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A Freshman Engineering Design Graphics Collaboratory

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Abstract

This paper briefly reviews the author's experiences over the past four decades in transforming the Engineering Design Graphics (EDG) curriculum. During this time, the field has seen a remarkable evolution from manual drafting to 3-D computer modeling with its many applications to engineering design and analysis. The paper will further discuss the current status of the EDG curriculum at the author's home institution. The current concept is an EDG collaboratory space, in which teamwork and a design project are the overarching theme in which graphics and 3-D modeling fundamentals are taught.

Introduction and Background

Changes in the Engineering Design Graphics (EDG) curriculum over the last four decades have been driven by changes in technology. The drafting machine has been replaced by a computer, and the manual pencil and paper have been replaced by 3-D modeling software. Faculty were aware of solid modeling in the 1980's, but transitioning to solid modeling as the core topic in the EDG curriculum started to accelerate in the 1990's and beyond (Barr, et al., 1994; Ault, 1999; Branoff, et al., 2002; Bertozzi, et al. 2007). A logo shown in Figure 1a was developed to express the author's ideas at that time, and the logo has subsequently been translated into other languages as shown in Figure 1b (Borges and Souza, 2015).

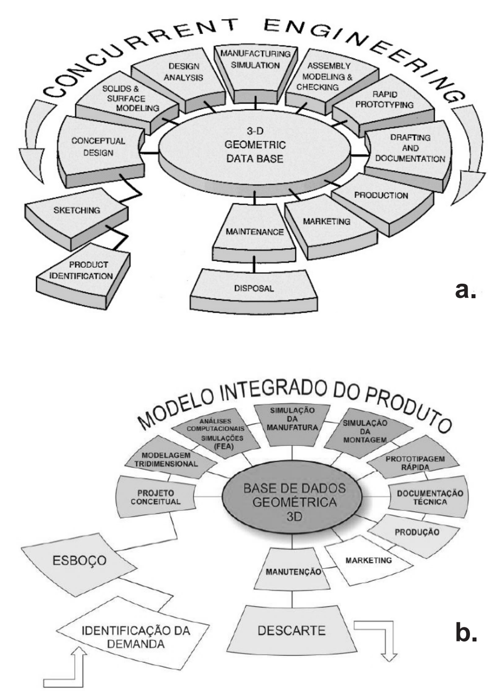

Figure 1. a. Logo to describe 3-D geometric modeling by Barr, et al. (1994) b. Logo translated into Portuguese by Borges and Souza (2015).

As the 3-D modeling paradigm took hold in engineering education, EDG faculty began exploring applications of the model to design projects (Smith, 2003), engineering analysis using finite elements (Balamuralikhrishna and Mirman, 2002; Groendyke and O'Dell, 2002), 3-D animation studies (Lieu, 2004), and 3-D rapid prototyping applications (DeLeon and Winek, 2000). These advances in 3-D geometric modeling further advanced the role of Engineering Design Graphics in

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developing modern spatial skills (Sorby, 2005; Connolly, 2009) that are so important in engineering education today.

A triad schematic of the relation between graphics fundamentals, computer modeling fundamentals, and computer model applications has emerged as shown in Figure 2 (Barr, 2012). A group of EDG faculty are currently working to consolidate a graphics concept inventory (Sadowski and Sorby, 2014) which will greatly aid in determining the important graphics fundamentals that should remain in the EDG curriculum (top box of Figure 2).

Authors from Europe and the United States (Danos et al. 2014) recently coined a term "graphicacy," calling for a universal improvement in graphics capability for all students, thus extending EDG principles beyond engineering into everyday society. With the makerspace phenomena on campuses that is spanning all majors, along with the advent of low-cost 3-D printers and new forms of modeling software to run them, the thought of universal graphicacy in society may already be happening.

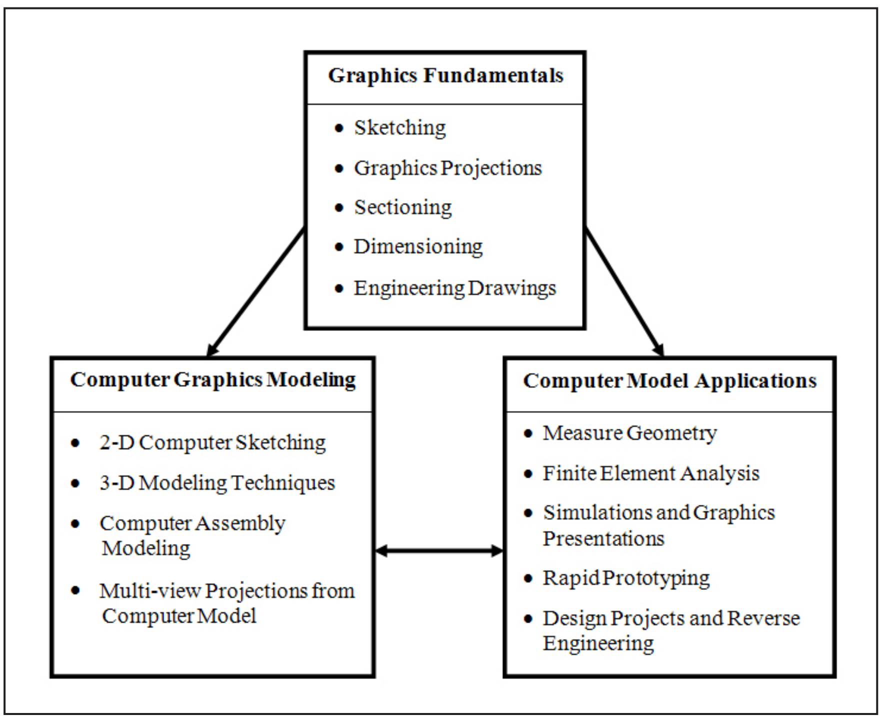

Figure 2. The Engineering Design Graphics Triad for Instruction (Barr, 2012).

Engineering Design Graphics Collaboratory

According to Wikipedia (Wulf, 1993) the word "collaboratory" is used to describe a creative process where a group of people work together to generate solutions to com-

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plex problems. In this context, by fusing two elements, “collaboration” and “laboratory”, the word “collaboratory” suggests the construction of a space where people explore collaborative innovations. The current space used for Engineering Design Graphics at the author’s institution is shown in Figure 3. Old drafting tables and front lecture dais were replaced with flat tables with four chairs surrounding each table, to enable students to interact face-to-face. The instructor’s podium is in the middle of the room for facilitation, with projection systems on walls around the room to display key instructional concepts. The university-supplied computers were sent to surplus and replaced with student-supplied laptops running the latest version of SolidWorks. The use of teamwork and a reverse-engineering design project (Barr, et al. 2014) are the overarching theme in which the EDG triad of instruction (Figure 2) is delivered.

Most of our students are freshmen, and it is important to focus on creating an engineering design thinking mindset in the class. To accomplish this design thinking goal, the instructor discusses the four C’s (Figure 4) in the context of design. The four C’s are a different way of looking at the design process, while helping to develop the crucial inter-personal professional skills that are dearly needed in engineering.

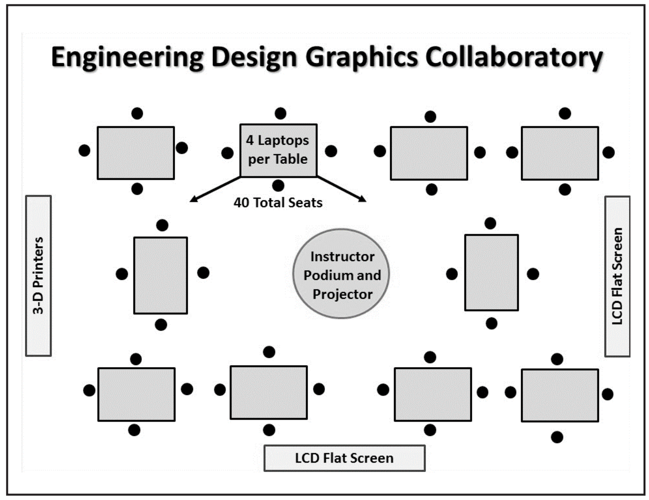

Figure 3. Layout for the EDG collaboratory.

Critical Thinking: You start as a freshman in engineering and in your first engineering course you learn that engineers solve problems. So you need to develop and use critical thinking.

Creativity: As you critically think about the problem, you will come up with many ideas for a solution, some perhaps good and others perhaps a little unusual. So you need to become creative in your thinking to expand the possibilities.

Collaboration: As you try to decide which ideas are best, you find the need to talk to other people about your ideas. Hence you need to collaborate and learn about teamwork to solve complex problems.

Communication: As members of your team start to talk to each other to explain their ideas with words, sketches, and computer images, you find out that effective communication is essential, and is the most important “C.”

Figure 4. The Four C’s are used to establish a design thinking mindset in the students.

Student Survey

This was the first academic year in which the Engineering Design Graphics course was taught as a collaboratory. The instructional triad shown in Figure 2 served as the

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basis for the sketching, computer modeling, and design application exercises used in the course. A student survey of all the topics was conducted to gain feedback from the students. The survey asked students to rank the topics based on how helpful the activity would be in their future engineering career. The responses were on a seven-point Lickert scale, with 7 (extremely helpful), 4 (somewhat helpful), and 1 (not helpful at all). The results of the survey (N = 84) are shown in Table 1 for sketching exercises, Table 2 for computer exercises, and Table 3 for design project exercises. Not surprising, the highest ranked topics pertained to 3-D computer modeling using the popular software SolidWorks. Five of the ten computer topics received scores of 6.00 or higher. Some of the sketching exercises, and in particular isometric sketching, also received good scores. The students also liked the team design project, particularly the 3-D printing aspect of the project.

Discussion and Conclusion

It is gratifying to note that the relationship of graphics to engineering design was ranked very high (score of 6.19). The most important objective of the course was to transition from an historical drafting course, with one-hundred year roots on campus, to a design-centric course. Thus, showing how graphics can contribute to a design project is extremely important. Also, the lowest rated topic was the method of assigning teams (score of 4.79). Experienced faculty might think that using a personality-typing method, such as the MBTI, would be very useful in forming teams. However, these results disprove that thinking. As faculty, we must realize that college freshmen nowadays have other ways of intermixing, socializing, introducing themselves, and finding team partners. The MBTI is a foreign concept.

One final comment was offered by one of the students in the survey. It pertains to the perception that sketching and graphics fundamen-

Table 1
Graphics Fundamentals Through Sketching

Design Sketching: Visualization Techniques	**6.05**
Design Sketching: Isometric Views	**6.02**
Design Sketching: Section Views	**5.89**
Design Sketching: Dimensions	**5.87**
Design Sketching: Orthographic Multi-Views	**5.83**
Design Sketching: Sketching Lines	**5.77**
Design Sketching: Design Features and Modifications	**5.60**
Design Sketching: Oblique Views	**5.51**
Ave.	**5.82**

Table 2
3-D Computer Modeling Fundamentals

SolidWorks: Creating 3-D Parts and Features	**6.54**
SolidWorks: Creating Parts Using Extrusions, Revolutions	**6.52**
SolidWorks: Assembly Modeling and Mating	**6.45**
Loading and Using SolidWorks on Your Laptop	**6.15**
SolidWorks: Kinematic Animation	**6.10**
SolidWorks: Creating Section Views	**5.96**
SolidWorks: Dimensioning Layout Drawings	**5.95**
SolidWorks: Finite Element Analysis, Re-Design	**5.93**
SolidWorks: Mass Properties Analysis, Design Tables	**5.77**
Ave.	**6.15**

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tals are less important now during this age of 3-D computer modeling. This student quoted: “The results of the survey will probably show that the class thinks the sketching assignments are less helpful for their careers. However, I believe that the sketching exercises helped me understand 3-D objects and made learning SolidWorks easier.” Visualization is the key to good design work and team interaction, and the various forms of graphics projected in the course help to develop this visualization skill. As we move forward into the second year of the EDG collaboratory, student feedback like the ones presented here, will help to further shape and improve the curriculum.

Table 3
Application to Team Design Project

Relationship of Graphics to Engineering Design	**6.19**
Team Project: Printing Rapid Prototypes	**6.15**
Team Project: Oral Presentation	**6.01**
Introduction to Engineering and Teamwork	**5.96**
Team Project: Dimensioned Layout Drawings of Parts	**5.94**
Team Project: Computer Modeling and Mass Properties	**5.88**
Team Project: Final Written Report	**5.85**
Team Project: Project Re-Design	**5.81**
Team Project: Sketching Project Parts and Assemblies	**5.63**
Team Project: Written Proposal	**5.61**
Team Project: Planning Charts and Diagrams	**5.55**
Team Project: Materials and Manufacturing	**5.49**
The MBTI and Assigning Teams	**4.79**
Ave.	**5.76**

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