Session 1338

Results of an EDG Student Outcomes Survey

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Abstract

Student outcomes are the knowledge, skills, and abilities that students should be able to demonstrate at the completion of an educational experience. This past year, our group has developed a list of potential student outcomes that could be used for a modern Engineering Design Graphics (EDG) course. In an effort to obtain consensus on these EDG outcomes, a survey was conducted at the Midyear Meeting of the Engineering Design Graphics Division of ASEE in Scottsdale, Arizona in November 2003. The survey was implemented in two stages. First, an interactive real-time survey was conducted during the oral paper presentation using the Classroom Participation System (CPS). Secondly, a more extensive pencil and paper survey was distributed to the attendees at the start of the conference, and was returned to the authors before the completion of the conference. This paper presents the results of that survey and attempts to interpret the results as a means for developing a modern taxonomy for the EDG field.

Introduction

The field of Engineering Design Graphics (EDG) has been influenced significantly by the advancement of computers and other new technologies. Within a span of two decades, the discipline has gone from teaching manual drafting, to teaching 2-D computer drafting, and now to the use of 3-D solid computer modeling. Near-future trends in digital analysis, virtual reality, and 3-D printing bode for even more dramatic changes in EDG practice. Attempts to define the modern course content for Engineering Design Graphics have been presented in recent journal papers.[1, 2, 3, 4] Development of a modern taxonomy for the EDG curriculum is the logical next step for the discipline.

In an effort to attain consensus on a modern EDG curriculum, a student outcomes survey was conducted at the Midyear Meeting of the Engineering Design Graphics Division of ASEE in Scottsdale, Arizona in November 2003. The survey was implemented in two phases. First, an interactive real-time survey was conducted during an oral paper presentation[5] using the Classroom Participation System (CPS). Secondly, a more extensive pencil and paper survey was distributed to the attendees at the start of the conference, and was returned to the authors before the completion of the conference. Results of these two surveys have been compiled and are presented in this paper. Some group consensus is also proposed.

The Classroom Participation System (CPS)

The Classroom Participation System (CPS) is an interactive, computer-based instructional tool that allows the presenter to poll the audience on important topics during a live presentation or lecture. Each attendee is issued a handheld responder that looks like a television remote-control device. The presenter can pose a multiple-choice question to the group during the talk, and each audience member in return presses a button corresponding to their answer to the question. Using a classroom computer or laptop hooked up to a projector, the CPS registers all the responses to the question, calculates class data, and then projects it onto the screen. Typically, this can be conveyed in the form of a bar chart showing the number of responses to answer A, B, C, or D. The audience can then instantly see the results and compare their response to others. The correct or dominant response can be then be discussed, essentially in real-time, if that is the purpose. The presenter can also save the data gathered during a CPS session for further study and analyses. Although the CPS system was used this time as a survey-gathering tool at a professional conference, the implications for use in the teaching classroom were readily obvious to the attendees.

Results of the CPS Survey

A total of ten student outcomes were proposed during the oral presentation. Each outcome was presented to the audience with a representative student example and a question posed as to its level of importance in the modern EDG curriculum. The members in the audience (N = 38) then selected a button on their remote control responder according to the following ranking scale:

A. Very Important
B. Important
C. Somewhat Important
D. Not Important
E. Not Important at All

The first outcome question addressed the student's "Ability to Sketch Engineering Objects in the Freehand Mode." The results for this outcome are shown in Figure 1. As can be seen from the chart in Figure 1, over 80% of the audience rated this ability as either A, "Very Important" or B, "Important." Thus, based on these results, freehand sketching would be viewed as a desirable student outcome.

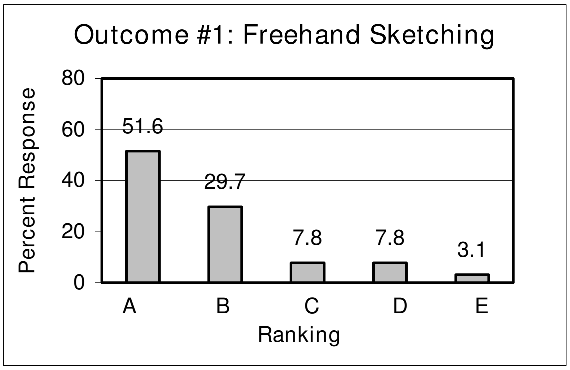

Figure 1: Results for Student Outcome #1, Ability to Sketch in the Freehand Mode.

The second outcome was concerned with the "Ability of Perform 2-D Computer Sketching." The results for this outcome are presented in the chart in Figure 2. All attendees ranked this outcome at a C, "Somewhat Important" level or higher.

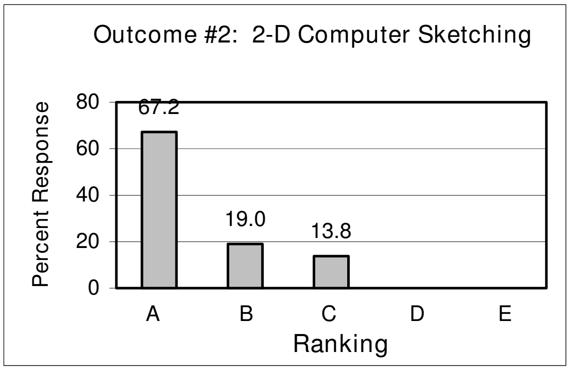

Figure 2: Results for Student Outcome #2, Ability to Perform 2-D Computer Sketching.

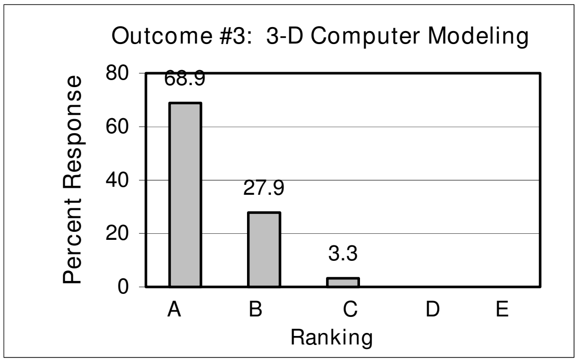

Figure 3: Results for Student Outcome #3, Ability to Create 3-D Computer Models.

The third graphics outcome was the "Ability to Create 3-D Computer Models." Results of this outcome (Figure 3) again show that all attendees rated this outcome as C, "Somewhat Important" or higher. A similar result for outcome #4, "Ability to Build Computer Assembly Models," is shown in Figure 4. One can conclude that the graphical skills needed by engineering students certainly include use of modern computer-aided design (CAD) software.

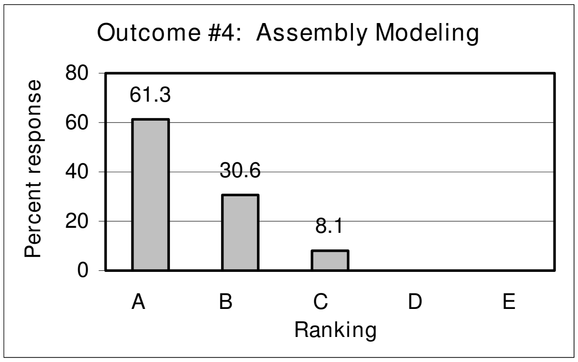

Figure 4: Results for Student Outcome #4, Ability to Build Computer Assembly Models.

The fifth student outcome in the survey was the "Ability to Analyze 3-D Computer Models." These analytical abilities would include mass properties analysis, stress-strain studies, and load deformations. As shown in Figure 5, the results of this outcome show a diversity of opinions, with no strong consensus. Over half of the attendees ranked this outcome as C, "Somewhat Important" or lower. But, no one ranked it as E, "Not Important at All."

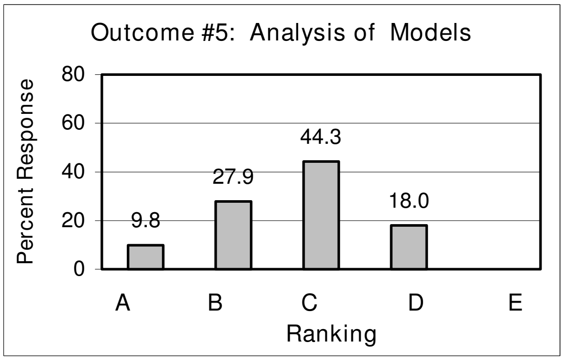

Figure 5: Results for Student Outcome #5, Ability to Analyze 3-D Computer Models.

The sixth and seventh student outcomes continued the questioning on graphical applications of the computer model. Figure 6 shows the results for "Ability to Create Kinematics Animations" and Figure 7 shows the results for "Knowledge of Rapid Prototyping and Manufacturing." In both cases, the attendees showed a diversity of opinions, somewhat resembling a bell-shaped curve centered at response C. This suggests that graphics faculty are uncertain about these modern CAD applications, although they realize the potential. It could also reflect lack of resources at some schools.

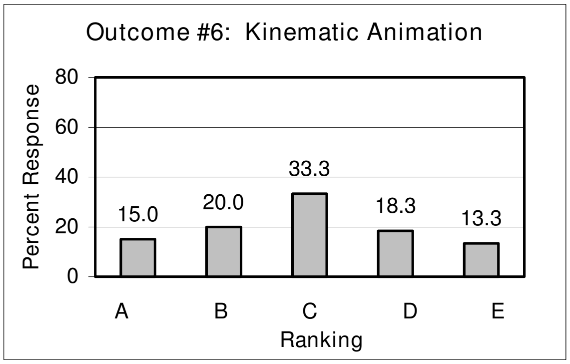

Figure 6: Results for Student Outcome #6, Ability to Create Kinematics Animations.

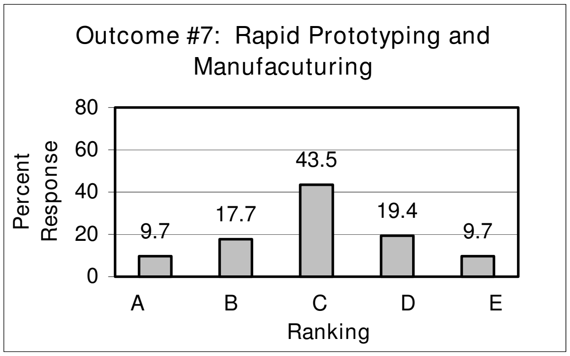

Figure 7: Results for Student Outcome #7, Knowledge of Rapid Prototyping and Manufacturing.

The seventh and eighth student outcomes returned to questions about more traditional graphics topics. Figure 8 shows the results for outcome #8, "Ability to Create Section Views in 2-D and 3-D." As can be seen, over 80% of the audience rated this section view outcome as either A, "Very Important" or B, "Important." Thus, graphics faculty feel confident about the continued importance of this traditional topic, including its application now to 3-D computer modeling.

Figure 9 shows the results for outcome #9, "Ability to Generate and Dimension Engineering Drawings." In this case, almost 60% of the responses were A, "Very Important." However, the remaining 40% of the responses were somewhat randomly distributed across B, C, D, and E.

The final student outcome was concerned with "Design Projects and Teamwork," which would include the design process, report writing and oral presentations. Figure 10 shows the results for this outcome. It can be seen that about 60% of the responses support a design graphics project, while about 40% are less enthusiastic or find no need for a team design project as part of the graphical communication education of their students.

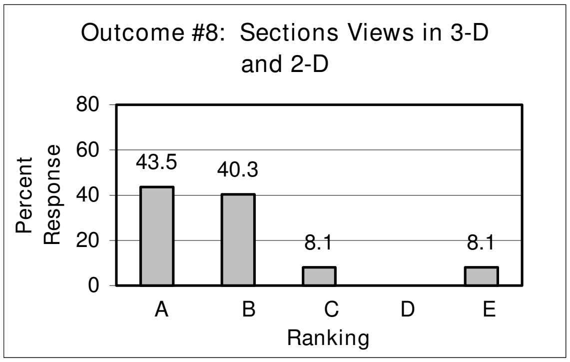

Figure 8: Results for Student Outcome #8, Ability to Create Section Views in 2-D and 3-D.

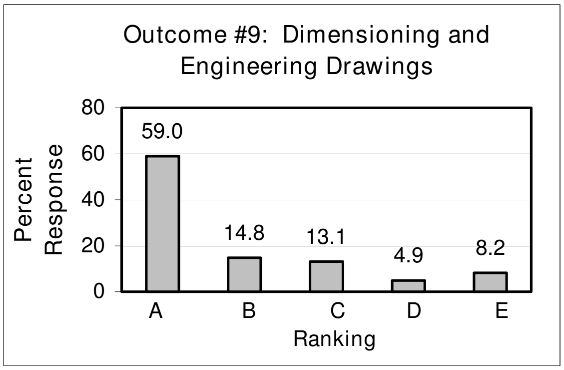

Figure 9: Results for Student Outcome #9, Ability to Generate and Dimension Engineering Drawings.

Weighted Analysis of CPS Results

One final analysis was performed on the CPS data to rank order them in level of importance based on all the reponses. A numerical weight was applied to each of the CPS letter reponses as follows:

A = 5
B = 4
C = 3
D = 2
E = 1

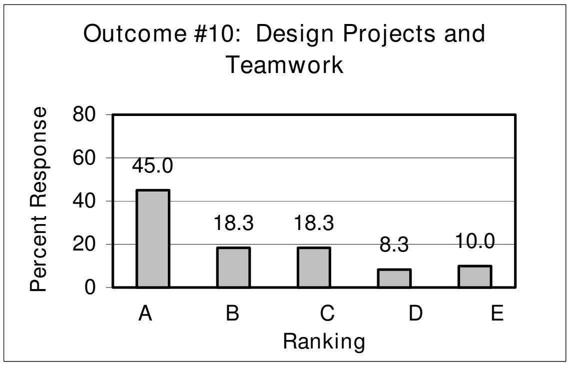

Figure 10: Results for Student Outcome #10, Ability to Perform Team Design Projects.

A weighted total ranking was then calculated for the ten outcomes using the formula:

Weighted Rank* = [(% A)*5 + (% B)*4 + (% C)*3 + (% D)*2 + (% E)*1]/100

The results of this final weighted average are depicted in Table 1. Based on these results, several observations can be mentioned. First, all of the computer-related outcomes are ranked the highest. The modern approach to computer-aided design starts with a 2-D computer sketch that is then extruded or revolved into a 3-D model. From there, the model is completed and can be mated into an assembly of parts. This process appears to be the computational core for EDG.

Second, the traditional graphics topics (sketching, dimensioning, sectioning) are ranked in the middle of the survey results. This indicates that, while the trend is towards more computer graphics usage, there is still some need for graphical exercises that build visualization and simple manual communication skills. Teaching the concept of an engineering drawing is still a viable educational objective for engineering graphics instruction.

Finally, the modern applications of 3-D computer graphics models are ranked the lowest in the survey. This is to be expected since digital analysis, animation, and prototyping capabilities are still fairly new to education, and graphics instructors are still uncertain, as a group, about how to implement this new technology into the EDG curriculum.

Table 1: Weighted Ranking of CPS Student Outcomes Results

Graphics Outcome	Weighted Rank*
Ability to Create 3-D Computer Models	4.66
Ability to Perform 2-D Computer Sketching	4.53
Ability to Build Computer Assembly Models	4.53
Ability to Sketch in the Freehand Mode	4.19
Ability to Generate and Dimension Engineering Drawings	4.12
Ability to Create Section Views in 2-D and 3-D	4.11
Ability to Perform Team Design Projects	3.80
Ability to Analyze 3-D Computer Models	3.30
Ability to Create Kinematics Animations	3.05
Knowledge of Rapid Prototyping and Manufacturing	2.99

Extended EDG Student Outcomes Survey

An extensive paper survey was conducted at the same meeting.[5] This survey expanded on the list of CPS survey questions by including all potential graphics educational objectives derived from recent journal papers.[1, 2, 3, 4] This extended EDG survey resulted in fourteen student outcomes. In addition, each outcome included a sub-list of performance criteria that demonstrate the achievement of that outcome. In all, over 80 questions were posed to the attendees, who were asked to rank each outcome or performance criteria according to a numerical scale comparable to the CPS scale:

5 = Very Important
4 = Important
3 = Somewhat Important
2 = Not Important
1 = Not Important at All

The returned paper surveys (N=24) were processed after the conference and the results were tabulated as follows by: *a*. ranking the 14 major outcomes, and *b*. ranking the performance criteria for each major outcome.

Results of Extended EDG Student Outcomes Rankings

The results of the major EDG student outcomes survey are shown in Table 2, listed in order from the highest to lowest average rank. The results from this extended paper survey are comparable to the CPS results. In particular, 3-D computer modeling is again the highest ranked outcome. Also, traditional graphics topics such as dimensions and section views are ranked somewhat in the middle, and the graphics applications like analysis and prototyping are ranked near the bottom. One notable observation is that descriptive geometry and construction with hand tools are the only outcomes ranked well below the 3.00 level.

Table 2: Ranking of Major EDG Student Outcomes from Paper Survey

Major Graphics Outcome	Average Rank
Ability to Create 3-D Solid Computer Models	4.75
Ability to Sketch Engineering Objects in the Freehand Mode	4.67
Ability to Visualize 3-D Solid Computer Models	4.46
Ability to Create Dimensions	4.38
Ability to Generate Engineering Drawings from Computer Models	4.33
Ability to Create 3-D Assemblies of Computer Models	4.29
Ability to Create 2-D Computer Geometry	4.21
Ability to Create Section Views	4.13
Ability to Perform Design Projects	3.96
Ability to Analyze 3-D Computer Models	3.71
Knowledge of Manufacturing and Rapid Prototyping Methods	3.42
Ability to Create Presentation Graphics	3.42
Ability to Solve Traditional Descriptive Geometry Problems	2.29
Ability to Create Geometric Construction with Hand Tools	2.13

Results of Performance Criteria Rankings

Each of the major EDG outcomes included a list of performance criteria that would demonstrate student achievement for that outcome. The attendees ranked the performance criteria using the same 5 to 1 scale. The results are presented in the ranked order of outcomes of Table 2, from highest to lowest.

Performance Criteria for 3-D Computer Modeling Outcome

Table 3 shows the results for the performance criteria for the 3-D computer modeling outcome. It can be seen that all performance criteria were ranked above 4.00. The main approaches to creation of 3-D geometry (extrude, revolve, edit, and apply feature) were all rated highly. The method of Boolean operations was rated slightly lower, an indication that feature-based solid modeling is becoming dominant over the older constructive solid geometry (CSG) approach.

Table 3: Performance Criteria for "Ability to Create 3-D Solid Computer Models"

Performance Criteria	Rank
Demonstrate ability to extrude or revolve 2-D profiles into 3-D model	4.71
Demonstrate ability to edit 3-D features of a computer model	4.67
Demonstrate ability to add 3-D features to a base computer model	4.63
Demonstrate ability to apply Boolean operations to 3-D primitives	4.08

Performance Criteria for Freehand Sketching Outcome

Table 4 shows the results for the performance criteria for the freehand sketching outcome. It can be seen that several criteria were highly accepted by the group, while others were soundly rejected. For example, orthographic and isometric sketching techniques were strongly supported. Applying dimensions and section views to the sketches were also ranked above 4.00. On the other hand, freehand lettering, oblique sketching, and perspective sketching were ranked very low in the survey. In addition to the raw rankings, a more subtle observation can be made here. It appears that sketching exercises not only develop the student's psychomotor skills, but also offer an opportunity to teach the various modes of engineering visualization like orthographic, isometric, and auxiliary views.

Table 4: Performance Criteria for "Ability to Sketch in the Freehand Mode"

Performance Criteria	Rank
Demonstrate ability to make orthographic multi-view sketches	4.71
Demonstrate ability to make isometric sketches	4.54
Demonstrate ability to apply dimensions to freehand sketches	4.25
Demonstrate ability to make section view sketches	4.17
Demonstrate ability to make auxiliary view sketches	3.04
Demonstrate ability to do freehand lettering	2.79
Demonstrate ability to make oblique sketches	2.46
Demonstrate ability to make perspective sketches	2.38

Performance Criteria for Visualizing 3-D Computer Models Outcome

Results for the performance criteria for the visualizing 3-D computer model outcome are shown in Table 5. The normal modes for viewing computer models, such as setting the orthographic or axonometric view directions, and zooming, panning, and rotating the object, are rated above 4.00. On the other hand, graphics faculty do not see the need to include advanced techniques, such as stereoscopic viewing or virtual realty, in the current EDG curriculum.

Table 5: Performance Criteria for "Ability to Visualize 3-D Solid Computer Models"

Performance Criteria	Rank
Demonstrate ability to select axonometric or orthographic views	4.29
Demonstrate ability to set view direction	4.25
Demonstrate ability to pan, rotate, and zoom computer model	4.13
Demonstrate ability to set the transparency of model faces and edges	2.88
Demonstrate ability to use stereo or virtual reality to view computer models	1.92

Performance Criteria for Ability to Create Dimensions Outcome

Results for the performance criteria for the ability to create dimensions outcome are shown in Table 6. As can be seen, the various styles of dimensioning practices (vertical, horizontal, diameter, radius, notes, etc.) were all ranked above 4.00. With the possible exception of thread notes, these results show general support for dimensioning in the EDG curriculum.

Table 6: Performance Criteria for "Ability to Create Dimensions"

Performance Criteria	Rank
Demonstrate ability to apply vertical and horizontal dimensions	4.38
Demonstrate ability to apply diameter and radius dimensions	4.38
Demonstrate ability to apply standard dimension notes	4.25
Demonstrate ability to apply tolerances to dimensions	4.00
Demonstrate ability to apply thread notes	3.71

Performance Criteria for Ability to Generate Engineering Drawings from Computer Models

Table 7 shows the results for the performance criteria for generating engineering drawings. In general, the results support all the abilities needed to accomplish this outcome: orthographic projection, setting line types, adding centerlines, and setting the title block.

Table 7: Performance Criteria for "Ability to Generate Engineering Drawings"

Performance Criteria	Rank
Demonstrate ability to project orthographic/auxiliary views into a drawing	4.33
Demonstrate ability to set visible and hidden lines on the drawing	4.29
Demonstrate ability to set proper centerlines on the drawing	4.08
Demonstrate ability to set up a drawing sheet in computer space	3.96
Demonstrate ability to insert a title block and annotations on the drawing	3.83

Performance Criteria for Creating 3-D Assemblies of Computer Models Outcome

Results for the performance criteria for creating assemblies of computer models outcome are shown in Table 8. The abilities to mate and to move or rotate the parts in the assembly were viewed by the graphics faculty as necessary skills for this outcome, and thus were rated above 4.00. The need to explode an assembly (move parts away from the core in an organized fashion) received a middle ranking of 3.58. However, there was little support for the ability to color the various parts to visually distinguish them in the assembly.

Table 8: Performance Criteria for "Ability to Create 3-D Assemblies of Computer Models"

Performance Criteria	Rank
Demonstrate ability to mate individual parts in an assembly	4.33
Demonstrate ability to move and rotate individual parts in an assembly	4.25
Demonstrate ability to explode an assembly of parts	3.58
Demonstrate ability to color parts in an assembly	2.88

Performance Criteria for Creating 2-D Computer Geometry Outcome

Table 9 shows the results for the performance criteria for creating 2-D computer geometry. All of these performance criteria were ranked 3.75 or higher. This is consistent with the high rankings of the 3-D computer modeling performance criteria, since most 3-D solid models start with some 2-D layout geometry.

Table 9: Performance Criteria for "Ability to Create 2-D Computer Geometry"

Performance Criteria	Rank
Demonstrate ability to apply relations and dimensions to 2-D sketch	4.29
Demonstrate ability to create 2-D lines and primitives	4.25
Demonstrate ability to a use 2-D editing features	4.13
Demonstrate ability to set up grids, units, and sketch planes	3.75

Performance Criteria for Ability to Create Section Views Outcome

Table 10 shows the results for the performance criteria for creating section views. It can be noted that the attendees supported creating section views in both 3-D models and 2-D drawings. They also supported instruction in the various types of sections views (full, half, offset, broken out, etc.). However, there was less support for teaching the different cross-hatching patterns that were prevalent during the manual drafting days.

Table 10: Performance Criteria for "Ability to Create Section Views"

Performance Criteria	Rank
Demonstrate ability to create a section view of a 3-D computer model	4.04
Demonstrate ability to generate a 2-D section view from computer model	4.00
Demonstrate knowledge of various types of section views	3.96
Demonstrate knowledge of cross-hatching practices in section views	3.46

Performance Criteria for Ability to Perform Design Projects Outcome

Table 11 shows the results for the performance criteria for design projects. As can be seen, the group ranked teamwork, oral and written reports, and knowledge of the design process right at 4.00. Knowledge of reverse engineer received a lower ranking, but still above 3.50.

Table 11: Performance Criteria for "Ability to Perform Design Projects"

Performance Criteria	Rank
Demonstrate ability to work in teams	4.00
Demonstrate ability to make an oral technical presentation	4.00
Demonstrate knowledge of the design process	3.96
Demonstrate ability to write a technical report	3.96
Demonstrate knowledge of reverse engineering	3.63

Performance Criteria for Ability to Analyze 3-D Computer Models Outcome

The results of the analysis of 3-D computer models student outcome are shown in Table 12. Mixed opinions seem to prevail in this outcome. The group was reasonably supportive for measuring geometry, using design tables, and mass properties analysis. All received rankings between 3.00 and 4.00. However, finite element analysis was less supported, receiving an average ranking of only 2.63.

Table 12: Performance Criteria for "Ability to Analyze 3-D computer Models"

Performance Criteria	Rank
Demonstrate ability to measure geometry of a computer model	3.88
Demonstrate ability to use spreadsheets, design tables and other solvers	3.29
Demonstrate ability to analyze mass properties of a computer model	3.21
Demonstrate ability to perform finite element analysis (FEA)	2.63

Performance Criteria for Manufacturing and Rapid Prototyping Outcome

Table 13 lists the results for the knowledge of rapid prototyping and manufacturing outcome. Knowledge of design features, and to a lesser extent machine shop practices, were supported. Knowledge of modern concurrent and life-cycle engineering received mixed results. The remaining topics (welding, materials, rapid prototyping) were generally not supported.

Table 13: Performance Criteria for "Knowledge of Manufacturing and Rapid Prototyping"

Performance Criteria	Rank
Demonstrate knowledge of common design features (fillets, rounds, etc.)	4.08
Demonstrate knowledge of machine shop processes (lathe, mill, drill, etc.)	3.46
Demonstrate knowledge of concurrent engineering and product life-cycle	3.13
Demonstrate knowledge of welding and fastening	2.92
Demonstrate knowledge of material selection practices	2.71
Demonstrate knowledge of rapid prototyping	2.71

Performance Criteria for Ability to Create Presentation Graphics Outcome

Table 14 shows the results for the ability to create presentation graphics. Reasonable, but not strong, support is shown for the making of charts and graphs for technical reports, and for making computer slide presentations. Less support is given to animation and web graphics.

Table 14: Performance Criteria for "Ability to Create Presentation Graphics"

Performance Criteria	Rank
Demonstrate ability to make data graphs and charts	3.46
Demonstrate ability to make electronic computer slide shows	3.42
Demonstrate ability to make rendered color hardcopies of computer models	3.08
Demonstrate ability to make kinematics animation files of computer models	2.88
Demonstrate ability to make graphics presentations on the WWW	2.79

Performance Criteria for Ability to Solve Traditional Descriptive Geometry Problems Outcome

Table 15 shows the results for descriptive geometry problem solving skills. It can be seen that all categories were rejected, with all ratings below 2.50. Thus, this traditional topic is outdated and should be dropped from the EDG curriculum.

Table 15: Performance Criteria for "Ability to Solve Traditional Descriptive Geometry Problems"

Performance Criteria	Rank
Demonstrate ability to locate points, lines, and planes in space	2.50
Demonstrate ability to solve intersection and development problems	2.42
Demonstrate ability to solve line and plane relationship problems	2.33
Demonstrate ability to solve revolution problems	2.29
Demonstrate ability to solve graphical vector geometry problems	2.21
Demonstrate ability to solve spatial curve problems	2.17
Demonstrate ability to solve topographic problems	2.17
Demonstrate ability to solve dihedral angle problems	2.13

Performance Criteria for Ability to Create Geometric Construction with Hand Tools Outcome

Table 16 shows the results for the geometric construction using hand tools outcome. It can be seen that all categories were rejected, with all ratings below 2.50. Thus, using hand tools like a compass and drawing triangle are no longer viable in the EDG curriculum.

Table 16: Performance Criteria for "Creating Geometric Constructions with Hand Tools"

Performance Criteria	Rank
Demonstrate ability to construct parallel and perpendicular lines	2.46
Demonstrate ability to construct arcs, circles, and polygons	2.42
Demonstrate ability to construct tangencies and irregular curves	2.38

Conclusions

This paper has presented the results of two complementary EDG student outcomes surveys conducted at the Midyear Meeting of the Engineering Design Graphics Division of ASEE in Scottsdale, Arizona in November 2003. The first survey was presented using an interactive Classroom Participation System (CPS) that, in addition to gathering the data, demonstrated the potential of this approach to the faculty in attendance. The second paper survey asked a more extended set of outcomes and their related performance criteria. In reviewing and interpreting the results of this study, it appears that the modern EDG curriculum should focus on three areas of instruction, as shown in Table 17. This trichotomy of instruction should include: *a*. computer modeling fundamentals; *b*. engineering graphics fundamentals; and *c*. application of the computer model to digital analysis, manufacturing, presentation, and design.

Table 17: Trichotomy of Modern EDG Curriculum
A. Computer Graphics Modeling Fundamentals
Creation of 3-D Computer Models
Creation of 2-D Computer Geometry
Building Computer Assembly Models
B. Engineering Graphics Fundamentals
Freehand Sketching
Generation of Engineering Drawings
Dimensioning
Sectioning
C. Computer Graphics Modeling Applications
Digital Analysis
Animation and Simulation Presentations
Rapid Prototyping and Manufacturing
Design Projects

Bibliography

1. Barr, R. E., "Planning the EDG Curriculum for the 21st Century: A Proposed Team Effort," *Engineering Design Graphics Journal*, 63(2):4-12, 1999.

2. Meyers, F.D., "First Year Engineering Graphics Curricula in Major Engineering Colleges," *Engineering Design Graphics Journal*, 64(2):23-28, 2000.

3. Branoff, T.E., Hartman, N.W., and Wiebe, E.N., "Constraint-Based Three Dimensional Solid Modeling in an Introductory Engineering Graphics Course: Re-Examining the Curriculum," *Engineering Design Graphics Journal*, 66(1):5-10, 2002.

4. Smith, S.S., "A Design-Based Engineering Graphics Course for First-Year Students," *Engineering Design Graphics Journal,* 67(2):33-42, 2003.

5. Barr, R.E., Krueger, T. J., and Aanstoos, T. A.: "Defining Student Outcomes for Engineering Design Graphics," *Proceedings of the 2003/04 Midyear Meeting of the Engineering Design Graphics Division of ASEE,* Scottsdale, Arizona, November 2003.