Putting CAD In Its Place: A New Approach For Enhanced Virtual Product Design Teaching

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Introduction

This paper describes a new approach for enhanced and integrated virtual industrial/product design teaching. The paradigm and approach has proven its effectiveness through a CAD course where new industrial design students recently placed high in a major product design competition. Methods, principles and outcomes of the approach are described including aesthetic form development, human factors, visualization/communication, geometry creation strategies, product material specification, design for production, and a comparison of virtual and physical interaction with 3-D geometry.

Faculty and students are challenged with an ever-changing array of powerful CAD tools available today that may or may not be relevant tomorrow. Faculty face increasing pressures to pack more content into an already crowded curriculum. This paper describes an approach to teaching virtual product design that minimizes the concerns above and effectively brings a student to an advanced level of skill and knowledge that will continue to be of value to them in their future careers. This paper also compares this approach with common approaches that are less effective.

Why put CAD in its place?

It is often said among designers and design educators that computer aided design (CAD) is a “tool.” This view seems accurate because in the hands of a designer with CAD experience the computer and the design software on it can be used to create designs more effectively and efficiently than without. However, when CAD is thought of as simply a tool in an industrial design (ID) curriculum the educators may be missing several important educational opportunities for their students. Rather than perceiving and treating CAD as a separate tool or set of tools (e.g. drawing tools, modeling tools, presentation tools, etc.), CAD can be perceived and treated much the same way physical studio space is thought of.

While never a replacement for a designer’s creativity, knowledge and traditional analogue skills, design in a virtual studio, using CAD software, can promote a collaborative approach to design. It provides a common space (in parallel with physical space) where distinct parts of a design may be worked on by separate individuals or groups concurrently. This virtual design space, which exists on the computers and servers of design organizations, also houses various tools—not unlike tools found in physical spaces. Virtual tools have counterparts that are not unlike their physical counterparts such as saws, drills, measuring devices, sheet metal benders, mills and sanders. Some virtual tools also have capacities that are far beyond the realm of physical possibility that can provide information and help the design team change directions rapidly. These capacities are not always possible with physical material and prototypes.

Designers of an award winning automobile said, “The math-based tools allowed us to get to a full-size, 3-D sketch very quickly so everyone could interact with it and understand very easily
how it could translate into an actual production vehicle” (Durmisevich and Witzenburg, 2004). This statement suggests that 3-D CAD tools in general can be thought of as distinct items within a virtual space that can be used to facilitate activities or help designers manipulate things as one goes through the design process. A computer in a design studio represents not only a tool, but a kind of portal into a parallel studio space where various tools are used and design is facilitated. Simply describing the computer as a “tool” fails to recognize the profound role it plays in the modern processes of product design. In the world of fast passed product design 3-D virtual space is a necessary place for designers to be intimately familiar with in order to be successful (Arnold, 2006). Not only is the virtual studio part of mainstream product design, it is always changing. Software brands and paradigms grow, shift, evolve and change. Training future industrial designers to operate in current and anticipated contexts can be challenging. What should an ideal CAD course for industrial design look like?

A typical model for teaching CAD

Many CAD courses are taught based on the brand of software that has been purchased by the educational unit. Software is purchased under a variety of considerations: licensing fees, maintenance fees, perceptions/experience/preferences of the instructors, and of course, recommendations from industry—both from practitioners and vendors. Courses taught based on brand are subject to at least three major shortfalls:

Firstly, these courses typically include a heavy reliance on tutorials published by the brand’s authors and demonstrations that are most successfully given by instructors with much experience (preferably professional). Courses taught in this way tend to produce designers who are confident in a narrow segment of CAD options. Also, if there is a two-course sequence where one CAD software is taught followed by another, the students tend to gravitate towards using the most recently learned software rather than the previously learned software—even though the previous software would be more effective at expressing their design.

Secondly, brand based courses tend to give students skills in the use of software but not necessarily the knowledge, decision making skills and perspective of the appropriate use CAD in the design process. There is a need for the designer to intelligently choose when to use CAD and when not to. Brand authors or software companies should not necessarily dictate how CAD should be used—this represents a possible conflict of interest and can unnecessarily place an undue emphasis and reliance on CAD to solve design problems.

Finally, brand based courses may not be relevant in future years because software brands change in popularity and competitiveness and the roles of designers differ or are in a state of change, in various industries. CAD principles, rather than mechanics only, should be emphasized; giving students a foundation for future learning that they will certainly need to rely on. After all, if CAD represents a virtual studio rather than simply a tool then teaching beyond the brand is necessary.

CAD can be taught both in terms of mechanics (i.e. learning the software) and in terms of context and application (i.e. studio mode of teaching and learning) where broader topics are emphasized beyond simply learning the software. This approach goes beyond tutorial-based learning and treats the CAD course as a studio that has its own content and incorporates/applies content from other courses and studios; coinciding with the idea that CAD represents a virtual
design studio space. In the author’s experience, there is simply not enough time in the curriculum to devote a whole course to just the mechanics of software in a disconnected manner from other courses especially when CAD can be much more than a distinct tool. It is also the author’s experience that perceiving and treating CAD instruction as more of a studio experience taught in collaboration with other ID courses enhances the educational experience of the ID students—mainly because the students apply principles learned in a context that is bigger than the context of the CAD course. This paper presents and promotes this approach based on experiences with ID students at Ohio State University (OSU). Currently, the ID program at OSU begins with a “foundations” year at the sophomore level (ID with other design disciplines) followed by ID specific training at the junior and senior levels. CAD courses (one basic and one advanced) are during the first and second quarters of the junior year.

What does this approach look like?

One component of the approach presented here involves “studio” teaching and learning—a familiar mode among most ID faculty, students, and former students who are now in practice. Studio mode is not necessarily emphasized as much as an instructor running a project based design studio course would, but it is applied in at least half of the face-to-face time that the instructor spends with the students. The pattern: explain, demonstrate and apply is relied upon heavily. The explanations and demonstrations typically take on a lecture format where principles are shared and discussed. These tend to be short; no more than half of a given class time. During the lecture appropriate methods are demonstrated; the instructor creates a form, feature, rendering or other component of a design using several different methods in the context of a project that the students are working on for the course or another related design course. The principles, methods and demonstrations presented relate directly to what the students are currently working on or will work on in the near future. As the instructor demonstrates a method the students complete the same exercise that the instructor demonstrates while the instructor is demonstrating or immediately thereafter. In this way the students learn the mechanics and the underlying principles of CAD during the same exercise. One-on-one time with each student is spent during the remainder of class time.

This approach works best if there are approximately five projects/exercises during a 10 week term (OSU is currently on a quarters system). The first three are two-week assignments that focus on fundamentals taught in the class. The last, or final project, coincides with another course and should be coordinated between instructors. For example, a project based studio course could proceed through research and ideation phases during the first weeks of the quarter, then during the last part of the quarter, while the CAD course is transitioning into its final project, the students in the studio course could be in the design phase where CAD is appropriate. Both the studio course and the CAD course benefit because the students may apply what they are learning in the CAD course to a design process (in the studio course) they are working through in another context. Likewise, these students also benefit because they have, in effect, the vested interest of two instructors for one project and additional time to focus on creating a better design than would have been created if the projects were separate.

As stated above, the author focuses on principles and methods rather than brands. At OSU, Rhino and Solidworks are the main 3-D software packages used in a “Basic CAD” for ID (or Basic CAID) followed by an advanced course.
The Basic Course

The basic course focuses on modeling using both software brands, separately and interchangeably for various assignments. Both Non-Uniform Rational B-Spline (NURBS) and Solids/Parametric modeling approaches are dealt with in a balanced manner. Projects are designed to help the students gain experience with either modeling approach so they can determine what to use during future projects and on the job after they leave school. By not attaching assignments to a brand, but to an approach/strategy for modeling (i.e. NURBS or Solids/Parametric) the author has found the learning objectives are better accomplished and are clearer in the minds of the students. Without this emphasis the default attitude of the students has been to evaluate the course solely on the instructor’s level of familiarity and ability to teach a particular brand of software.

The basic course has the following learning objectives:
- Understand and be able to apply appropriate modeling methods according to form intent
- Gain basic skills in NURBS and Parametric 3-D modeling techniques
- Expand 2-D and 3-D form giving ability and sensitivity

Assignments from the Basic Course Syllabus:

Tutorials > Pick a total of seven tutorials from the help menu in Rhino and Solidworks. You may complete any of the tutorials listed; they do not need to be in any particular order or level of complexity. You will only get credit for completing seven tutorials but you may, of course, do more.

Demo Exercise 1-8 > These in-class demonstrations/exercises are designed to teach you methods of form creation related to your form giving assignments and product design assignments (i.e. Speed, Playful and Rugged Form). Complete these and turn in a .jpeg or .tiff of each with the appropriate form assignment.

Speed Forms – Vehicle > Design a simplified form that represents a vehicle that is intended to travel at great speed. Create two versions of this form; one using a NURBS modeler and one using a parametric modeler. Prior to your computer work, you need to generate five 8.5”x11” pages of ideation sketches and a foam model of appropriate scale. At least one page of your ideation sketches needs to show value change and form change – texture and color are optional.

Playful Forms – Communication Device > Design a form that represents a communication device that has a “playful” appearance. The rest of the details for this assignment are identical to the Speed Form assignment above.

Rugged Forms – Hand Tool > Design a form that represents a hand tool with a “rugged” appearance. The rest of the details for this assignment are identical to the Speed Form assignment above.

Product Design (your studio product design) > The intent of this assignment is to apply the principles, methods and tools you learn in this course to your studio work and allow
me to help you with your studio project. Obviously, you will in effect, have more time for your studio product design. A copy of your final deliverables for your studio project should be sufficient for me to grade your work. I will focus on grading your form giving, modeling and presentation work rather than on research aspects of your design work.

Figures 1 and 2 below describe results of two of the assignments. Having a design in mind and planned, prior to working on the computer through sketching is emphasized to ensure that the designer controls the design rather than the CAD system. Also, human factors and scale are addressed through physical modeling. The author has found that inexperienced designers need some kind of physical interaction to more fully gain familiarity with virtual dimensions and scale during the design process.

Figure 1. Rugged Form assignment, Basic CAD Course (designer, Jacob Stanton)

Figure 2. Speed Form assignment, Basic CAD Course (designers from left to right: Trevis Kurz, Nick Vallo, Benjamin Funk)

Figures 3 and 4 below depict final designs that two Basic CAD course students created as part of their submissions for the Product Design Project in the course. This project also doubled as final deliverables for their Intermediate Studio Course taught by Scott Shim, IDSA.
The Advanced Course

Again, the advanced course balances NURBS and Solids/Parametric modeling where appropriate. However, as would be expected, there is a greater emphasis on Solids/Parametric when addressing areas of part design such as assemblies, component fit and mold-ability (e.g. injection molding design with wall thickness, ribs, bosses, etc). The advanced course focuses on the following learning topics and objectives:

### Output
- rendering
- rapid prototyping
- 2D drawings
- basic animation

### Form Development
- component fit
- ergonomic
- function
- meaning and aesthetics

### Geometry & Part Design
- enclosure and skin approach
- structure and mech approach
- moldability
- assemblies and mates

Assignments from the Advanced Course Syllabus:

**Assignment 1 (week 1)** > Design a design a backpacker’s stove. It needs to provide additional functional and aesthetic/meaning above what is currently available. Rendering, meaning/aesthetics, ergonomics, function, assemblies/mating and a structured/mechanical approach to design will be emphasized.

**Assignment 2 (week 2)** > Design a child’s remote control w/ provided circuit board. Rapid prototyping, component fit, moldability and an enclosure/skin approach will be emphasized.

**Assignment 3 (week 3)** > Design a pitcher for liquid dispensing. Basic animation, 2D drawings meaning/aesthetics, ergonomics, and function will be emphasized.
Project #1 (weeks 4, 5, 6) > Find an existing mass-produced high volume product at a thrift store or one that you are discarding. The existing product will be the same one used for Project 2 of your materials and manufacturing processes course. Disassemble the product and securely attach all parts in an exploded view 3-D format, illustrating how the product was assembled in manufacturing including all sub-assemblies. Highlight and label all parts indicating what each part is made of and the manufacturing processes used to make the part. Model all major parts and model smaller intricate components as a simplified version.

Project #2 (weeks 7, 8, 9, 10) > Develop a product concept of your choice rendering, basic animation, 2D drawings, rapid prototyping (possibly), component fit, meaning/aesthetics, ergonomic, function, assemblies/mating and moldability.

Figures 4, 5, and 6 below depict submissions for the Advanced CAD course. Figures 4 and 5 depict stand alone assignments teaching output, form development, geometry and part design strategies. Figure 6 below depicts final designs that three advanced CAD course students created as part of their submissions for Project #1 in the course. This project also doubled as deliverables for their Materials and Processes course. Based on their individual design intent the students were free to use either NURBS or Solids/Parametric modeling software or both.

Figure 4. Assignment 1, Backpacker’s Stove, Advanced CAD Course (designer, Nick Vallo)
Conclusions

The author has found that each student learns differently. Few are completely satisfied with tutorial based learning while many seem responsive to hearing, seeing and immediately applying what they learn so that they are forced to absorb the skills and knowledge being taught. If the learning objectives of a CAD course include bringing a student quickly to an advanced level of proficiency while teaching them about such broader topics such as the design process, form giving, manufacturing processes and lifelong learning skills then the approach described here can be highly effective.
Figure 7 below depicts four OSU entries for the most recent international housewares competition and in conjunction with their intermediate ID studio course. Because visualizing a design is a significant factor in a design competition the author believes that CAD work depicted here contributed to the success of these entries and helps validate this approach to teaching CAID. These designs and CAD work were completed during the first quarter of these students junior year, during their first CAD course.

Figure 7. International Housewares Competition entries
(From left to right, top to bottom: Trevis Kurz, 1st place Smoke Alarm, Jamie Perrin, 3rd place Amputee Shoe-lacer, Kayla Rosebrook Laudry Aid, honorable mention, and Emma Sanders Composter, honorable mention).

Focusing on and teaching just the mechanics of a particular brand may not be the most effective approach to teaching CAID because brands change and students will need to learn for themselves how to apply principles using other software packages of the future. If only one brand were available, and it did not change, then strict brand focus might begin to have merit, but that situation simply does not exist. A balanced, principled, approach to CAID education is necessary where principles can be learned and applied no matter what brand is used. Communicating this learning objective clearly to students is necessary and the author has found students to be notably patient and motivated to learn under this paradigm.

CAID courses that integrate with other courses help students effectively learn broader knowledge because learning by doing is inherent. Also, integrated CAD courses help students become accustomed to CAD as a virtual design studio space rather than merely a tool. Finally,
designs in a studio can be refined, visualized and explored more fully if there is a CAD course that shares a project with it. Likewise, if a CAD course is used as a studio for a seminar course, like materials and manufacturing processes, then learning is enhanced because the doing and applying of knowledge builds expertise and experience.

References
