RE-THINKING THE CAD COURSE:

Design, not Drafting

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The CAD course has become an important part of many high school technology programs. Computer-based drafting partially or wholly replaced board-based drafting beginning in the 1980s and continues to evolve. In some schools, courses focusing on CAD are attracting students interested in engineering and architectural careers and challenging students with a wide range of ability levels. As the capabilities of new CAD software grow more powerful and present more options, the opportunities for students and teachers also grow.

Early CAD programs in use in schools were only capable of drawing lines on the screen and plotting or printing them, so CAD naturally meant computer-aided drafting. As the sophistication of both software and hardware evolved, programs were developed that enabled true design work to take place on the computer. In industry today, CAD means computer-aided design. It is this focus on design that is the central theme of this article.

A VERY BRIEF HISTORY OF CAD

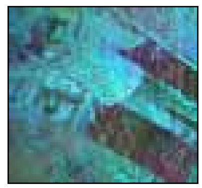
In the mid 1950's, the first true CAD software was developed for mainframe computers, but it wasn't until the 1980's that microcomputer-based CAD packages were introduced. To learn these programs required a huge investment in time. The computer mouse was not yet an integral part of the desktop computer, so a large number of keystroke operations needed to be memorized before an individual became proficient in the use of the software.

These early 2D programs only allowed the draftsperson to use the computer to create and modify lines. The output from 2D software was plotted or printed drawings of components in orthographic projection. While there are many of these systems still in use today, the software and hardware technology has moved on.

Early entries into the world of 3-dimensions were in the form of wireframe models generated by 2D drafting systems. A component was represented by its edges in an isometric or other 3D view. The surfaces were open (not rendered) and designs were open to visual interpretation. Output from early 3D wireframe modeling systems was limited to plotted or printed images.
Wireframe modeling continued to evolve and the functions of drafting were integrated into wireframe systems. The degree of complexity of these systems required lengthy training and took the draftsperson into the realm of the computer expert.

The introduction of solid modeling had a huge impact on industry. While early solids software was slow and simplistic in its representation of surfaces and shapes, the solid part created data on physical properties, such as volume and mass. More importantly, however, creating a solid permitted the output of information that could be used to create cutter paths for numerical-control machining. A part created on the computer could, in theory at least, be directly manufactured on a machine.

As the sophistication of solid modeling evolved, such innovations as hierarchical solid modeling, parametric CSG (constructive solid geometry), and feature-based modeling were developed. Current solid modeling software has come a long way from the early CAD programs of the eighties, both in capabilities and ease-of-use.



"A part created on the computer could, in theory at least, be directly manufactured on a machine"

CAPABILITIES OF CAD TODAY

A number of CAD packages today offer an extraordinary range of features and capabilities. Parametric, feature-based, solid-modeling software allows students an opportunity to do much more than draft lines. Because design work is done in 3D, and automatically produces 2D orthographic drawings, these packages challenge the idea that students need to learn drafting principles.

There was a time when industry relied on "shop drawings, "hand-drafted, orthographic images that would allow the machine operators, machinists, and skilled craftspeople to create the components specified in the drawings. While these activities still go on today, industry is steadily moving toward computerizing most of these operations, and this move has by-passed the traditional way that products come to market.

Today, a component can be designed on the computer and an output file created that will allow a prototype to be made inexpensively on a variety of computer-controlled rapid prototyping machines. The prototype is checked and any changes are made in the original file. The revised output file is then ported to a computer-controlled machine and the part produced. The time it takes from design to manufacture is significantly reduced, and, as a result, the product development costs involved are decreased.
Some CAD software allows component data to be stored and retrieved from spreadsheet programs, such as

Microsoft's Excel. Specification revision is done within the spreadsheet file, allowing non-technical people to make these changes. Suppliers and subcontractors any place in the world can access component specifications and make revisions or corrections over the Internet.
In an MCAD Vision article on why CAD solid modeling is so important to industry, Joe Gasper, Senior Mechanical Applications Engineer, describes seven reasons companies are rapidly making the move to solid modeling software:

- **visualization** Even non-technical people can view the part or product and full-color renderings, assemblies and animations can be developed for evaluation. Many pictures of products that appear in catalogs are renderings from the early stages of the design process.
- **analysis** Mass properties, center of gravity, kinematics and other factors may be analyzed in many software packages. Finite Element Analysis (FEA) is an important part of the engineering design of many components.
- **increased revision speed** Data to describe a component or assembly of components in the software is associative, so revisions update to all places the data is used. For example, changing the diameter of a hole in the 3D design of a part automatically changes that diameter in the orthographic drawings of the part, in the product assembly, in the rendering of the product, and anywhere else where the part is used.
- **drawing creation** 2D drawings are automatically generated from the 3D solid. Dimensions or constraints specified in the 3D solid file are transferred into the 2D drawings. Sectional and auxiliary views may also be generated from the 3D data.
- **manufacturing input** The geometry of the designed part is captured and can be exported in file formats that drive CNC and other CAM equipment.
- **rapid prototyping** Output files that drive a variety of rapid prototyping equipment can be exported, such as the Stereo-Lithography (STL) format.
- **data sharing** Ease of sharing data and specifications among vendors, contractors and customers is one of the most powerful features of solids software. Maintaining data in spreadsheets allows non-technical people to use and revise part specifications and share data on the Internet.

The advantages that today's CAD solid modeling programs offer to industry add up to a more efficient product design and development process and a decrease in the time it takes for a product to reach the marketplace.

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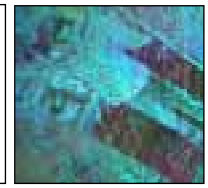

CAD IN SCHOOLS

If orthographic drawings are now generated automatically by software, and the role of the draftsperson is fast disappearing from much of modern industry, what impacts should these developments have on what we teach our students?

Traditional school drafting exercises usually required students to interpret isometric or perspective illustrations and create orthographic drawings. Through these experiences students learned drafting conventions and skills. In industry of the time, the draftsperson was an integral part of the product development team. Industrial Arts was challenged to interpret industry for children and provide them with insights and experiences reflecting the industrial world. The industrial world has moved on, as has the role of technology education in its evolution from industrial arts.

The development of more sophisticated, easier to learn CAD software provides teachers with the opportunity to give their students rich, challenging and valuable experiences not possible before. Earlier CAD packages required months or even years to develop proficiency and to use successfully. In some cases, the learning time for modern CAD packages can be measured in days and weeks (certainly not true of the high-end packages, such as PTC's Pro/ENGINEER, but it is true of the new breed of affordable PC-based solids software). While students may not become proficient enough to use all the features of the software in that period of time, sufficient knowledge and skill can be acquired to actually use the software to design parts or simple products.

A shift in focus from technique and board skills resulted from the evolution from board drafting to computer-aided drafting. Now a transistion from computer-aided drafting to computer-aided design solid modeling provides opportunities for another focus shift.

A CASE FOR DESIGN

The Standards for Technological Literacy, released in April 2000, represent design as a primary strategy for teaching and learning about technology. Design, in this case, is used to describe the process by which technology develops. Technological products and systems come in a controlled manner and with clear goals in mind. In fact, the Standards abound with references to the learning of design processes, design thinking, design skills and design assessment.

In the world of industry, the design of a product or individual part may involve a number of specialists and groups, including mechanical engineers, industrial designers, stylists, marketing people, managers, manufacturing engineers, sales people, consumers, and others. In order to bring a product to market successfully, all kinds of specialized knowledge and skills are required, so designing involves a "conversation" between and among these individuals and groups. However, conflicts may exist between some of these constituencies. The stylists may desire some shape that is too difficult or expensive to manufacture. Management may force cost-cutting that affects the product design. To design is to compromise, to weigh alternatives and make decisions that affect the outcome. Students experience the same dilemmas when designing and require knowledge and skills that they will need to apply to the process.

For students, learning involves the process of design and requires practicing strategies and techniques for progressively developing ideas through a number of design stages. Designing in technology also involves applying technical knowledge – knowledge of material properties, technical processes, and engineering principles – as well as aesthetic sensibilities. Economics, safety, environmental and human factors also contribute to design capability.

It is the role of the teacher to structure student activity to achieve course goals. As states bring curriculum in line with the new standards, design should become a focus of student activity. Solids CAD software provides

Dan Schuessler's pride is evident as he displays his desktop clock design concept.

Dan Buchanan checks final details of his fanciful remote control design.

teachers with new opportunities to involve students in design work that is interesting and challenging.

A DESIGN CHALLENGE

Here is an example of a computer-aided design challenge: Design and model a product that will provide illumination for roadside emergencies, such as a flat tire. The product should be portable, battery-powered and easy to use. For students new to design work and who have limited technical knowledge, the teacher will need to provide adequate structure for the

Ryan McCaskill is putting his concept car design on the screen by modifying Pro/DESKTOP's basic geometric elements into the 3-D forms he imagines.

design experience. This will typically involve providing students with "constraints" under which they must work.

For example, the student is required to use a 6-volt lantern battery. The battery will dictate a size and shape and therefore provides the student with a starting point. Providing the student with a 3D solids file of the battery eliminates the need to draw the battery and lets the student concentrate on the design of the light case that must incorporate the battery. Likewise, other standard components might be specified, such as the switch, the bulb, and even the reflector.

With only limited experience with solids software, the student will be able to use the program as a tool to design. The emphasis is on the process of designing, the application of taught knowledge, and the quality of thinking that goes into the design. There is motivation for becoming more proficient with the software because students will gain more freedom to design as they master new features and can express themselves more effectively with the program.

Additional specifications or constraints might include intended manufacturing materials and/or processes (injection-molded plastic case), among others. Less experienced designers need more structure and specifications to reach success. As experience grows, less structure is needed.

Attempting design without sufficient knowledge results in an unsatisfactory outcome. Designers need to know enough about the various design decisions to be made in order to make good decisions. A product design may require knowledge about materials, manufacturing processes, and aesthetics, but may also require specialized knowledge such as electronics or kinematics. When setting a design problem, the understanding required for success should be kept in mind.

REFLECTIONS/SUMMARY

Solid modeling software available today gives us the opportunity to engage students in real-world designing. It also gives students the opportunity to develop valuable thinking skills and acquire an understanding about the technological world we live in. At the same time, these programs challenge us to re-think some of the goals and values that have been a part of the teaching of technology. As the technological world changes, some of the experiences we provide our students will change as well.

3D Solids software is not the only way for students to engage in design. But it is clearly a strategy that reflects modern business and industry practices and provides students with a learnable tool for creative visualization. It is now realistic to use computer-aided design software in middle school programs that run only a marking period as well as in courses that have traditionally taken a year or more for students to master a CAD software package.

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