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The Multidisciplinary Environment of Engineering Design Graphics

Abstract

The purpose of this paper is to demonstrate the limitations of the current graphics curriculum and to propose methods for better preparing students entering the multidisciplinary field of engineering. A review of popular graphics textbooks shows how the historical roots of graphics in mechanical engineering results in incomplete training of today's engineers at the multidisciplinary level. Literacy in graphics includes the ability to read the graphics dialect across the engineering disciplines, create drawings as they are applied in the field including instrument and computer drawings, and to transfer mental images to a graphic design, which is the beginning of the creative design process.

Introduction

The Accrediting Board for Engineering and Technology (ABET) sets the criteria for a broad based engineering graphics program to include: "an ability to function on multi-disciplinary teams"; "an ability to communicate effectively"; and "an ability to use the techniques, skills and modern scientific and technical tools necessary for professional practice".[1] A multidisciplinary graphics program prepares the student for the fluid and global market of today. Students are also prepared for multidisciplinary communication. The EC2000 mandate that students be able to work effectively on multidisciplinary teams has generated active curricular research, and led preeminent universities such as Purdue University to create courses to build interdisciplinary connections in the students' minds.[2]

By nature, graphics is a pictorial language that should be universally understood, transcending written language and the engineering disciplines. The introductory design graphics course is the ideal course to introduce the multidisciplinary concept of engineering. As evidenced in this paper, there is a significant trend in graphics courses to teach only a portion of the necessary skills to effectively communicate. Historically, institutions have supported traditional mechanical engineering graphics which inadequately prepares future engineers for the work they will encounter in complex situations that require the ability to communicate with professionals in other disciplines. According to the National Association of Colleges and Employers (NACE) "Job Outlook 2004", engineering graduates have deficient communication skills and many lack a realistic view of the work place.[3] With proper training in a broad-based graphics program, engineering students will be prepared to enter the multidisciplinary field of engineering capable of communicating across the disciplines, increasing efficiency and avoiding costly mistakes.

Graphic Texts Lack Multidisciplinary Approach

Many graphic courses are an outgrowth of mechanical drawing courses, tracing their origins to the industrial revolution. This is evidenced by existing and popularly used design graphic texts.

A review of widely used engineering graphic texts reveals a strong mechanical base, omitting architectural/civil and electrical/electronic graphics.[4,5,6,7,8,9]

The following chapters listed below in Table 1 from the seminal publication Engineering Graphics by F.E. Giesecke et al[6] illustrate the dominance of mechanical graphics. The text is representative of the engineering graphic texts in current use.

Table 1. Table of Contents from Engineering Graphics by F.E. Giesecke et al.[6]

Even within the scope of mechanical engineering, a vast majority of the training relates to the mechanical parts and associated views with minimal emphasis on the assembly and systems of the mechanical parts. A typical text will instruct students to recognize the developments of flat sheet metal fittings, but not integrate that information into a working system, i.e. a duct system.

Current graphics programs commonly omit pipe design, widely used in multidisciplinary engineering projects including mechanical, civil, chemical, electrical and other disciplines. Related electrical pipe design includes the lay out of conduit used for running wire and cable. Students should have a working knowledge of piping, valves, and fittings in order to design pipe systems. These pipe system designs include conducting water, steam, waste, sewage, venting, fuel, gases, wire, cable, as well as various structural applications. In addition to the current curriculum, instruction should include design installation drawing of mechanical and electrical systems.

Electrical and electronic graphics is the newest and currently largest member of the engineering graphics disciplines. The electrical/electronic graphics language functions as a common interface between major engineering disciplines throughout the industry worldwide. Electrical and electronic symbology and drawings are not drawn to scale unless required by a machine or structure interface. The division of electrical/electronic engineering design drawings includes block, line, schematic, wiring, terminal and logic diagrams. All engineering graphics students should be familiar with electrical symbols and basic diagrams.

Design graphic courses should include the basic graphics of architecture, mechanical and electrical disciplines. The knowledge of architectural graphics permits the engineering student to visualize how the engineering disciplines relate to each other within the graphic framework. Consider the analogy of the design of a structure as if it were a puzzle of interlocking pieces. If the student does not have a clear understanding of the shape where their particular component will fit, then the process of design will be filled with guesswork and inefficiencies.

Strengthening the Multidisciplinary Experience in Engineering Graphics

A proposed curriculum for an introductory design graphics course that is broad based and introduces the basics of the major engineering disciplines is presented in Table 2. The suggested semester course includes a minimum of 2 hours of lecture and one hour of computer lab per week.

Table 2. Proposed curriculum, week by week, for a multidisciplinary introductory design graphics course.

1. Define engineering and engineering design including the steps in the engineering design process.
2. Describe instrument and computer drawing and the scales used to make them. Students should start instruction in creating computer drawings using a basic software program such as AutoCAD.
3. Instruction in basic types of 2-dimensional and 3-dimensional engineering drawings, including orthographic, axonometric and perspective. This should be done using freehand sketching to aid students in a basic component of the design process.
4. Orthographic drawing utilizing the computer, instruments and freehand drawing as required, as these are the most common of all engineering drawings.
5. Auxiliary and sectional views as developed from orthographic drawings.
6. Dimensioning of basic types of engineering drawings including both mechanical and architectural based design drawings.
7. Heating Ventilation and Air Conditioning (HVAC) design graphics.
8. Pipe design graphics including piping, valves, and fittings.
9. Manufacturing or industrial design graphics including local or regional design problems in aerospace, agricultural, biomedical, chemical, civil, mining, and other specific engineering design areas.
10. Electrical and electronic graphic design.
11. Architectural/structural graphic design including mechanical and electrical components.[10]
12. Overview of the different types of design drawings and methods of drawing storage and reproduction.
13. A brief documented formal design project based on industrial models including:
    - Coversheet
    - Table of Contents
    - Written description of the design
    - Design drawings

At the end of first six weeks of instruction, students will be able to receive instruction in specific engineering topics of national, regional, and local demand. Mini-design projects should be incorporated into class lectures. Course work should not be limited to design of single items or to a mechanical drawing. A graphics course should include designs of installation plans, contract or guidance plans as well as pipe design, electrical design, and structural design in steel, concrete and wood frame.

In addition to traditional quizzes and exams to assess student learning, two surveys should be administered to the students:

1) at the end of the semester to assess the success of course objectives and instructor effectiveness (which is already implemented for all courses at Northeastern University). The existing survey could be modified using input from the Valparaiso model.[2]

2) after a co-operative education work experience and/or after graduation to assess engineering relevance of the new multidisciplinary graphics course. This survey would be incorporated into the existing co-op and post-graduate system of student and employer feedback.

In order to accommodate the proposed curriculum changes, several graphic topics that are traditionally included in introductory design graphics courses would need to be less emphasized or tied more closely to local industrial needs. These topics are listed in Table 3.

Table 3. Graphics topics that would be less emphasized in order to accommodate the proposed curriculum changes.

1	Drawing instruments	13	Lettering
2	Geometric construction	14	Points, lines and planes
3	Design visualization	15	Intersections and developments
4	Graphs/nomography	16	Vector graphics
5	Empirical equations	17	Technical data presentation
6	Perspective pictorials	18	Tolerances
7	Gears	19	Cams
8	Welding	20	Materials and processes
9	Screws, fasteners, bearings and springs		

Graphics courses should emphasize the multidisciplinary role of graphics as the universal language of engineers. The current popular graphics texts are mechanically based and do not meet the needs of a broad based, multidisciplinary graphics course. Additional text materials may be developed from alternate sources, as outlined in Table 4.

Table 4. Alternate sources of graphics text materials to achieve multidisciplinary graphics instruction.

1. Instructor's notes and problems, and practice-based problems from industry with examples of contract or guidance plans.
2. Custom printed text books from publishers, including Prentice Hall, who will combine sections and chapters from their published texts into a unique course text.
3. Industrial and professional internet web sites.
4. Developing web sites, including Scott McNealy's (chairman of Sun Microsystems) website: www.curriki.org. Curriki is a web site which will contain text books with subjects for all grade levels. This open-source technology will enable students to access current instructional materials affordably.
5. Architectural graphics standards, Sweets Catalogues, Time Saver Standards, and national and state codes.

Another consideration in improving engineering graphics coursework involves the preparedness of the instructors. An ideal background would include work experience in a variety of different engineering fields bringing life experience to the classroom. Smaller engineering firms frequently provide broad based experience as opposed to larger firms in which design projects tend to be specialized. Engineering registration in more than one discipline and use of the engineer's stamp on design drawings are further evidence of broad based experience. Another option is to develop a course to be team taught, faculty members contributing in their area of special interest. Guest speakers from industry may also be used to broaden the base of information presented.

A survey of industry for current requirements in engineering design may be selectively incorporated in the design graphics course. An Industrial Advisory Board (IAB) is an excellent source of multidisciplinary engineering design problems and may provide real work criticism of the students' level of preparation. Meetings with the IAB have reiterated the importance of students' ability to read and design plans, to use the scales and tools of various disciplines and to understand the relationship of the disciplines in the design process.

Conclusion

Engineering graphics is traditionally taught as a mechanically based course. A review of the most widely used textbooks illustrates this orientation.[2,4,5,6,7,8,9] Engineering graphics is a threshold course that should encompass the major disciplines in engineering to define and familiarize students with the engineering profession. A multidisciplinary approach in graphics prepares the student for upper level courses, communication among the disciplines and the ability to design and read working plans throughout the engineering professions. The inclusion of working design problems that incorporate installation drawings; structural drawing; ventilation, pipe and electrical plans; and contract or guidance plans in a basic graphics course introduces multidisciplinary design. Graphics is the universal language that unifies the engineering profession creating a common language among applied and research engineering, engineering technology, designers, drafters and technically trained people worldwide. Engineering graphics should not be limited by its historical roots in mechanical engineering.

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