First Year Engineering Graphics Curricula in Major Engineering Colleges

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Abstract

There is a great variance in the amount of time devoted to basic graphics instruction and in the content of the courses among American engineering colleges. Nine universities were visited, classes attended, and syllabi reviewed with faculty. The commonalities and differences are analyzed and possible directions for graphics programs presented.

Introduction

There is a great variety in engineering graphics courses offered in engineering colleges and in the content of these courses. Graphics instruction in major engineering colleges has been reduced, and in some cases eliminated, as we have moved from practice-based engineering taught in the first half of this century to science-based engineering which has dominated the last half of the 20th century.

This revolution began in the 1920's and '30's as European educated engineers became engineering professors in the United States. They noted the lack of mathematics and science in engineering curricula in American universities (Seely, 1999). World War II further demonstrated the need for a more analytical approach and the Grinter report, published in 1955, gave impetus to the adoption of science-based curricula (Grinter, 1955). The Grinter report called for more basic science and mathematics courses and fewer "skill" courses. However it did not specifically target graphics - usually cataloged as "engineering drawing" at that time. Item 6 of the implementation called for "a high level of performance in the oral, written and *graphical* communication of ideas." (italics by this author) Almost fifty years later ABET Criteria 2000 call for "an ability to design...", "an ability to communicate effectively", and "an ability to use techniques, skills, and modern engineering tools necessary for engineering practice (Phillips, 1997)." Despite the efforts of executives of the EDGD, ABET has not specifically mentioned graphic communication as an important ability. Seely states that the key to the push for more science in curricula was military research funding: "schools seeking to grow had to develop graduate programs to support the fundamental research programs, and emphasize engineering science. But the goal was not to save industry, rather to attract federal research funds (Seely, 1999)."

The engineering faculty members and administrators of today have been educated and worked in university environments so dominated by the call for grant-funded research in engineering colleges that practice-based engineering is almost forgotten. Few engineering faculty have had experience in an economy-based commercial organization where design must result in a salable product or service. Much of what is taught as design is not a comprehensive study of the design process but only that portion which uses mathematical tools for analysis. The process of design follows the structure of the scientific method and has been outlined similarly by many authors; one comprehensive outline by Bertoline is

given below; he notes that the three overlapping areas can all share the same 3-D CAD database (Bertoline et al., 1995).

Ideation
- Problem Identification
- Preliminary Ideas
- Preliminary Design

Refinement
- Modeling
- Design Analysis
- Design Visualization

Implementation
- Servicing
- Financing
- Marketing
- Producing
- Planning
- Documenting

Clive Dym states in a recent paper "we have done a much better job over the last fifty years teaching analysis than we have done teaching design (Dym, 1999)." He notes there has been an increased interest in design in recent years and that we need to recognize that there are several "languages of engineering design: verbal or textual statement, graphical representations, mathematical or analytical models, and numbers that represent design information." Analysis alone is not design;it is but one element in the iterative process of design.

In recent years we have had a great diversity among the papers presented to the Engineering Design Graphics Division of ASEE. Some still present methods for solving descriptive geometry problems with hand tools while others present projects describing advanced computer animations. My own institution, where graphics has been taught in various forms for over 100 years, now has three different options for beginning engineers to learn graphics (and related topics). We have been conducting surveys of our alumni and their employers and modifying curricula in an effort to better prepare our students for professional careers (Meyers et al., 1993). After discussing these variances and needs it seemed appropriate to visit some major institutions and learn first-hand what is happening in beginning graphics education.

The Visits

Nine universities were selected because of their reputation, or knowledge of a welcoming colleague, or being in the path of a projected tour. Universities included are:

Arizona State (2 campuses)
Colorado (2 campuses)
Colorado School of Mines
Iowa State
Ohio State
Pennsylvania State (State College)
Purdue (West Lafayette)
Texas (Austin)
Worcester Polytechnic Institute

Engineering graphics, in some form, was required in the beginning engineering programs in all but one of the campuses visited. (How do you present design without graphics?) Two of the largest institutions house graphics instruction in a School of Technology, where it is taught as a service course to the College of Engineering. Some Colleges do not require a course in beginning graphics, but do include a required intermediate or advanced course (assuming that the students arrive with some knowledge of graphics - a beginning course is provided as an option). Most of the institutions visited do provide beginning and advanced courses in graphics. The two technology schools within major universities have departments which are offering comprehensive four year curricula with specialization in various sub-disciplines of graphics.

Graphics is taught within departments that specialize in this discipline, or within a department granting engineering degrees, or as a service by one degree-granting department to other departments. It may be required in all engineering degree programs

or by only selected programs: typically, mechanical and industrial engineering would require it and electrical and computer engineering may not. The topics included vary widely - affected by the amount of time allotted to the subject, the orientation of the faculty, and the demands of other departments within the institution. The spreadsheet (*Figure 1*) summarizes the major topics included at each campus in the beginning graphics course or the beginning engineering course in which graphics is included.

	Ohio State University				Arizona State	U of Colorado		Colo Mines	Iowa State		Penn State	Purdue	U of Texas	WPI
	Engineering Graphics		Engineering College		Technology	Mech Engr	Arch Civil		Ag/Env Engr	Civil Engr	Engr Design	Tech	Mech Engr	Mech Engr
	EG 166	Honors	2 quarters		ETC 100			EPICS			ED&G 100	CGT 155	ME210	ES 1310
TOPICS														
Visualization	X	X	X	X	X	X		X	X	X	X	X	X	X
3-D Modeling - CADD	CADKEY	CADKEY		CADKEY	AutoCAD	AutoCAD	AutoCAD	AutoCAD	AutoCAD	AutoCAD	SilverScreen	AutoCAD	AutoCAD	CADKEY
Orthographic Views	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pictorial Views	X	X	X		X	X		X	X	X	X	X	X	X
Section Views	X	X	X		X	X	X	X		X	X	X	X	X
Dimensioning	X	X	X		X	X	X	X	X	X	X	X	X	X
Fits & Tolerances	X	X	X		X				X					X
G D & T	X	X												
Fastening & Welds	X				X	X						X		X
Working Drawings	X	X		X		X	X	X	X		X		X	X
Space Geometry	X							X	X				X	X
Charts & Graphs	X	X	X			X		X			X			
Spreadsheets/Solvers			X			X		X			X		X	
Hands-on Labs		X	X	X				X	X		X		X	X
Team Projects		X	X	X				X	X		X			X
Other Topics				PowerPoint	WWW			Build 3-D model		Topo map	WWW Ind'l project		FEA Prototype	
	Advanced courses required	Advanced courses required	Advanced courses available		Advanced courses required	Advanced courses required	Advanced courses required		Advanced courses available		Advanced courses available	Advanced courses available	Advanced courses available	Advanced courses available
TOOLS														
Sketching	X	X	X		X	X	X	X	X	X	X	X	X	X
Triangle & Compass					X			X			X		X	
CADD	X	X	X		X	X	X	X	X	X	X	X	X	X

***Figure 1** - Major topics in Engineering Graphics curricula 1998-99 academic year.*

Score:		Score:	
5.00	Developing 3-D Visualization Skills	3.13	New Computer Lab Development
4.44	Parametric Modeling	3.06	Drawing Standards & Codes
4.38	3-D Solid Modeling	3.00	Threads, Tolerancing, etc.
4.38	Manual Sketching	2.94	Auxiliary Views
4.00	New Generation of Teaching Materials	2.94	Rapid Prototyping
3.81	Team Projects in EDG	2.94	Computer Animation/Simulation
3.75	Design Process Stages	2.88	Mass Properties Analysis
3.69	Orthographic and Multiview Projection	2.88	Hardware & Software Skills
3.63	Dimensioning	2.69	Finite Element Analysis
3.50	Sections	2.63	Color Rendering & Visual Realism
3.50	Pictorials	2.63	Charts & Graphs
3.44	Use of WWW in EDG Instruction	2.38	Computational Geometry
3.44	Use of Multimedia in EDG Instruction	2.25	Descriptive Geometry
3.31	2-D CADD	2.13	Virtual Reality
3.31	Reverse Engineering	1.81	Manual Construction Using Instruments
3.19	Surface Modeling	1.75	Lettering

***Figure 2** - Survey results from curriculum planning session - Barr.*

Topics are listed in an order which includes the most common topics near the top of the list and the topics not so universal in the lower part of the list. "Tools" have been separated from "topics" to emphasize the idea that we do not teach tools - we use different tools as a means for learning about the topics. The course offered at Penn State and the introduction to engineering at Ohio State include beginning graphics and also hands-on laboratory projects which require teamwork and report writing. The pertinent course at the Colorado School of Mines is a beginning design problem course - graphics is not in the title, however the students learn graphics as they present their solutions to the given design problems.

Two recent papers have listed topics most likely to be included in an engineering graphics course: Barry Crittenden of Virginia Polytechnic Institute presented "Requirements for Successful Completion of a Freshman Level Course in Engineering Design Graphics" in 1995 (Crittenden, 1996) and Ron Barr of the University of Texas at Austin who has been pursuing curriculum issues for several years presented the findings of his most recent workshop in a paper entitled "Planning the EDG Curriculum for the 21st Century: A Team Effort" in 1998 (Barr, 1999). Comparing the topical areas found in this study with their work shows that about half of the topics listed in Barr's summary *(Figure 2)* were covered in the beginning courses and that most of the topics covered were noted by his panel. Crittenden's respondents *(Figure 3)* included most of the topics with the exception of those found in the introductory engineering courses as distinguished from the beginning engineering graphics courses, such as spreadsheets and solvers, hands-on labs, and team projects. (This author has not attempted a comparative statistical analysis of the topics covered: the sample, while representative of major institutions, is too small for a statistical study.)

The CADD packages used for beginning courses are the ones found in the usual discussions of CADD: AutoCAD, CADKEY and Silver Screen. Some institutions have used packages which are more often used for

descriptive geometry	intersections	sectional views
developments	kinematics	sketching
dimensioning	lettering	software use
drafting skills	mathematics	solid modeling
geometric construction	orthographic projection	threads and fasteners
geometry	reading engrg. drawings	tolerances
graphing	scales	visualization

***Figure 3** - Major topics covered in freshman level graphics courses - Crittenden.*

intermediate or advanced courses: SDRC: Ideas, Pro-Engineer, and Solid Works.

Conclusions

There is a wide diversity in the offerings at different institutions, however topics of visualization, orthographic views, pictorial views, section views, dimensioning and working drawings appear in all the curricula. Beyond these topics there is diversity depending upon the predominant discipline in charge, time available, the availability of complementary advanced courses and the orientation, whether it be toward graphics only or toward a first course in engineering experiences. The technology schools at Purdue and Arizona State offer complete 4-year curricula, while a degree-granting department at Arizona State requires no graphics.

As we evaluate these programs and our own we must focus on the "customer". Who is the customer? This author believes that the student is the primary customer and that downstream faculty, future employers and society, as a whole, are secondary customers. The student may not be in a position to know what she/he needs downstream; we know from evaluations by employers and downstream faculty what they perceive as strengths and weaknesses of our graduates. The pertinent areas we can impact include: communication skills, ability to read drawings, teamwork, use of commercial CADD packages, and use of spreadsheets and data bases (Meyers et al., 1993). Depending upon the goals and degree programs of our students we can prepare them with "straight" engineering graphics courses and leave other communication skills to other courses, or offer them introduction to engineering courses which include other communication and teamwork skills, or prepare them to be technical specialists in the fast moving world of computer graphics with virtual reality, animations, and web site design. Whichever course we take the one thing certain is change.

Acknowledgements

The author deeply appreciates the courtesy of the colleagues who welcomed me to their institutions and shared their time and knowledge:

Arizona State	Jon Duff
Colorado - Denver	James Gerdeen
Colorado - Boulder	David DiLaura
Colorado School of Mines	Robert Knecht

Iowa State	Jim Shahan
Pennsylvania State	Dhushy Sathinathan
Purdue	Gary Bertoline
Texas	Ron Barr
Worcester Polytechnic	Holly Ault

And, Ms. Jacque Williams of Metro State College, Denver for making arrangements in Colorado.

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