A Gallery of CAD Generated Imagery: Pedagogical Reflections

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Abstract

A gallery of imagery generated from many of the recent CAD (computer-aided-design, or *graphics*) projects undertaken by St. Thomas undergraduates in mechanical engineering courses (*Engineering Graphics* in particular) are presented. The CAD projects vary widely, e.g. as characterized by the geometric features present in the parts, assembly structure, number of parts in the assembly, overall complexity, physical scale, industry represented, in addition to coloring and other presentation and viewing issues. The primary purpose of this effort is to elegantly showcase the body of quality work generated in a relatively compact manner to permit an enjoyable perusal and reflection that may be of use to others teaching future CAD courses or others, such as students interested in CAD work in a BSME program. In addition, one can see the natural evolution of the course since it was first taught over the past 3 ½ years. The projects demonstrate the application of CAD knowledge acquired in the freshman *Engineering Graphics* course where SolidWorks® has been taught recently. However, because of the wide applicability of CAD, projects from other courses (such as *Kinematics and Mechanism Design*, *Machine Design and Synthesis*, the *Senior Design Clinic* sequence, and occasionally *Introduction to Engineering*) are emphasized as well, although not all of them are presented. Finally, as a result of the success of the *Engineering Graphics* course, a course description is provided and a number of pedagogical issues are discussed: modeling strategies, motions/mechanisms involved, number of components, length of time for project, number of team members, along with other practical advice for maximizing the successful implementation of CAD projects for students.

Keywords: computer-aided-design, CAD, solid modeling, instruction, project work

Introduction

The history of computer-aided-design (CAD) coursework at St. Thomas, a liberal arts university, dates back to 1995 when the *Engineering Graphics* course was offered for the first time. In those days, the Engineering Department offered a BS in Manufacturing Engineering, but not a BS in Mechanical Engineering (BSME). Of course, CAD instruction is required for both degrees, so a section of the course has been offered at least yearly since that time, and as many as 4 sections per year recently. The course was developed and taught by the third author and based upon similar courses taught at Dunwoody College of Technology, known for its Manufacturing and Mechanical Engineering Technology (MET) programs. The course had two tracks: (1) interpreting engineering drawings (IED) which is traditional drafting, and (2) CAD training (AutoCAD, release 12). Textbooks for the course were *Interpreting Engineering Drawings* by Jenson and Hines for the IED track and *Using AutoCAD Release 12* by J. E. Fuller for the CAD track[1,2]. Students were also required to complete a computer-aided-drafting project (such as the "trolley" assembly from the IED book).

Currently, the course retains the same basic format, although as technology has advanced, the CAD software has necessarily changed over the years from what was largely computerized drafting using AutoCAD, release 12 to true solid modeling, including limited animation, using SolidWorks® (current version in use: 2004); for textbooks see[3-7].

The course objective is:
To provide an overview of graphical communication as it is applied to the engineering discipline. Topics covered will include sketching and visualization, descriptive geometry, multi-view drawings, dimensioning, creation and interpretation of working drawings and three-dimensional modeling.

The course description is:
Students will learn the basics of engineering graphics including freehand sketching and computer-aided-design/drawing using SolidWorks® 2004. The course will include extensive hands-on drawing time (free-hand and computer) as well as demonstrations, some extra time on the computers during open laboratory time in addition to the time provided in class (laboratory hours will be arranged).

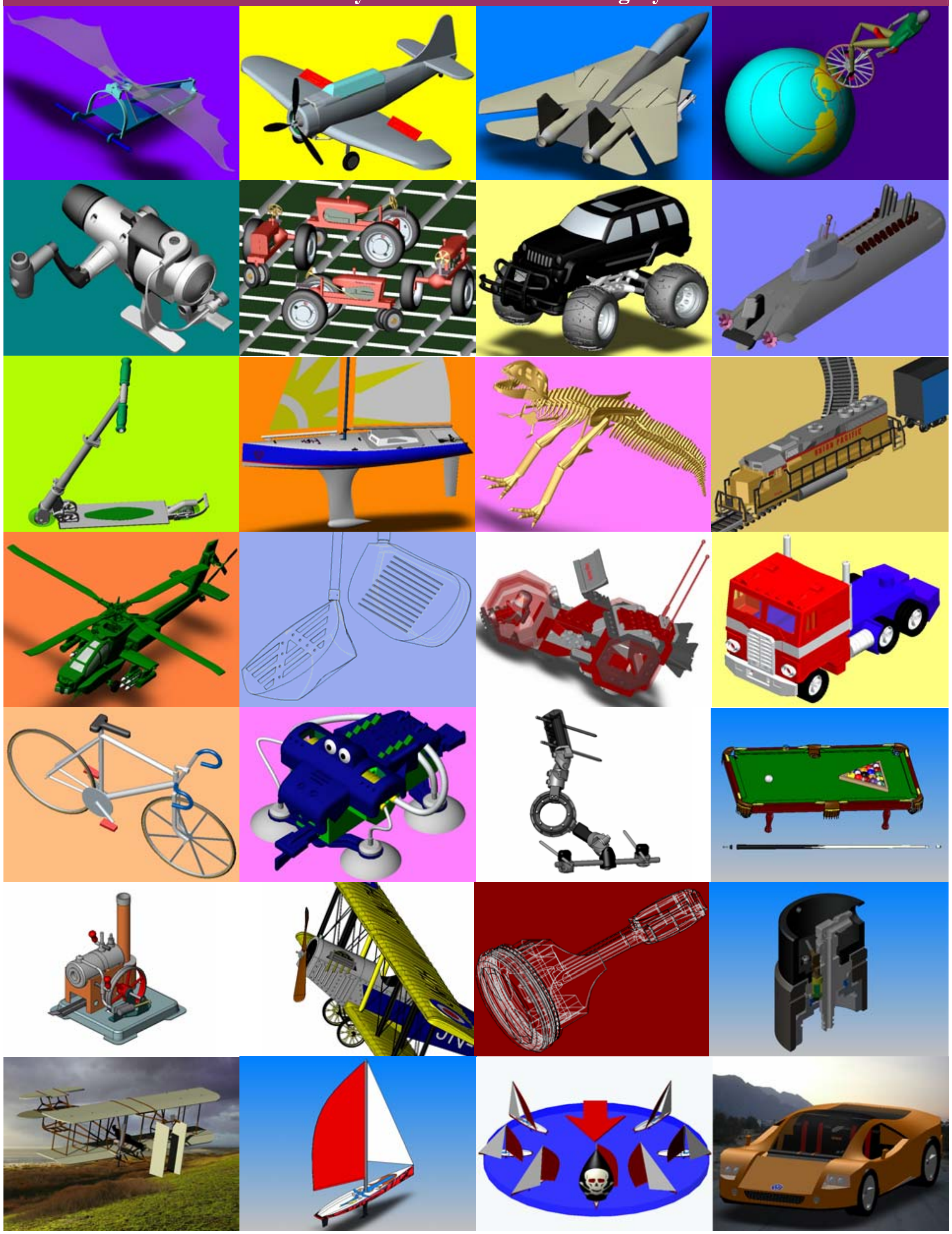
CAD is used in other courses (i.e. besides *Engineering Graphics*) throughout the BSME program[8] as well as in St. Thomas' entry in SAE's 2002-4 Midwest Mini-Baja competitions[9]. Specifically, it is used in *Kinematics and Mechanism Design*[10,11]*, Machine Design and Synthesis*[12]*,* the *Senior Design Clinic* sequence, and occasionally in *Introduction to Engineering* by students who are concurrently registered for *Engineering Graphics.*

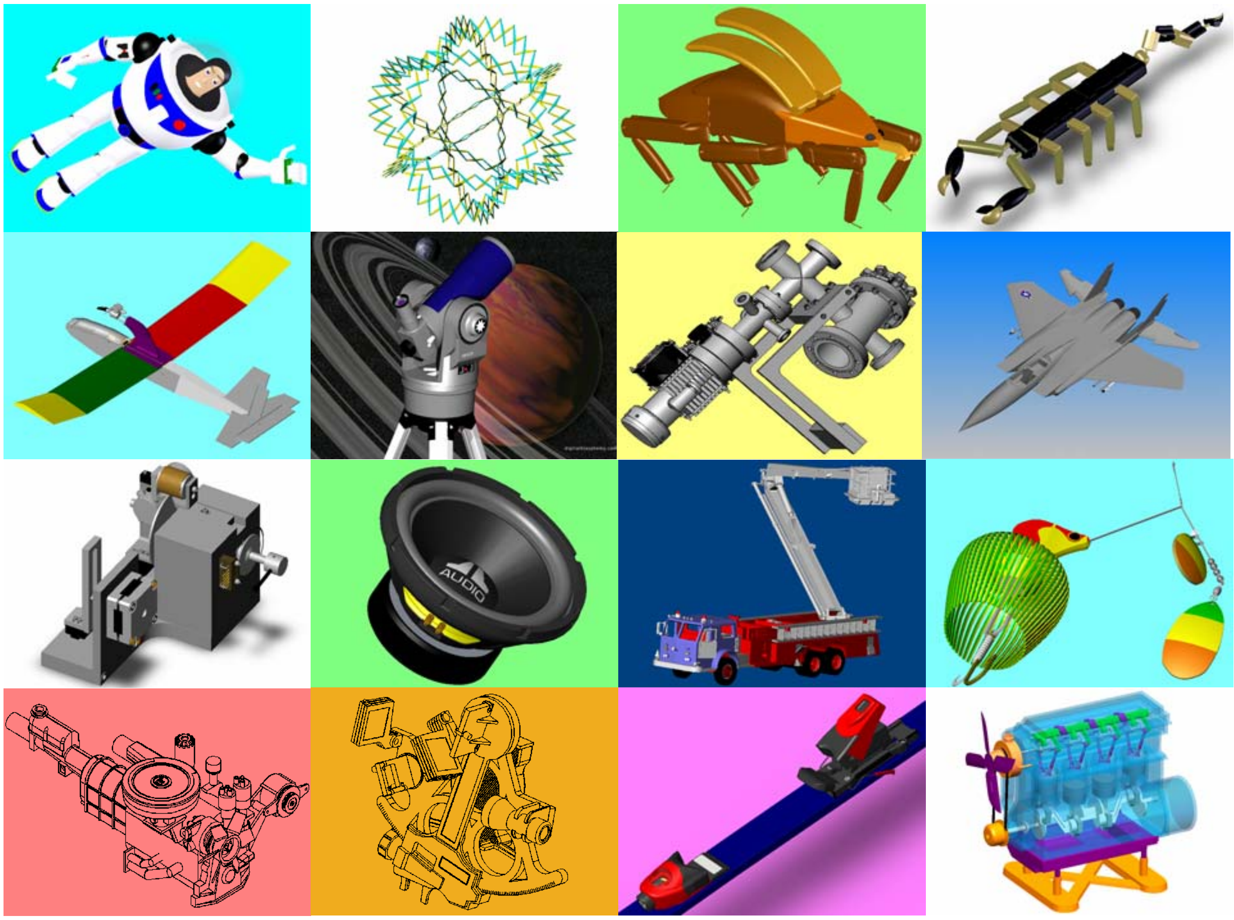
While CAD has been a traditional industrial/commercial and vocational topic for quite some time, several recent academic papers discuss topics related to CAD instruction and/or generation of "galleries" of computer-generated artwork. Nikolic[13] notes that CAD is a popular topic with undergraduate mechanical engineering students – this has been our experience as well. Ray and Farris[14] teach a traditional graphics course at the freshman level and focus on understanding the interrelationship between both design and manufacturing through the use of class projects. Jensen *et al.*[15] emphasize the underlying mathematics of high end CAE/CAD/CAM systems and associated project work. Finally, as for "galleries," Carazza and Mead[16] describe the development of a virtual art gallery based on game engine technology.

A Gallery of CAD Generated Imagery

A representative gallery of CAD generated imagery using SolidWorks® from projects undertaken by students in *Engineering Graphics* (4 semesters) and *Kinematics and Mechanism Design* (2 project-based J-term courses) over the last 2 years is shown below in chronological order for a total of 44 images. A separate authorship table indexes the images by row and column (i,j). In some respects, this follows the efforts of the lead author's prior experience in teaching computer-aided-engineering coursework, where the IDEAS™ package was used[17]. Individual course galleries generated from the previous block of 3 semesters and 1 J-term are illustrated in Hennessey *et al.*[18]; generally the project work presented in this paper is more complex and varied. Due to space limitations and the need for variety, confidentially issues, and on a rare occasion, quality or state of completeness, most (i.e. at least 95%) but not all student work is showcased. Generally, to promote wide usage of CAD, the projects vary considerably, in terms of geometric features represented, number of parts in the assembly, assembly structure, overall complexity, physical scale, industry represented, in addition to coloring, and other presentation and viewing issues.

Gallery of CAD Generated Imagery





***Engineering Graphics* Gallery (Fall 2002)**	
1,1: **Leonardo daVinci's Flying Machine** *(Jessica Klaers, Thomas Schulzetenberg, and James Zoss)*	1,2: **Dauntless Airplane** *(Jesse Stripe and Kari Thompson)*
1,3: **F-14 Tomcat Airplane** *(Joseph Kattar, Ian McLaughlin, and Benjamin Rick)*	1,4: **Unicycle on a Sphere** *(Adam Harding, Tim Jorgenson, Kelly Kanz, John Klein, and Rosemarie Malcolm)*
2,1: **Fishing Reel** *(Joseph Heiderscheidt, Erik Sorensen, and James Zoss)*	

***Kinematics and Mechanism Design* Gallery (J-term 2003)**	
2,2: **Allis-Chalmers Tractor** *(Carlos Baires, Andrew Clausen, Francis Ssennoga, and Kara Torgerson)*	2,3: **RC Jeep Liberty** *(Luke Hacker, Brent Hassler, Timothy Jorgenson, Kelly Kanz, Robert Roberts, and Adam Spah)*

***Engineering Graphics* Gallery (Spring 2003)**	
2,4: **Submarine** *(Amber Beck, Nickolas Dalbec, and Kenneth Oatman)*	3,1: **Razor Scooter** *(Daniel Eaton, Bradley Ragozzino, and Jacob Weinmann)*
3,2: **RC Sloop Sailboat** *(Matthew Gartmann, Eric Kaplan, and Ryan Shortridge)*	3,3: **Tyrannosaurus Rex Dinosaur Skeleton** *(Hezbon Mose, Dorothy Paszek, and Lina Salah)*
3,4: **Train Set** *(Peter Bulinski, Taylor Luke, and Colin Sullivan)*	4,1: **Apache Helicopter** *(Gerald Grabowski, Nathan Hildebrand, Aaron Knuttila, and Nicholas Scanlon)*
4,2: **Golf Clubs – RH Wood, LH Iron** *(Thomas Johnson)*	4,3: **LEGO Assembly** *(Ryan Lovik and Jerry Xiong)*
4,4: **Transformer Toy** *(Joel Seipel and Paul*	5,1: **Bicycle** *(Charles Soller)*

Tandberg)	
5,2: **CLIMBaTRON Window Climbing Robot** *(Ryan Boudewyns)*	

***Engineering Graphics* Gallery (Fall 2003)**	
5,3: **Fixator Medical Device for an Arm** *(Joel Farley, James Hull, and Shanon McIntyre)*	5,4: **Miniature Pool Table System** *(Michael Moran and Dustin Olynyk)*
6,1: **Steam Engine** *(Conor Gray and Hans Zimmerman)*	6,2: **Curtis JN-7H Jenny Airplane** *(Christopher Carson, Justin Mensen, and Jacob Stewart)*
6,3: **Piston and Connecting Rod** *(Angelo Fruci)*	6,4: **RFID Liquid Dispenser** *(Christopher Baye)*
7,1: **RC Wright Flyer** *(Gregory Bjork, Brian Farnes, and Andrew Fried)*	

***Kinematics and Mechanism Design* Gallery (J-term 2004)**
7,2-3: **Sailboat and Configurations at Different Points of Sail** *(Brian Farnes, Gerald Grabowski, Nathan Hildebrand, Thomas Johnson, Shanon McIntyre, William Stipe III, and Jerry Xiong)*

***Engineering Graphics* Gallery (Spring 2004)**	
7,4: **Volkswagon Nardo** *(Janell Brown and Jaymes Olson)*	8,1: **Buzz Lightyear** *(Anne Denn and Alan Twomey)*
8,2: **Hoberman Sphere – 6 Rings, 360 Links** *(Matthew Des Marais, Andrew Seykora, and Jonathan Soldner)*	8,3: **Beetle** *(Gebriel Dinku)*
8,4: **Scorpion** *(Rex Njoku)*	9,1: **STEPS Airplane** *(Melissa Hoppe, Anna Perell, and Lesley Wyckoff)*
9,2: **Telescope** *(Sarah Jager, John Larson, and Adam Stugelmayer)*	9,3: **Vacuum Chamber** *(Heather Helgeson, Kimberly Jasch, and Anna O'Brien)*
9,4: **F-15 Eagle Airplane** *(Brett Dimond, Michael O'Donnell, Logan Riordan, and Jared Sandstrom)*	10,1: **Chaos Demonstrator** *(Maximilian Aponte, Robert Ertel, and Michael Rouse)*
10,2: **Speaker** *(John Galvin and Brock Norman)*	10,3: **Fire Truck** *(Jon Peterson, John Tushaus, and Peter Vogt)*
10,4: **Musky Fishing Lure** *(Laura Eaton and Jacalyn St. Dennis)*	11,1: **Rotary Engine** *(Theodore Dinkelman, James Letourneau, and David Wobig)*
11,2: **Sextant Navigation Instrument** *(Charlie Bloemendal, Andrew Casey, and Andre Trawick)*	11,3: **Downhill Ski with Bindings** *(Joseph Crimando, Peter Jacques, and Andrew Schmidt)*
11,4: **Smithsonian 4-Cylinder Engine** *(Christopher Deno, Andrew DePompolo, Nicholas Kampa, and Brian Kjersten)*	

Comments on the Gallery

By design, the CAD projects undertaken exercised the student's knowledge of core CAD topics covered, and sometimes even the CAD software package![1] Some common CAD topics include: (1) 2D sketching, including use of splines, (2) geometric constraints, (3) extrusions and revolved 3D features (bosses & cuts), (4) patterning, (5) filleting, (6) shelling, (7) ribs, (8) part configurations, (9) sweeping & lofting, (10) basic assembly modeling, (11) assembly configurations, (12) traditional drawings, (13) viewing, and (14) use of color. Aside from the demonstration of specific CAD concepts, perhaps the most important issue concerns the range of projects considered, which is consistent with the ubiquitous nature of CAD in industry today. From a pedagogy point of view this is one the most important concepts learned in the course; the entire class benefits from seeing other projects developed and presented.

[1] Note: filleting can be notorious in this regard (across various CAD software packages).

Student Feedback

Generally, the student feedback for the course and instructor in *Engineering Graphics*, the course that emphasizes CAD (SolidWorks®), has been uniformly positive over many semesters (7, including the 4 semesters emphasized in this paper). Certainly, some of this is due to the quality of instruction including significant interaction while students learn the CAD package, but is it also fair to point out our observation that many mechanical engineering students enjoy CAD work immensely and being able to work on a meaningful project where their creativity can be applied. Requiring CAD work is a useful and popular idea for other courses as well, such as *Kinematics and Mechanism Design*, *Machine Design and Synthesis*, and *Senior Design Clinic I-II* (if appropriate).

Recommendations and Associated Rationale Regarding CAD Project Implementation

After defining many CAD projects, advising students, and witnessing the result of the project efforts, a number of specific recommendations and associated rationale have emerged to maximize the learning, fun, and project success:

- Project scale and complexity level must be appropriate for the number of students and project time allocated (typically 2-3 students over one month) -- too simple and the students don't learn very much, too difficult and students become frustrated and the project is of low quality.
- It is advisable for each team to have an overall strategy, or "game plan" before beginning the detailed modeling for how to model each component (part or assembly) and its features plus the organizational structure of the entire assembly. This game plan can then be reviewed with the instructor early-on for feedback and additional ideas.
- Geometric data such as part features, assembly structure, and dimensions must be readily available to the project team. Relatively inexpensive, clean, durable, hand-held, essentially rigid part, physical models that can be easily and non-destructively assembled/disassembled (if necessary) next to the computer seem to work the best. Students can then use standard metrology equipment such as dial calipers, micrometers, and protractors to easily obtain accurate dimensions that feed directly into the CAD model. While certainly not a requirement, toys, such as models and sporting goods often make for good projects.
- Construct assemblies with at most 30 or so parts, depending on their complexity. That said, some students are very intrigued by CAD and are quite willing to model many more parts – don't expect it but don't discourage it either.
- Mechanisms, versus structures, are preferred since internal motions (or degrees of freedom (DOF)) lend themselves to interesting visualization using configurations, movement, or animation, a commonly available capability.
- Projects that are truly 3D in nature are preferred – otherwise why bother using solid modeling?
- Don't be a perfectionist! It is completely acceptable and realistic for the student teams to construct approximate models of reasonable fidelity, even possessing a "façade effect" on occasion – as shown in this paper. Having said that, there are some models that aren't that appropriate for a typical first CAD class; e.g. models that possess fairly arbitrary geometry, e.g. highly sculpted artwork with textured surfaces.

- A low student to faculty ratio is essential since CAD packages are notorious for idiosyncrasies and students often get stuck and they need easy access to the instructor. For example, we currently have a cap of 16 students in the *Engineering Graphics* course.
- The poster-board concept for displaying the CAD work is a great idea for a number of obvious reasons. Upon project completion, the physical model and the poster can be placed into a display case if desired and available. This information can also be made available to students to include in their electronic portfolios.
- The projects lend themselves to use of student teams that can be a great learning experience that can be carried into other courses.
- It is not necessary to have a theme to the class "project portfolio" -- project variety and student motivation are more important (e.g. if students select their own project). As an aside, with rare exception, we have never used the same project twice.
- The class expertise can be made available to interested "customers" (e.g. such as other academic departments) – students enjoy working on a project that other people care about.
- Use of multiple colors and transparency makes a difference. While this can be done artificially, it is better if these properties are intrinsic to the parts/assembly in addition to being aesthetically pleasing.

Conclusions

Conclusions are as follows:

- With current CAD software, in 1 semester students can create quite elaborate models of parts, assemblies, even including the possibility of animations and videos. Generally, the entire process can be a fun learning experience for all involved.
- The freshman CAD experience (i.e. *Engineering Graphics*) has wide applicability in other follow-on courses in a BSME program.
- Based on our combined experience of teaching the *Engineering Graphics* course many times, a number of specific recommendations have been identified that serve to maximize the fun and the impact of the learning experience.

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