, syllabus, assignments, PowerPoint presentations, etc. are freely available via email at gkwatkin@uncc.edu.

Appendix 2 – ETGR 1104, Technical Drawing II

Text: Shih, *AutoCAD 2004 Tutorial, Second Level: 3D Modeling*, SDC Publications, 2003

Course Website: http://www.coe.uncc.edu/~gkwatkin/ETGR1104/

This course carries two semester credit hours, and is taught with one lecture and three lab hours per week.

Week	Topic
1	Review of AutoCAD
2	Introduction to 3D
3	3D Wireframe Modeling
4	User Coordinate Systems, Viewports
5	3D Surface Modeling
6	Solid Modeling – Constructive Geometry
7	Regions, Extrude, and Solid Modeling
8	Multivew Drawings from 3D Models
9	Symmetrical Features in Designs
10	Advanced Modeling Tools and Techniques
11	Rendering
12	Rendering (cont'd)
13	Assign Project
14	Project Work
15	Project Work
16	Student Presentations

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Appendix 3 – ETME 2202, Introduction to Mechanical Design

Text: Shih, *Parametric Modeling with Autodesk Inventor R8*, SDC Publications, 2003

Course Website: http://www.coe.uncc.edu/~gkwatkin/ETME2202/

This course carries two semester credit hours and is taught with two lecture hours per week.

Week	Topic
1	Getting Started
2	Parametric Modeling Fundamentals
3	Constructive Solid Geometry Techniques
4	Model History Tree
5	Parametric Constraints Fundamentals
6	Geometric Construction Tools
7	Parent/Child Relationships
8	Part Drawings and Associative Functionality
9	Datum Features and Auxiliary Views
10	Symmetrical Features in Designs
11	Advanced 3D Construction Tools
12	Assembly Modeling
13	Assign Project
14	Project Work
15	Project Work
16	Student Presentations

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