Integrating Graphics in a First-Year Engineering Program

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Abstract

In the fall of 2000, Michigan Tech implemented a common first-year engineering program. Prior to the implementation of this program, students enrolled in courses during their first-year depending on their declared major. Students with no declared engineering major enrolled in a variety of courses that would likely "count" towards most engineering degrees. Before the switch, graphics courses were required for students in mechanical, civil, environmental, biomedical, mining, and materials engineering. Students in electrical, chemical, geological, and computer engineering had no graphics requirement prior to 2000. In developing the two core first-year engineering courses, compromises on all sides were required. The graphics content for some programs was necessarily reduced while the content for others increased significantly. Another feature of the new program was that the graphics content was integrated throughout the first-year courses instead of existing as a stand-alone topic in the curriculum. This paper will discuss the graphics content in the first-year engineering courses at Michigan Tech and will present assessment results that compare graphics performance achieved with that achieved prior to the adoption of the first-year engineering program.

Introduction

In recent years, several universities have adopted common first-year engineering programs. There are many advantages inherent to a common first year of engineering studies. Students are able to spend a year making up their minds about which engineering discipline they wish to pursue, before committing to a specific program. Since many 18-year olds do not typically understand the differences between engineering disciplines, and since many of our programs are relatively "unknown" (such as materials, geological, etc.), enabling students to spend a year exploring their options before making a choice will likely mean that they are more satisfied with the major they eventually choose. Another advantage to common first-year programs is that they facilitate engagement between engineering faculty and freshman students in a meaningful way. Faculty involvement is seen as a key to student retention and engineering programs have often been criticized for the contact that first-year students have with faculty in the disciplines. Finally, first-year programs enable universities to manage enrollments in some programs more effectively. If neces-

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sary, a GPA minimum can be placed on certain "hot" engineering programs to limit the number of sophomores who eventually end up in it.

Graphics has a long tradition of being an engineering course in which entering students enroll meaning that graphics has been a "natural" topic for inclusion in first-year programs. In designing the content of the first-year engineering courses at Michigan Tech, we noted that there were two basic program designs employed at other universities with common first-year programs. At some universities, such as Virginia Tech, students enroll in a problem solving course during their first semester and in a graphics course during their second semester. At other universities, such as Texas A & M, students enroll in two first-year courses which have graphics and problem-solving integrated throughout. Because Michigan Tech was implementing a first-year program in an environment where several departments did not previously require a specific graphics course, it was deemed that an integrated approach to graphics instruction might be more palatable to the College of Engineering as a whole. The challenge then was to ensure that students in those programs who had traditionally received extended graphics instruction were not shortchanged.

Graphics Instruction at Michigan Tech Prior to Fall 2000

Prior to the conversion to semesters and the adoption of the common-first-year engineering program, Michigan Tech students enrolled in a variety of graphics courses depending on their abilities and their declared major. The Michigan Tech quarters were 10-weeks in duration. Each of the five main graphics courses offered in the College of Engineering pre-2000 are described in the following paragraphs.

ME104: Engineering Graphics Fundamentals

ME104 was the first of two fundamental graphics courses in the Mechanical Engineering Department of MTU. The course was 3-credits and consisted of 3 one-hour lectures per week. Fundamentals in Descriptive Geometry were the primary focus of the course. Orthographic representation of points, lines and planes, determination of the true length of a line and the true shape and size of a plane, determination of the shortest linear distance between lines and planes, and parallelism and perpendicularity of such geometric entities such as lines and planes were topics in the course. Other course topics included intersections between two planes and between a solid and a plane as well as pattern developments of solids. Isometric projection was introduced so that students could make pictorial sketches of three-dimensional objects. Approximately one-seventh of the course was devoted to learning Pro/Engineer to develop a computer model of a three-dimensional object. Students spent most of the time in this class using drawing instruments including triangles, dividers, compasses, and protractors. Scales, lettering, and geometric constructions using instruments were also included in the course. The primary mode of instruction was by lectures with a small amount of time during lecture spent on individual work. A significant amount of individual work was done by students as homework. Suggested problems from a workbook were assigned by the instructor, but they were not required to turn in their solutions at a later date.

ME105: Geometric Modeling and Engineering Graphics in Design

ME105 was a 3-credit course that met for two hours of lecture and two hours of computer lab each week. The focus of the course was on solid modeling and design. Some of the topics in the course included: basic shape modeling techniques using wireframe, surface and solid representa-

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tions, geometric analysis, drawing extraction from 3-D parts, and assembly modeling. Sketching was an emphasis in the course, although there was some instruction in the use of drawing instruments. Other course topics included multiview drawings, pictorial drawings, sectional views and dimensioning. Geometric Dimensioning and Tolerancing was also introduced in this course. Teams were assigned a semester-long design project in the course, and the primary software tool was Pro/E.

GN131: Introduction to Engineering Graphics
GN131 was a 2-credit course in the fundamentals of engineering graphics. The course format included 2 two-hour laboratory periods per week. In each lab, the topic for the day was introduced during the first 20-30 minutes of the period. Students then worked problems on the topic for the remainder of the time. Solutions to the problems were available so that they had immediate feedback on their level of understanding of the topic. The course was completely sketching based--no drawing instruments were utilized by the students. The topics included in the course were: points, lines and planes in space (cartesian definition), points, lines and planes in space (descriptive geometry definition), pictorial sketching, object transformations, multi-view projection of 3-D objects, scales, sectional views, and dimensioning practice. Students also spent a significant portion of time on understanding/interpreting real-world engineering drawings supplied to us by industry. Students maintained a sketching journal throughout the course. They were required to sketch 3-D objects of their choosing approximately 15-20 minutes each night in their journals. Hand-held models and instructional manipulatives were used throughout the course where appropriate.

GN135:Introduction to Computer Aided Design
GN 135 was a 2-credit solid-modeling course in Computer Aided Design. It met for one hour of lab lecture and one two-hour computer lab per week. The students were required to complete nine lab exercises during the course. Of these exercises, five utilized the parametric modeling capabilities of I-DEAS Master Series software and four utilized AutoCAD 2-D drafting software. Students completed six homework assignments during the course. Four of the assignments were based on I-DEAS software and two were based on AutoCAD. In addition, students completed a design project for the course which utilized the 3-D solid modeling capabilities of I-DEAS software. Thus, much more than 50% of the course work was performed in a 3-D modeling environment. The topics in 3-D modeling that were covered in the course included profile extrusion, profile revolution, combining solids (cut, join, intersect), modifying objects, lofting, sweeping, assembly modeling, and drawing set-up. The 2-D drafting techniques in the course included drawing geometric entities (lines, circles, arcs, etc.), modifying geometry, adding annotation in the form of dimensions, labels and cross-hatching, dealing with layers in a drawing, inserting blocks, and managing a drawing (setting limits, etc.). The various ways of viewing objects and/or drawings were covered for each type of software.

Graphics in the Semester Curriculum

In the first year engineering program at Michigan Tech, there are two required engineering courses that all students must take. The first of these courses, ENG1101, has a primary focus on computer tools and communication skills. The computer skills in this course are developed in problem-solving applications such as a spreadsheet and a math solver. The students complete a team design project and must write a report and make a presentation in class. Limited graphics

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topics are introduced in this class. Isometric sketching and multiview drawings (sketching only) are introduced so that students can include some sketches in their design project reports. A brief introduction to a 2-D CAD package is also given in this course so that students can create drawings for their design project report, if they choose.

The second course in the first-year program, ENG1102, has a much stronger emphasis on graphics and visualization than the first. In ENG1102 students learn solid modeling with I-DEAS, they learn about sectional views, conventional practice, and dimensioning. They also spend some time on visualization exercises as well as some time on reading working drawings. A team design project is also assigned in ENG1102, but it has a computer modeling focus (the project in ENG1101 is design-build-test). In addition to the graphics portion of the course, there is a module on programming with MATLAB. (It should be noted that beginning in the fall of 2002, most of the visualization exercises have been moved from ENG1102 into ENG1101.)

The total amount of time spent on graphics-related (including design) topics over this two-semester sequence is approximately 24-26 sessions. (It should be noted that each class session is 1.5 hours in length to allow time for hands-on work during class.) Thus, on face value, it seems that the graphics content in the curriculum has been significantly reduced for majors such as civil, environmental, and mechanical engineering.

Assessment of Student Performance

As part of the assessment of the first-year program, two tools were utilized to determine the effectiveness of the graphics component. Both of these tools were utilized in ENG1102, since that is where the strongest graphics component was found. To assess improvements in 3-D spatial skills, the Mental Cutting Test (MCT)[1] was administered as both a pre- and a post-test. To assess basic graphics understanding a multiple-choice test developed as a placement test for graphics prior to the fall of 2000 was administered as part of the final exam in ENG1102. Since we had conducted several studies with both of these testing instruments in our prior graphics courses, we felt that they would be excellent indicators of the effectiveness of our new graphics instruction.

MCT Test Results

Table 1 includes data from pre- and post-testing with the MCT for the spring 2001 offering of ENG1102 along with data gathered in GN131 and ME104 during the fall of 1998[2]. As it can be

Table 1: Results from Pre-/Post-testing with MCT

	Mean Pre-Test	Mean Post-Test	Mean Gain	n	Level of Significance
ENG1102 (2000)	60.32	69.15	8.83	510	$p<0.0001$
GN131 (1998)	51.4	60.0	8.6	84	$p<0.005$
ME104 (1998)	60.8	67.0	6.2	119	$p<0.005$

seen from the data presented in this table, spatial skills, as measured by the MCT, were improved

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at the same rate or slightly better in our new model for graphics instruction when compared to historical data. The difference in level of significance between fall 2000 and fall 1998 is likely due to the large increase in sample size that we experienced.

Placement Test Results

The second assessment tool we used was a “standardized” test we developed at Michigan Tech that we used as a graphics placement exam prior to the fall of 2000. Due to space limitations, we did not include all 50 questions from the standardized test on our final exam for ENG1102, however, we selected 28 questions and made sure that we picked one easy, one difficult, and one of medium difficulty from each of the problem sets on the original exam. Table 2 includes data from a detailed item analysis of student performance on the 28 problems that were included in the test.

Table 2: Detailed Item Analysis of Student Performance on Standardized Test Questions

Type of Question	# of Questions	Average Score
Visualization-Rotations	3	92%
Visualization-Orthographics	6	75%
Drawing Conventions	2	83%
Sectional Views	4	75%
Dimensioning	4	80%
Reading Working Drawings	9	93%

Table 3 includes average scores on the subset of the graphics placement exam that was included in the ENG1102 final as well as data from various quarters in which the exam was given as the final in our quarter-based graphics courses[3].

Table 3: Comparison of Standardized Test Results with Historical Data

	Spring 2001 ENG1102	Spring 1999 ME104	Winter 1998 ME104	Winter 1998 GN131	Winter 1999 GN131
Final Exam Score	83.9%	83.0%	76.6%	79.3%	83.2%

From the data presented in Table 3, it seems that ENG1102 students attained a level of understanding of graphics concepts that was comparable to what they achieved in our quarter courses.

Conclusions

A first-year engineering program was implemented at Michigan Tech that integrates graphics instructions rather than including it as a stand-alone topic in the curriculum. Although the amount of time devoted to graphics instruction was reduced significantly for some majors, it seems that

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we are still achieving an improvement in visualization skills and understanding of graphics principles that are comparable to those we reached during our quarter classes.

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