Assessing Student Outcomes in an Engineering Design and Graphics Course

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Abstract

The Mechanical Engineering Department at the University of Texas at Austin has embarked on systemic educational reform throughout the curriculum. Called PROCEED, for Project-Centered Education, this curriculum reform is an attempt to bring real-world projects into the classroom that underscore the need to learn fundamental principles while adding excitement and relevance to the experience. The "Engineering Design and Graphics" course at the University of Texas is an integral part of PROCEED. This freshman course emphasizes the development of a 3-D geometric computer model and application of this digital database to all phases of the design process. The students make freehand sketches, build computer models, mate assemblies of parts, perform various analyses, create kinematics simulations, build rapid prototypes, and generate final design drawings. An assessment of student outcomes in the course was conducted in the Fall 2002 semester using a series of self-reported learning surveys. This paper depicts examples of class work that support these graphics learning activities and presents the results of these preliminary surveys, which universally showed a positive learning trend in the course.

Introduction

The freshman "Engineering Design and Graphics" course at the University of Texas at Austin continues to evolve from its inception many decades ago. In its early days, and up until about 1985, the course was primarily a drafting course that taught engineering students how to make manual board drawings and how to solve spatial geometry problems. The advent of affordable desktop computers ushered in a short-lived era of "electronic" drafting. In the 1990's, the Engineering Graphics program at the University of Texas at Austin received a series of NSF education grants (Barr, 1990; Barr, 1997) to develop a new graphics curriculum based on 3-D solid modeling principles. It was in this era that the core element of the course changed from making an orthographic drawing to building a 3-D computer model. This recent era also slowly unveiled the important applications of the 3-D model to engineering analysis, manufacturing, and downstream documentation. Low-cost analysis, simulation, and rapid prototyping software and hardware systems are now becoming available for educational purposes, and the power of this latest design paradigm is now being realized by the engineering design and graphics education community(Wiebe, 1999; Newcomber, McKell & Raudebaugh, 2001).

Project PROCEED

An engineering student project is an exercise that usually requires integrating several tasks to achieve a defined goal. It can be an individual project or a team project, or even some form of both. The Mechanical Engineering Department at the University of Texas at Austin has embarked on systemic educational reform throughout the ME curriculum. Called PROCEED, for Project-Centered Education, this curriculum reform is an attempt to bring real-world projects into the classroom that underscore the need to learn fundamental principles while adding excitement and relevance to the experience. One important aspect of PROCEED is garnering support from industrial partners who supply project ideas and personnel for the student projects. Two companies, Ford Motor Company and Applied Materials, have already

Engineering Design and Graphics Curriculum Modularization Scheme	
Module	**Activities and Learning Outcomes**
1	**Computer Sketching I:** Set up the sketch plane units and grid parameters; demonstrate all 2-D sketching primitives; demonstrate all line editing features; make simple extrusions and revolutions to get 3-D geometry. Print hardcopies of 2-D sketches and simple parts for submission.
2	**Computer Sketching II:** Demonstrate the creation and editing of dimensions; set geometric constraints; make simple extrusions and revolutions to get 3-D geometry. Print hardcopies of 2-D sketches and simple parts for submission.
3	**Solid Modeling of Parts I:** Create 3-D extrusions and revolutions of individual parts; use some basic sweep operations; edit the geometry in 3-D; render the parts. Print color hardcopies for submission.
4	**Solid Modeling of Parts II:** Create 3-D parts; add feature-based, parametric design features; use advanced sweep operations; edit the geometry in 3-D; render the parts. Print color hardcopies for submission.
5	**Assembly Modeling and Mating:** Create individual 3-D parts; assemble parts as a mechanical assembly; mate features as appropriate; check for clearance and interference of parts; create color rendering of assembly. Print color hardcopy of the rendered assembly for submission.
6	**Analysis and Design Modification I:** Create individual 3-D parts; perform mass properties analysis; generate a mass properties report; modify the design and compare mass properties before and after modification. Create a design table spreadsheet; make multiple design configurations using the design table. Print color hardcopies of the various designs for submission.
7	**Analysis and Design Modification II:** Create individual 3-D parts; perform a Finite Element Analysis (FEA) study: set up applied forces, fix constraints, perform meshing, display color stress contours, visualize and interpret results. Propose design modifications. Print a color hardcopy of the FEA results for submission.
8	**Kinematics Simulation and Rapid Prototyping:** Create a mechanical assembly; mate the parts of the assembly; simulate motion of the assembly; generate an animation (.AVI) file; play the .AVI file externally on a suitable player. Print a rendered color hardcopy of the assembly and submit it along with the animation file. Create individual parts of a mechanical assembly; generate an .STL file of each part; send the .STL files to a prototyping machine; assemble the rapid prototype parts. Submit the rapid prototype assembly once finished.
9	**Section Views in 3-D and 2-D:** Create individual 3-D parts; make different 3-D section views of the parts; export acceptable color image files of the 3-D section views for presentation purposes. Project 2-D section views of a model; incorporate the 2-D section views into a technical drawing; submit printed hardcopies.
10	**Generating and Dimensioning Three-View Drawings:** Create a 3-D part and make a three-view orthographic projection of the part; use a suitable drawing sheet style; add centerlines where appropriate; dimension the drawing; add a title block and appropriate notes. Print a black and white hardcopy for submission.
PROCEED Project	**Team Design Project:** Assign teams; acquire, study, and reverse engineer a common mechanical assembly; sketch shape and sizes of individual components; build computer solid models of parts and assemblies; perform appropriate computer analyses; make rapid prototypes of parts; generate drawings and other design documentation; propose design improvements. Submit final team project report.

Table 1

joined the PROCEED effort at the University of Texas, and have supplied projects for the freshmen students. In the "Engineering Design and Graphics" course, the PROCEED project consists of a team of four students who reverse engineer a mechanical assembly. They study the individual parts, make sketches and computer models, perform various analyses, and make rapid prototypes of their assembly. At the conclusion of this integrated graphics and design project, the team assembles a final written report.

Modularization and Assessment of Engineering Graphics

To facilitate this project-centered approach, the Engineering Graphics curriculum has been organized into a set of learning modules with specific educational outcomes. Table 1 lists the current modularization scheme and learning outcomes. It consists of ten units that serve as individual student projects, plus an integrated PROCEED project that is conducted at the conclusion of the course. With this modularization scheme, the ten individual units train students to develop computer skills

and abilities that can be later used in the larger team project.

These modern course outcomes, as outlined in Table 1, were fully implemented in the Fall 2002 semester using some preliminary computer graphics laboratory notes written by our group (Barr, Krueger, Aanstoos, & Juricic, 2003). The initial modules stress individual learning activities, which build the student's confidence in going from 2-D to 3-D solid geometric modeling. Once their confidence in computer graphics modeling is established, the students explore the many design applications for the 3-D model database. In so doing, they experience the concurrent engineering paradigm that underscores the course. Several computer graphics exercises are available for each laboratory module, thus allowing the students some choice in the objects they model and analyze. All objects selected for the exercises are real parts taken from commercial catalogs, or actual parts from the shop.

With the pedagogy and learning objectives established, the next step was assessment of the learning activities in the course. Two types of preliminary assessment metrics were gathered. Short pre- and post-surveys were conducted about the specific learning activities for the modules in selected sections of the course. These short surveys were started during the fourth week of the course, once the students had become confident with the modeling software. A second, larger survey was conducted across all sections at the end of the course. This second survey dealt with ABET student outcomes, and focused on how the "Engineering Design and Graphics" course contributed to improvement in these important student skills and abilities, as defined by the new EC2000 accreditation process11.

Student Outcomes Study 1: 3-D Solid Modeling

The first student outcomes study focused on the feature-based 3-D solid modeling unit. The learning objectives for this module included:
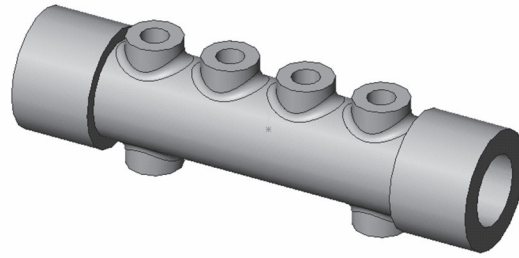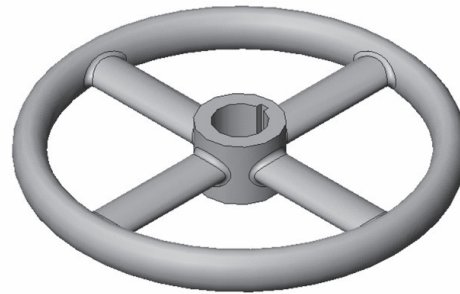

Figure 1 Air manifold

Figure 2 Hand wheel

learning basic 3-D features like extrude and revolve; creating advanced 3-D features like shell and sweep; inserting reference geometry planes; mirroring 3-D features; creating linear and circular 3-D patterns; and editing features like fillets. Typical objects for these student exercises are shown in Figures 1 (air manifold) and 2 (hand wheel). Other choices for modeling were also available.

Before the students started the module, a short survey form was completed and submitted. The survey asked the students to rank their level of understanding of the following three concepts:

1. Types of design features available in 3-D solid modeling,
2. Creating design features in 3-D modeling, and
3. Editing design features in 3-D modeling.

The response scale for the answers to the questions was: 5 (Exceptional), 4 (Good), 3 (Average), 2 (Below Average), 1 (None).

After the module exercises were completed, the same survey form was completed and sub-

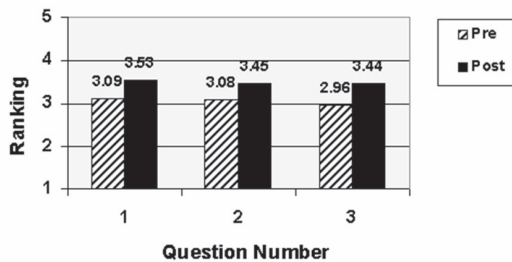| Survey 1 Results (N = 76)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	3.09	3.53	+0.44
2	3.08	3.45	+0.37
3	2.96	3.44	+0.48

Table 2

Study 1: 3-D Modeling

Figure 3 Results of Study 1

mitted to the instructor. The students were also encouraged to list things they both liked and did not like about the exercise. Results of the two surveys were compared using the pre- and post- average rankings for these three questions across the participating sections (student sample size N = 76). The average rankings for all three questions increased in the post- survey, as indicated in Table 2 and in Figure 3.

The positive increases in the rankings, for all three questions, indicate that the student learning outcomes were achieved, at least as self-reported by the students. More importantly, the students listed several common themes about what they liked about the exercises:
- They were real-world examples, not abstract.
- The software was easy to use and many features were learned.
- The visualization controls were very useful.

In contrast, the students almost universally commented on the lack of clarity in the written notes, which were still in draft form. Nonetheless, the general tone of the students
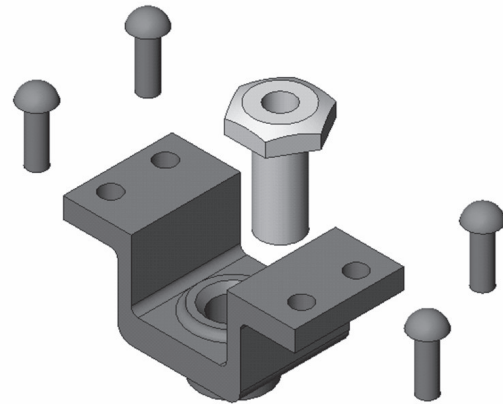

Figure 4 Terminal Support Assembly

written responses was quite positive for this first study.

Student Outcomes Study 2: Assembly Modeling and Mating

The next survey was conducted for the assembly modeling and mating module. The learning objectives for this laboratory were: 1) building multiple 3-D parts that will together; 2) starting a new assembly file; 3) dragging and dropping parts into the assembly; 4) moving and rotating components; and 5) mating the parts with different mate types. A typical student exercise consists of building the terminal support assembly, shown in Figure 4 before mating.

For this assembly module, the students learn how to change the colors of the assembly components and how to apply several mate conditions: parallel, concentric, coincident, and distance. They also get a color hardcopy of the whole assembly once the exercise is completed.

As before, a pre- and post- survey was conducted for the student learning outcomes (level of understanding) posed by the following three questions:
1. Building multiple parts in 3-D solid modeling.
2. Building an assembly of parts in 3-D solid modeling.
3. Mating parts in 3-D solid modeling.

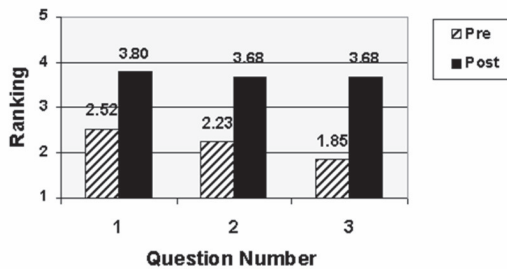| Survey 2 Results (N = 76)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	2.52	3.80	+1.28
2	2.23	3.68	+1.45
3	1.85	3.68	+1.83

Table 3

Figure 5 Results of Study 2

The same ranking scale of 5 (Exceptional) to 1 (None) was used again. Results of the pre- and post ranking averages are shown in Table 3 and in Figure 5. Again the difference between pre- and post- average rankings indicates a positive trend for all three questions. In particular, the students commented that the exercise was real-life and that they liked mating the colored parts. The one difficulty was that some mating surfaces were hard to identify without using a rotate control function, which is not an intuitive skill for the students.

Student Outcomes Study 3: Mass Properties and Design Table

The third student outcomes study was concerned with analysis of solid models using the capability of the software. The specific analyses chosen here were mass properties and design tables. For the mass properties exercise, the students build two versions of an object (like the rocker arms shown in Figure 6) and then compare how the geometric functionality differs between the two by generating mass properties reports (see Figure 7 for an example).

A design table uses a spreadsheet approach to design a family of parts. The parent
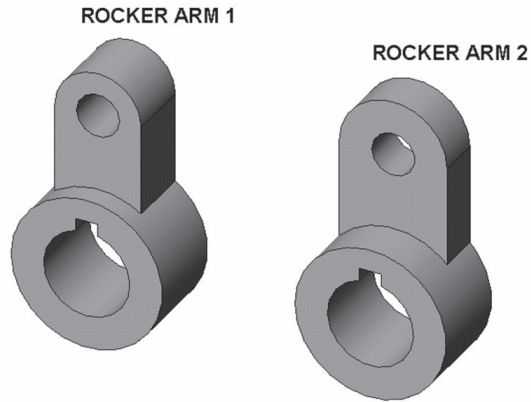

Figure 6 Two rocker arms

Density = 0.281 pounds per cubic inch
Mass = 1.264 pounds
Volume = 4.499 cubic inches
Surface area = 49.272 square inches
Center of mass: (inches)
  X = 0.000
  Y = 0.542
  Z = -0.001
Principal axes of inertia and principal moments of inertia
(pounds * square inches)
  I_x = (0.000, 0.001, 1.000) P_x = 0.894
  I_y = (1.000, 0.000, 0.000) P_y = 1.018
  I_z = (0.000, 1.000, -0.001) P_z = 1.442
Moments of inertia: (pounds * square inches) taken at the
center of mass and aligned with the coordinate system
  L_{xx} = 1.018 L_{xy} = 0.000 L_{xz} = 0.000
  L_{yx} = 0.000 L_{yy} = 1.442 L_{yz} = -0.001
  L_{zx} = 0.000 L_{zy} = -0.001 L_{zz} = 0.894

Figure 7 A Mass properties report

solid model is created, and key dimensions of this parent model are parameterized (e.g. D1@Sketch1). Then the spreadsheet cells are filled-in with the various values for the different design configurations, as shown in Figure 8. Once the design table is completed, the students execute the command that produces the different configurations of the model, for example, as shown in Figure 9.

The pre- and post- surveys posed the following three questions concerning the students' level of understanding about:
1. General engineering analysis of a 3-D solid model.
2. Mass properties analysis of a 3-D solid model.
3. Creating design tables for a 3-D solid model.

Figure 8 A design table spreadsheet

Figure 9 Design table configurations

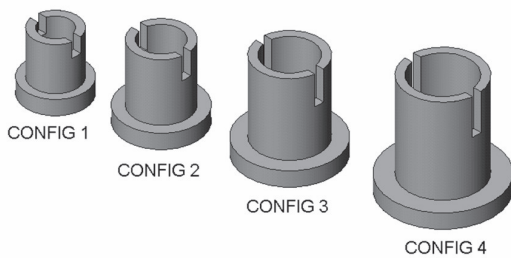| Survey 3 Results (N = 76)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	2.32	3.58	+1.26
2	2.00	3.65	+1.65
3	1.97	3.71	+1.74

Table 4

Figure 10 Results of Study 3

Results of the pre- and post ranking averages are shown in Table 4 and in the bar chart of Figure 10. Again, the differences between the pre- and post- average rankings are pronounced, and it indicates a positive increase in learning of the material.

In the post- survey form, the students offered the following general comments for study 3:
- The mass properties analysis was easy to follow.
- Liked changing the material densities to get different properties.
- Liked designing several parts with one table.

The main negative comment was that little explanation was given about the meaning of the different types of mass properties (e.g. moment of inertia) and about their units. In general, this exercise was very gratifying to the majority of the students and provided good insight about the real potential of solid modeling.

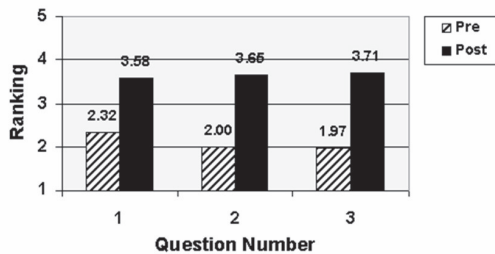### Student Outcomes Study 4: Finite Element Analysis

The fourth outcomes study dealt with finite element analysis (FEA). An example exercise used a pillow block and shaft assembly to illustrate the usefulness of FEA to analyze and improve upon a design. The students first build and assembled the solid parts. They next declare an FEA study. They assign different material properties to the two parts, and
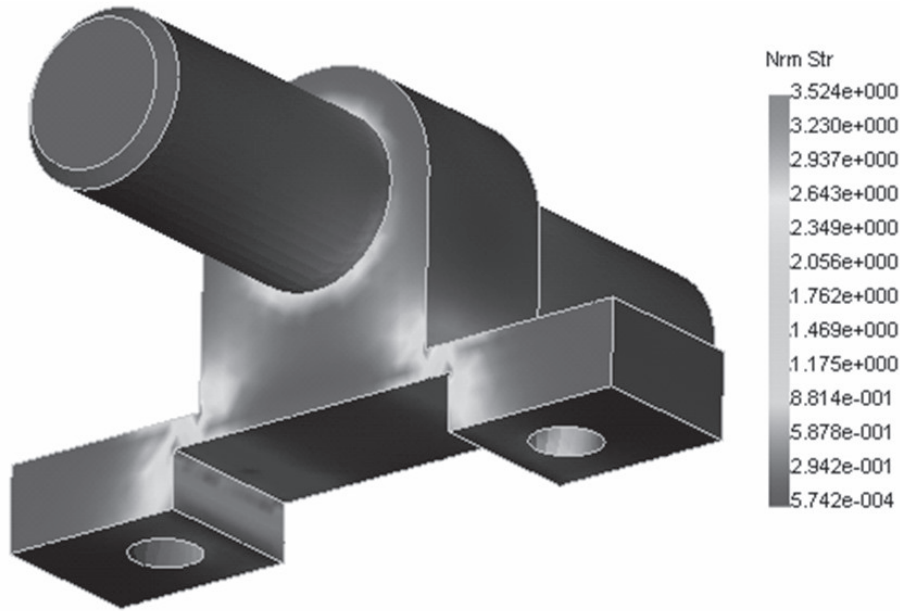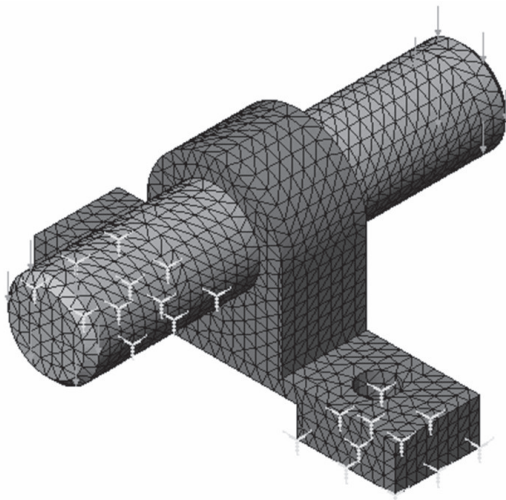
Figure 12 Stress concentrations

Figure 11 Applying a mesh

then apply constraints and forces in appropriate places. A mesh is next applied, as shown in Figure 11. They now run a static FEA study, which results in a display of the von Mises stresses, as shown in Figure 12.

The color gradient of the plot is particularly valuable in showing the stress concentrations, which are areas that need improvement in the pillow block design. The students then complete the exercise by modifying

the design. In this case, they add fillets in key places to thicken the material where the stresses had concentrated. This final step provides a vivid illustration of the advantage of the FEA method, particularly if they run a new FEA study on the improved design. This was not required, but many students ran the study anyway.

The pre- and post- surveys posed the following three questions concerning the students' level of understanding about:
1. Finite element analysis (FEA) of a 3-D solid model.
2. Applying constraints, loads and meshes to a 3-D solid model.
3. Visualizing results of an FEA study of a 3-D solid model.

Results of the pre- and post-ranking averages are shown in Table 5 and in Figure 13. Again, the differences between the pre- and post- average rankings indicate a positive increase in the general learning of finite element analysis of a solid model (at least in the context of this freshman exercise as self-reported by the students).

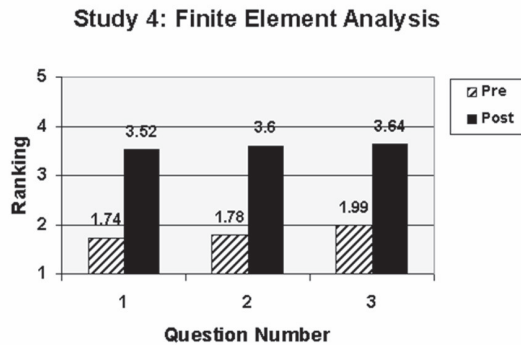| Survey 4 Results (N = 69)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	1.74	3.52	+1.78
2	1.78	3.60	+1.82
3	1.99	3.64	+1.65

Table 5
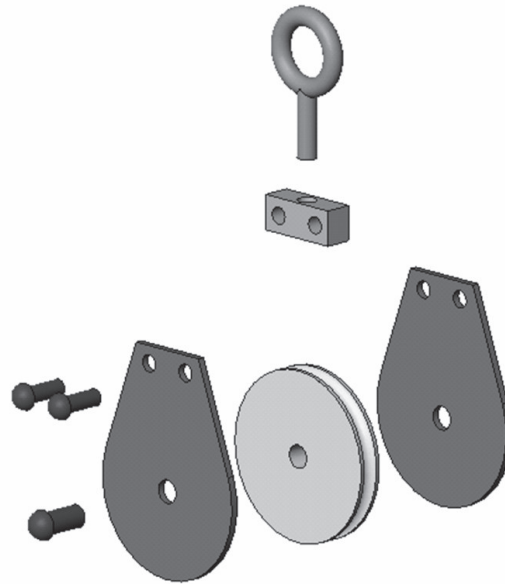

Figure 13 Results of study 4

Figure 14 Exploded Assembly

For this FEA study, the students offered the following favorable comments:
• The visualization of the results was great.
• Seeing the forces and stresses was helpful to understand the study.
• Very real-like engineering design example.

The main negative comment seemed to be universal amongst the students: the mathematics behind the finite element method remained elusive to them after the exercise was over, even though they saw the great potential for its application. One student commented while leaving the room: "This was a great exercise, but I still don't know what I did." This aspect of the FEA module needs to be improved as these types of advanced topics are introduced at the freshman level.

Student Outcomes Study 5: Kinematics Animation

The fifth student outcomes study was concerned with kinematics animation. For this module, the students either build a new assembly of solid model parts or use a previously built assembly (i.e. see study 2). While the software offers elaborate tools for creating motion pathways for animating 3-D models, a simple approach was taken in this exercise. Once the parts are properly mated into an assembly, the students use an "Explode Assembly" command available in the software. The parts are then exploded along nominal pathways as shown in Figure 14. Next they can use an "Edit Path" command for each part to create a new animation schedule. Finally they play the animation on an external viewer and then save it in a universal .AVI file format.

The pre- and post- surveys posed the following three questions concerning the students' level of understanding about:
1. Exploding a 3-D assembly of solid model parts.
2. Creating a kinematics animation of a solid model assembly.
3. Creating an .AVI animation file that can be played on an external viewer.

Results of the pre- and post- ranking averages are shown in Table 6 and in Figure 15. Once again, the differences between the pre-

Survey 5 Results (N = 67)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	1.88	3.79	+1.91
2	1.77	3.72	+1.95
3	1.88	3.70	+1.82

Table 6

and post- average rankings indicate a positive increase in the general learning activities, averaging almost +2 point increases for all three questions.

The students exit comments for this animation study were all very positive. A common comment was that it was a "cool" exercise. They liked creating an animation and saving it as an .AVI file that could be played externally. This was particularly gratifying since none of them had ever made an .AVI file before. The instructions were easy to follow, due mainly to the "Animation Wizard" and accompanying tools that were available in the software.
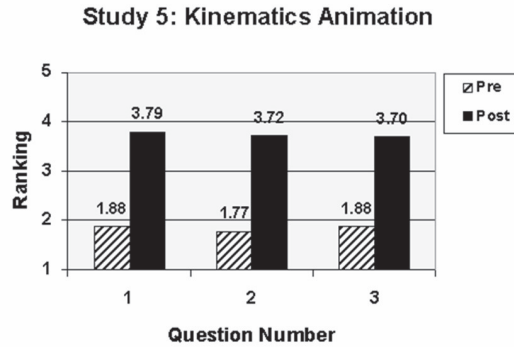
Figure 15 Results of Study 5

Student Outcomes Study 6: Rapid Prototyping

The sixth study was conducted during the rapid prototyping lab exercise. The learning activities for this module included: building a solid part; creating a stereolithography (.STL) file from the solid model data; transferring the .STL file to a rapid prototyping machine; and completing the rapid prototype. Some example parts used as student exercises for this module are shown in Figure 16. This
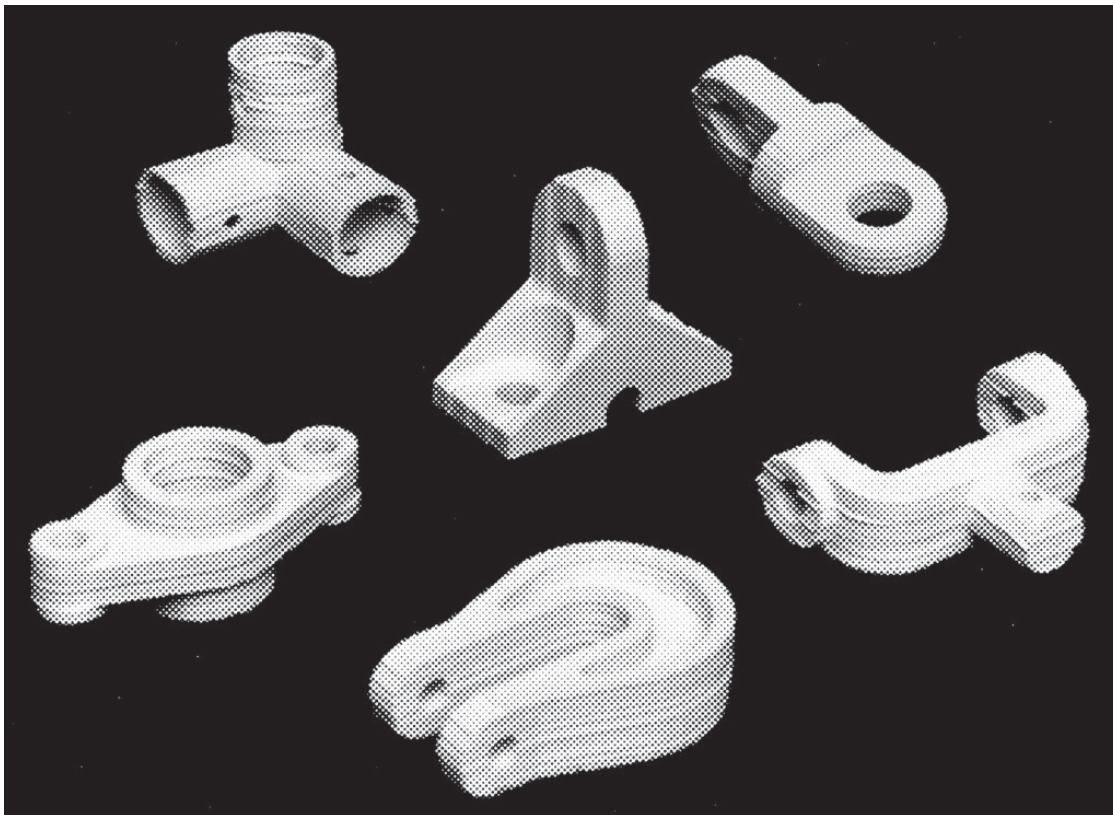
Figure 16 Rapid prototype of student parts

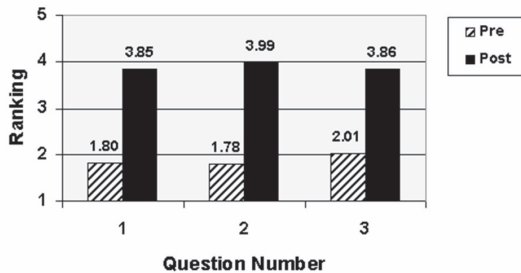| Survey 6 Results (N = 45)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	1.80	3.85	+2.05
2	1.78	3.99	+2.21
3	2.01	3.86	+1.85

Table 7

Figure 17 Results of Study 6

particular approach here uses the paper slicing and layer adhesion system.

The pre- and post- surveys posed the following three questions concerning the students' level of understanding about:
1. Generating an .STL file from a 3-D solid model.
2. Building a rapid prototype of a 3-D solid model.
3. The role of rapid prototyping in the design process.

Results of the pre- and post- ranking averages are shown in Table 7 and in Figure 17. Once again, the differences between the pre-
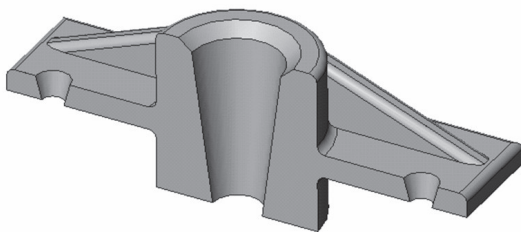
and post- average rankings indicate a positive increase in the general learning activities, averaging around +2.00 point increases for all three questions.

In general, the students enjoyed this module even though it was time-consuming due to the manual assembly requirements of the rapid prototyping system. They clearly enjoyed building a real part from a computer model. As one student stated simply, "seeing the computer sketches go to an actual model was very impressive."

Student Outcomes Study 7: Section Views in 3-D and 2-D

The seventh study focused on the traditional topic of section views, focusing on both 3-D and 2-D techniques. The educational objectives for this module included: 1) viewing 3-D section views of solid models; 2) projecting orthographic views onto a drawing sheet; 3) setting hatch pattern options; 4) creating the cutting plane line; 5) making a 2-D section view; 6) printing a section view drawing. An example of a 3-D section view student exercise is shown in Figure 18, and a 2-D section view student example is shown in Figure 19.

The pre- and post- surveys posed the following three questions concerning the students' level of understanding about:
1. Making a 3-D section view of a 3-D solid model.
2. Making a 2-D section view from a 3-D solid model.
3. Detailing a 2-D section view drawing.

Figure 18 3-D Section view
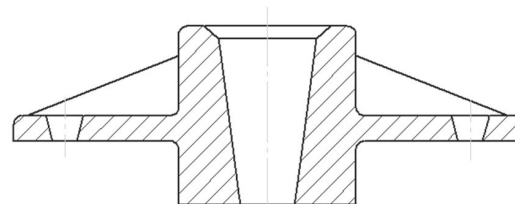
SECTION A-A

Figure 19 2-D Section view

Survey 7 Results (N = 66)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	2.13	3.84	+1.71
2	2.25	3.80	+1.55
3	2.11	3.64	+1.53

Table 8

Results of the pre- and post- ranking averages are shown in Table 8 and in Figure 20. Again, the differences between the pre- and post- average rankings indicate a positive increase in the general learning activities, although maybe not quite as large a differential as in studies 5 and 6.

Student Outcomes Study 8: Generating and Dimensioning Three-View Drawings

The final study focused on the traditional need to generate an engineering drawing for final design documentation. The learning activities and objectives for this module included: 1) inserting a drawing sheet onto the screen; 2) setting the drawing sheet options; 3) projecting three orthographic views of a solid model onto a drawing sheet; 4) adding centerlines; 5) dimensioning the drawing; 6)
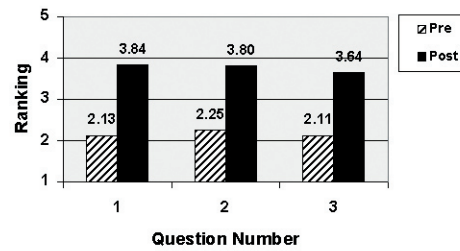
Study 7: 3-D and 2-D Section Views

Figure 20 Results of Study 7 (N = 66)

adding title block and annotations; 7) printing the drawing. A typical student computer modeling exercise is shown in Figure 21, and its projected and dimensioned engineering drawing is shown in Figure 22.

The pre- and post- surveys for Study 8 posed the following three questions concerning the students' level of understanding about:

1. Generating a three-view drawing from a 3-D solid model.
2. Arranging the three-view layout on a drawing sheet.
3. Dimensioning a three-view drawing.

Results of the pre- and post- ranking averages are shown in Table 9 and in Figure 23.
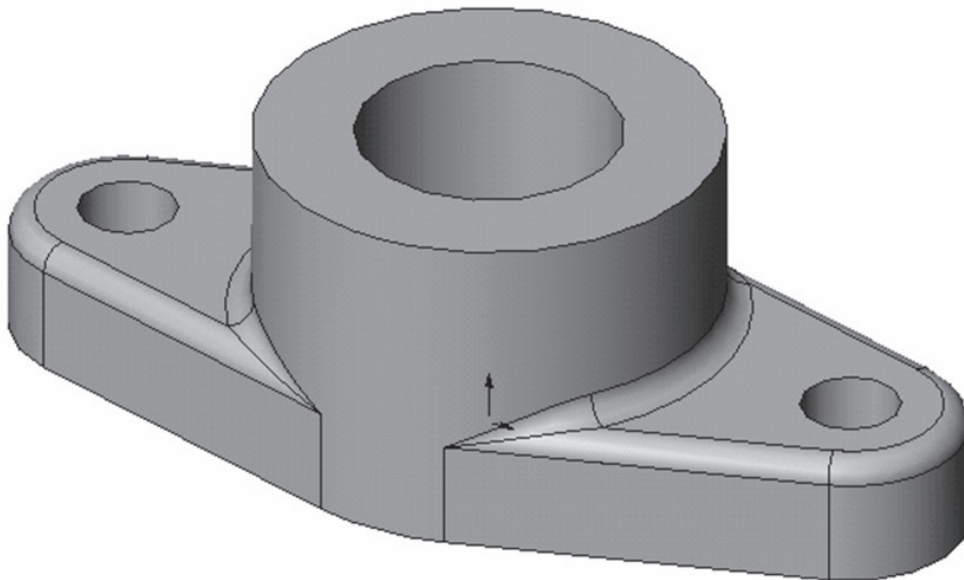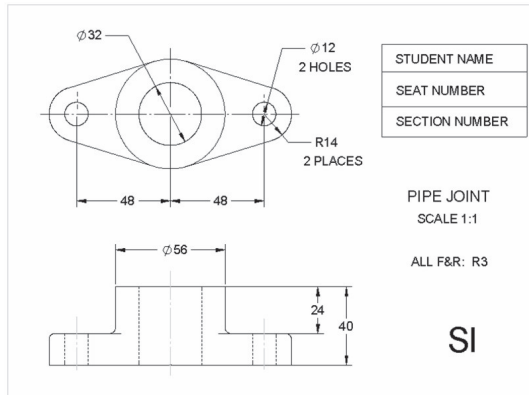

Figure 21 A 3-D computer model

Figure 22 A Dimensional drawing of a 3-D model

Again, the differences between the pre- and post- average rankings indicate a positive increase in the general learning activities, although maybe not quite as large a differential as in previous studies.

The students were generally receptive to this final learning activity, even though they realized that making an engineering drawing is relegated to a secondary role in the modern concurrent engineering paradigm. They frequently commented on the "ease" of creating three-views from a solid model with the current software. They also felt that the last two modules reinforced the basic concept of deriving design documentation from a solid model, rather than creating the documentation from scratch. The one consistent negative comment was the degree of difficulty in applying details to the final engineering drawing, particularly in placing centerlines and in deciding which dimensions to select.

Comparison of Eight Student Learning Outcomes Surveys

All eight student learning outcomes surveys showed a positive trend in learning, based on self-reported pre- and post- exercise surveys. This is to be expected, since the students gained some additional knowledge and skills doing each exercise, and appropriately reported that in the surveys. Table 10 lists the average pre- to post- increases, in descending order of average gain. It can be noted that study 6 (rapid prototyping) had the largest gain in self-reported learning, with an

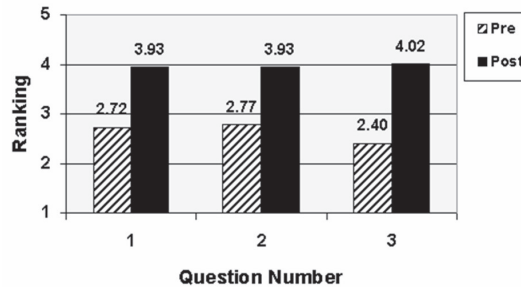| Survey 8 Results (N = 57)			
Question Number	Pre-Ranking	Post-Ranking	Difference (Post-Pre)
1	2.72	3.93	+1.21
2	2.77	3.93	+1.16
3	2.40	4.02	+1.62

Table 9

Figure 23 Results of Study 8

average increase of 2.04 ranking points, and study 5 (kinematics animation) was second with an average increase of 1.89. Conversely, study 1 (3-D solid modeling) had the lowest net gain of just 0.43 ranking points. That is not surprising since the students already had received three weeks of exposure to the modeling software before the surveys were initiated. A comparison of all the studies indicates that the advanced topics (prototyping, kinematics, FEA) were the most novel to the students and hence showed a bigger gain in the pre- to post- level of understanding of the topic. This underscores the students' enthusiastic reception of these modern, technology-based topics in their freshman engineering

Average Pre- to Post- Increases (Descending Order)	
Study	Average Increase
Study 6: Rapid Prototyping	2.04
Study 5: Kinematics Animation	1.89
Study 4: Finite Element Analysis	1.75
Study 7: Section Views in 3-D and 2-D	1.60
Study 3: Mass Properties and Design Table	1.55
Study 2: Assembly Modeling and Mating	1.51
Study 8: Dimensioning a 3-D Drawing	1.33
Study 1: 3-D Solid Modeling	0.43

Table 10

ME Program Outcomes

1. Knowledge of and ability to apply engineering and science fundamentals to real problems. (a)*
2. Ability to formulate and solve open-ended problems. (e)
3. Ability to design mechanical components, systems, and processes. (c)
4. Ability to set up and conduct experiments, and to present the results in a professional manner. (b)
5. Ability to use modern computer tools in mechanical engineering. (k)
6. Ability to communicate in written, oral and graphical forms. (g)
7. Ability to work in teams and apply interpersonal skills in engineering contexts. (d)
8. Ability and desire to lay a foundation for continued learning beyond the baccalaureate degree. (i)
9. Awareness of professional issues in engineering practice, including ethical responsibility, safety, the creative enter-prise, and loyalty and commitment to the profession. (f)
10. Awareness of contemporary issues in engineering practice, including economic, social, political, and environ-mental issues and global impact. (h,j)

* Mapping of ME program outcomes to the ABET prescribed a through k outcomes11.

Table 11

EC2000 Student Program Outcomes Study

A final survey of EC2000 student program outcomes was conducted across all ten sections of the "Engineering Design and Graphics" course in the Fall 2002. Program outcomes are defined to be the knowledge, skills, abilities, and attitudes engineering graduates should be able to demonstrate at the time of graduation. Table 11 lists the ten program outcomes for the Mechanical Engineering Department at the University of Texas at Austin. Included in the table is the mapping to the ABET prescribed a through k outcomes.

A survey was conducted to determine the level of improvement in these ME program outcomes from the beginning (pre-) of the class to the end (post-) of the class. The same pre-/post- survey form was used and it asked the students to "describe their skills and abilities supporting each outcome at the beginning (or end) of the course" using the following 5-point scale:

5 - Very significant skill/ability
4 - Significant skill/ability
3 - Some skill/ability
2 - A little skill/ability
1 - No skill/ability

Results of this survey for all the responding

students (N = 163) are shown in Table 12 and in the bar chart of Figure 24. It can be noted that all ten ME program outcomes improved from the pre- to post- condition, ranging in percent improvement from 11.3 to 67.0%. This is quite gratifying since the students felt that the graphics course was contributing to the overall departmental goals.

It is interesting to study which of the ten outcomes showed the greatest improvement, as self-reported by the students. Figure 25 shows a bar chart of the level of improvement from the pre- to post- condition. It can be noted that Outcome 3 (ability to design mechanical components, systems, and processes) and Outcome 5 (ability to use modern computer tools in mechanical engineering) received the two highest values of 67.0% and 58.8%, respectively. This is a very pleasing result, since the underlying objective of the course is to teach the modern design process using an integrated series of computer graphics exercises under the unifying theme of concurrent engineering.

No single course could realistically contribute significant improvement to all ten ME program outcomes. So there is some "halo effect" in these student ratings. For example, there was little course content on contemporary issues and global impact (outcome 10), even though the students rated it at a 30.7% improvement. Nonetheless, this

design and graphics coursework.

Results of ME Program Outcomes Survey (N = 57)				
ME Outcome	Pre-Score	Post-Score	Change (Post-Pre)	Percent Improvement
1	2.74	3.38	+0.64	+23.4%
2	3.06	3.59	+0.53	+17.3%
3	2.24	3.74	+1.50	+67.0%
4	2.62	3.3.6	+0.74	+28.2%
5	2.60	4.13	+1.53	+58.8%
6	3.13	3.91	+0.78	+24.9%
7	3.25	4.20	+0.95	+29.2%
8	3.45	3.84	+0.39	+11.3%
9	2.64	3.22	+0.58	+22.0%
10	2.41	3.15	+0.74	+30.7%

Table 12

Improvement in ME Outcomes in ME302

Figure 25 Improvement in Ten ME Outcomes for Fall 2002.
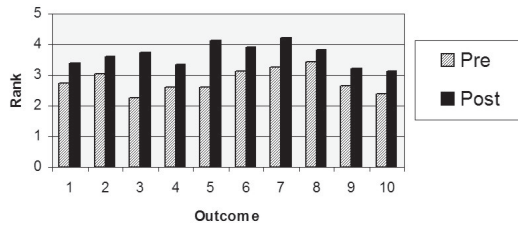
ME Outcomes Survey in ME302

Figure 24 Results of ME Program Outcomes Survey (N = 163).

survey raised an awareness in the students' minds concerning all the intellectual issues that ME faculty deem important during the students' undergraduate engineering studies. That awareness is certainly of benefit to the ME freshmen.

Discussion and Conclusions

The freshman "Engineering Design and Graphics" curriculum has evolved to a new era in which 3-D geometric computer models, and the design applications of the digital database, are the center of instruction. Table 1 lists a sequence of engineering graphics learning modules that systematically introduce the students to this new engineering design and graphics paradigm. This modular sequence was fully implemented in the Fall 2002 semester in all sections of the engineering graphics course at the University of Texas at Austin.

This paper presents the results of an initial, systematic assessment of the learning outcomes of this new approach to "Engineering Design and Graphics." Two types of assessment we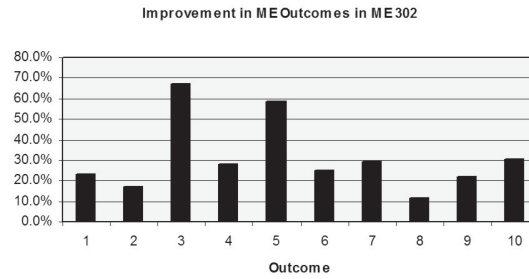re conducted. Specific learning activities for eight graphics modules were identified and formulated into a set of surveys. The surveys were conducted in three selected sections of the graphics course using self-reported pre- and post-study rankings. The results of these rankings are presented in Tables 2 through 9 in this paper. In all cases, the difference between the post- and pre- ranking score, deemed improvement in learning, showed a positive trend. This indicates that all the graphics activities resulted in a positive learning experience on the part of the students.

The second survey was conducted over all students in the course and measured the improvement in the ten ME departmental program outcomes during the course. These ten ME outcomes are listed in Table 11 and are the same ones used for the ABET EC2000 accreditation process. Results of this second study for all students in the course are listed in Table 12. A positive improvement was noted in all ten outcomes as depicted in Figure 25. While it is not surprising that engineering students would report that they learned something in a course, the overwhelming positive trend of all surveys conducted in this preliminary assessment suggests that, as a minimum, the course is well-received by the students and is on the right track. As a result of the learning activities achieved in this freshman course, it can be said that the students are prepared to meet the challenges of the ME program outcomes in subsequent courses.

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