CAD: Do Computers Aid the Design Process After All?

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It is impossible to deny that technological innovations have made profound and miraculous contributions to our society. There are, however, consequences that come with implementing new and revolutionary tools in a dynamic culture. For example, because of e-mail, parents and grandparents fear that children today will not appreciate the experience of receiving old-fashioned, hand-written letters delivered in the mail as they grow up. Text messaging and instant messaging have created a new language of abbreviated words, worrying English teachers everywhere that the use of correct grammar and proper English will be difficult to nurture and preserve in their youngest students. To stop such technological phenomena from infiltrating our society is not a feasible goal. Still, we should not take their effect on society lightly. We need consider who has taken advantage of these technologies and how their relationship to these technologies has changed to better understand their impact.

The relationship between the interface and its user is not one-sided. Many wrongly believe that technology has bombarded our society and forced its way into our daily lives. On the contrary; society has accepted it freely and allowed its role to grow for a reason. This dynamic relationship between technology and society is critical to an understanding of the broader implications of how cultural changes will affect technology and, conversely, how our culture will evolve with the technology. One technology that can be seen as an important innovation in this era is Computer-Aided Design (CAD). CAD has changed the face of the design industry and has influenced the lives of designers and engineers worldwide.

History of CAD

The first major push toward computer aided software systems occurred in 1969 when Ivan Sutherland created Sketchpad at MIT. Sketchpad was one of the first computer graphic systems and was a tool that engineers used to represent their ideas in a digital format. The software allowed engineers to plot points on x- and y-axes, and to connect those points to create lines and basic two-dimensional shapes. People applied Sketchpad to their work in the engineering industry. For example, in the 1970s, computer graphic software was used most heavily by the auto and aerospace engineering industries. Significantly, however, it was also used as springboard for more innovative graphic design software, helping groups like NASA to further their design process and pushing them into the new age of computer-aided design.

As the technology improved, tablet PC boards became the preferred tool for 2-D computerized sketching. These devices allowed a user to draw using a pen attached to the tablet, which was then connected to the computer to allow the drawn images to be transferred digitally. This push towards 2-D sketch rendering was a step in the right direction for designers, but it was not technologically advanced enough to justify the complete replacement of analog drawings. In 1972, Manufacturing and Consulting Services (MCS) released an original code for the most basic 3-D CAD systems in its Automated Drafting and Machining product. In the late 1970s and early 1980s, CAD products and the CAD industry as a whole grew exponentially. Different, more advanced variations of basic computer graphic software began to emerge. For example, in 1982, Autodesk, a major player in the CAD industry, was founded. Its foundational product, AutoCAD, is still one of the most well-known CAD programs that newer versions are based on. By the late 1980s and early 1990s, 3-D CAD technology had reached personal computers. Its user base continued to grow both at the company and industry level. Not surprisingly, 3-D CAD technological abilities and popularity has only continued to skyrocket ("The History of CAD," 2004).

CAD's functional capabilities developed in three stages. First, 2-D wireframing, which is an electronic representation of an object, like Sketchpad, allowed users to create geographic outlines that had shape but no mass or volume. Following 2-D wireframing came 3-D wireframing, which gave the outlines of an image in three dimensions. These shapes had volume, but still no mass. Lastly, today's technology offers 3-D solid models. This CAD gives the created objects shape, volume, and mass, allowing users to assign specific densities, materials, and material conditions to the parts they are digitally representing.

What CAD software is most praised for, however, is its dynamic ability to help users create complex representations of a concept that can be the blueprint for the product's eventual manufacturing. When working with CAD, a user is able to edit lines and shapes quickly and accurately, making measurements exact and mathematically scaled to the rest of the object. The user is able to mirror images and create replicas by using copy and paste shortcuts. A user can import graphics from a PDF file or from compatible software such as Adobe Illustrator or Photoshop. Because no material is needed to represent an idea digitally, production costs are cut and the design process is made dramatically less expensive.

Perhaps the most advanced aspect of CAD is the use of heat, stress, and conditional analysis to test the viability of the object being created. For example, an airplane model can be put through a flight simulation that offers highly windy conditions and the software will test whether or not the wings can hold under such pressure. As a result, CAD's most avid admirers are at the industry level because the software's capabilities have made manufacturing more time and cost-efficient.

As the technology has become more popular in the engineering industry, it has made its way into schools as a tool for training the next generation of product designers. Using CAD as part of the design process in an academic capacity, however, is vastly different than using it in industry. The introduction of CAD software has revolutionized the creative possibilities available to designers during the design process. It has also changed the culture of product design as a whole by giving birth to a new generation of engineers who are separated from their mentors by this technological divide. These generations differ in many ways. Mainly they are separated by their fundamental skill sets, their approaches to design, and their views of how the technology should be used in engineering training. Despite these generational differences, CAD it is still a remarkable tool, which, if it is used correctly, has the potential to bring the two groups together in the "CAD Era" of design to train the smartest, most efficient engineers possible.

CAD's Effect on the Fundamental Skill Sets in Engineers

One of the most significant examples of how the two generations are divided is in their training as designers. This divide can be understood by examining the differences in each group's comfort and ease with the fundamental, traditional engineering skills they learned when in school. Typically, current mechanical engineering faculty at universities spent their time in school in a machine shop, working directly with machines that performed different functions. The older generation was trained by working in a woodshop, spending hours hovered over a lathe or practicing welding pieces of metal. Research regarding the traditional academic training of these engineers and designers makes it clear that the main fundamental skill that was stressed more during the past was drawing (Buchal, 2002).

The ability to communicate ideas through simple sketching was, and still is, a vital tool for engineers. In an interview in February 2009, Craig Milroy head of the Stanford Product Realization Lab and lecturer in their design school of the Mechanical Engineering department, recalled how engineers were trained with a pen and pencil in hand before they learned how to use complicated machines. They were all taught to carry logbooks with them wherever they went and to treat them as an extension of their mind. The logbooks offered a space for engineers to represent visually their complex ideas and design on paper what they would later see in three-dimensional form once their idea was carried out. Logbook pages were to be filled with anything from mind maps, inspiring clips from magazines, and doodles. While doodles may seem silly to some, they often are the basis of what later become more detailed drawings of a developing idea. The act of drawing is itself said to be one of the most expressive forms of creativity, acting as an "extension of working memory, support for mental imagery, and mental synthesis" (Buchal, 2002, p. 113).

Before students had access to CAD, drawing was the foundation of their work and was believed to be necessary "during all the developmental stages of a mechanical design" (Ullman, 1990, p. 263). The reason drawing is thought to be so important in training is because it acts as a tool for problem solving out loud. In other words, "sketching remains a basic tool for speeding up visual problem solving in any engineering field by externalizing and representing design problems" (Contero, 2005, p. 27). As a result, engineers who were trained with a pen and pencil in hand have a different mindset when they approach a problem compared to engineers who were trained in computerized design technology. Sketching is inherently creative. By practicing and sketching frequently and well, designers become more creative thinkers (Hare, 2004). While CAD has the ability to guide the engineer through technical problems such as dimensions and mathematic scaling, it does not have the same ability to let a designer think aloud and present quick visualizations of a potential object the way drawing does. From a creative standpoint, entering data into CAD can be described as a "passionless activity of drawing points, lines, and circles" (Downey, 1998, p. 167). As Product Design masters student and Mechanical Engineering TA Matt Coleman said, "once you know exactly what you're drawing and why you're drawing it that way, CAD is phenomenal" (Coleman, 2009). But engineers in training need to work through their visual thought process and understand how and why they came to a specific design idea before committing to it fully enough to represent it in a CAD model.

Sketching as a tool can be seen as a more dynamic skill. It not only visually achieves a designer's goal of displaying an idea, but it also has the added dimension of representing how a developing engineer understands and communicates a concept. Drawing thus becomes a "mean[s] of extending and simultaneously transforming our understanding, rather than simply a means to let others know what we think or even ways of revealing to ourselves what we think" (Hare, 2004). Such an approach to design is so deeply ingrained in the pre-CAD generation that it defines how they approach the design process.

In contrast, as CAD began entering the academic environment in the 1990s, students became more intrigued by the technological functions of the software and started implementing the sketch functions that the early models offered instead of using traditional logbooks. In its early models, CAD offered pen-based interfaces that mimicked the act of drawing with a pen or pencil in hand. As technology progressed, tablet PCs were created to better preserve and implement the foundational skills of drawing. These interfaces were a step towards the more advanced technologies offered today. The tablet PC's capability "aims to provide an intelligent and interactive modeling support to visual thinking in product development's conceptual design stage, by exploiting freehand sketch input provided by a calligraphic interface" (Contero, 2005, p. 27). Newer CAD software allows users to sketch with their mouse directly onto blank digital "paper." Although the image that appears does mimic one you might sketch, the computer system reads it as data by nature of CAD's software codes. In this way, drawing on CAD doesn't necessarily recreate the process of drawing on paper, but instead creates a new element of drawing entirely: the digital image. In the end, CAD is still a software program that has the "ability to transform graphical representations into numerical ones" (Downey, 1998, p. 164), storing a linear concept or idea as a mathematical data set. While such improvements in the push towards digital drawing are on the right track toward understanding the importance of integrating sketching into the design process, it is undeniable that how the designer goes about initial representations of his or her idea is different when he or she is using CAD at the beginning of the design process.

In this way, CAD has pushed a new design generation to rely ever more heavily on technology. While people do not argue against the importance of drawing, they deemphasize the analog approach as a vital component and instead see the CAD version of sketching as an acceptable replacement. As anthropologist and author Downey (1998, p. 163) writes, "for engineering students, working on a CAD/CAM system transformed the physical practice of producing an engineering drawing, or drafting, into the computer practice of entering." The consequence of having the digital replace the analog entirely is that the benefits of pre-CAD training will be lost in the transition, not only by cutting out essential elements of engineering training, but also by changing the culture of design entirely. On this cultural level, educators worry that their students will not have their experience of collaborating over drawings with peers and teachers, bouncing ideas off of each other, and soaking in new design approaches and visual thinking. Instead, the new design culture in a classroom may be one that is individual, solitary, and focused mainly on the student interacting with a computer screen.

CAD's Effect on an Engineer's Approach to the Design Process

Another way that the two generations of engineers are divided is in their general approach to the design process. In this case, technology, and more specifically CAD, has "significantly changed the role of the engineer in design and manufacturing" (Richard, 1985, p. 19). At an industry level, CAD has been an extremely effective and necessary tool that engineers can use in order to maximize efficiency and create products in bulk in a shorter timeframe. During the rise of CAD in the 1980s, it was seen as a "promise of increased production efficiency" (Lichten, 1984, p. 237), seemingly as an answer to mechanics' and engineers' frustrations with the time and energy spent on the traditional design process to come up with a working representation of a final product. In this manner, CAD can be seen as a tool that targets production in industry rather than as a tool for creativity as it is in academia. Instead of an engineer feeling his or her way through the manufacturing and design process by working closely with a product, engineers are now able to design a product using CAD and dish out the manufacturing to other professionals. As Lichten (1984, p. 237) writes, "The primary aim of a designer's model of an object is to provide information required to manufacture that object, and the completeness and non-ambiguity of the model contribute heavily toward an object's efficient manufacture."

From this industrial and market-driven standpoint, "To achieve high productivity in manufacturing, there is no alternative [to] computer-aided manufacturing" (Lin, Ullan, and Harib, 2006, p. 336). Although this is true, an industry thinks of technological advances in engineering, such as CAD, as a way to produce as many products at the lowest cost for the highest profit. In academia, however, these technological advances have consequences for the integrity of the education provided. In this case, CAD should be used in a way to maximize training and skill-building, not as a means to redirect the focus and fundamental education of the students. Without guidance and perspective from traditional teachers to push their students to be well-rounded engineers, students will get caught up in the fact that industries believe that "graduates [that have] solid foundation in [CAD] are needed for the economic growth of a nation" (Lin et al., 2006, p. 336), and overlook the importance of having an education that is more well-rounded.

However, now that students feel the need to be proficient in CAD in order to keep up with industry-level design expectations that emphasize production, the academic design process has been altered dramatically to cater to the new CAD generation of engineers. Craig Millroy (2009) said that in many engineering departments across the country, teachers have implemented a "CAD 101" in the freshman curriculum, requiring new students to enter school with computers that have the correct CAD software already installed. In the new age of engineering, mentors of the pre-CAD generation fear that the consequence of relying heavily on technology to assist designing will be that students become so focused on the virtual image of their idea that they will fail to understand their concept as a realistic object. In this case, the role of the designer will change from interactive thinker to isolated student, working solely with a technology to help further develop their ideas.

Unfortunately, the result of losing the pre-CAD conceptualization stage of design means cutting out arguably the most vital stages of the process. This is significant because "computers can only enhance a good concept" (Unver, 2006, p. 326), making the training of engineers in the

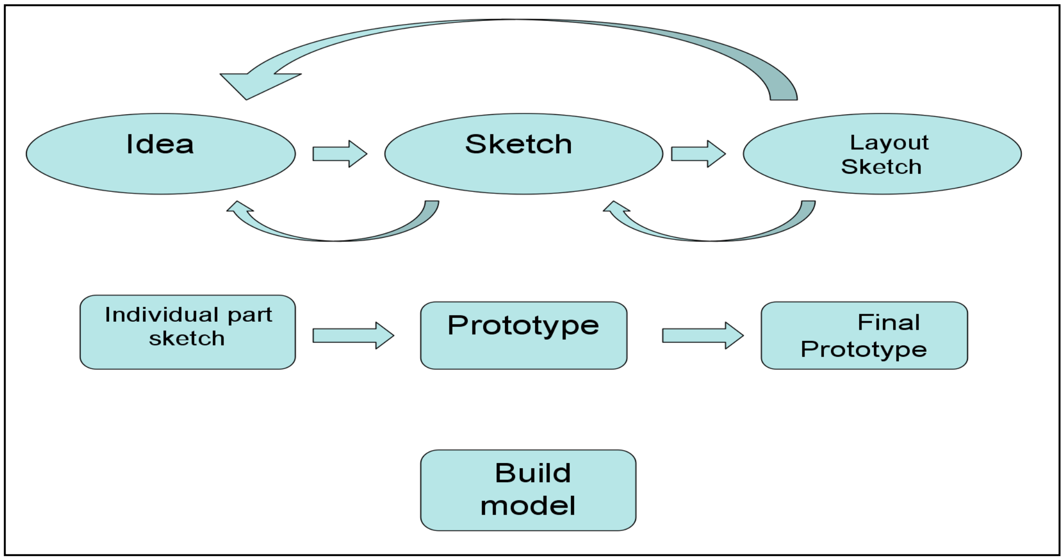

FIGURE 1. Design process before the introduction of CAD (Millroy, 2009).

mastery of the mental legwork of coming up with a concept all the more important. By using the pre-CAD process, the designer's role still requires working through the problem solving process and staying closely connected with the traditional steps of ideation that are at the core of engineering design. Craig Milroy and the engineering staff at Stanford University, for example, still firmly stress the value of the foundational training they received when they were students and ingrain the basic design process in their students today. Milroy sees the process broken down into several necessary, sequential steps (Figure 1).

A significant element of this vision is the dynamic, interchanging nature between the first three stages. The first row signifies the ideation and conceptualization phase where student ideas are in the working stage of being formed and reformed, as they turn the abstract vision they have into a working representation of their final idea. Sticking with this model, if a student has an idea and sketches it out but cannot quite make sense of one part or gets input from a peer on how to alter the idea, the designer can go back to the ideation stage, sketch up a quick representation of the new idea, and proceed developing it further from there. As scientist and educator Linus Pauling once said, "the best way to get a good idea, is to get *a lot* of ideas" (Kelley, 2002, p. 55), and the ideation and conceptualization phase is where to generate the most ideas possible. These brainstorming sessions build on the importance and necessity of fundamental drawing skills because they "are extremely visual. They include sketching, mind mapping, diagrams, and stick figures. You don't have to be an artist to get

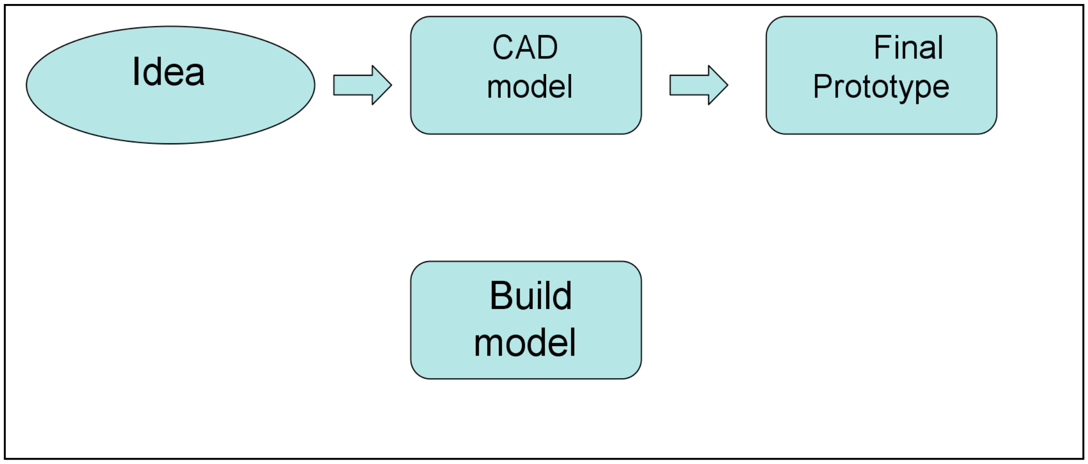

FIGURE 2. Design process after introduction of CAD (Millroy, 2009).

your point across with a sketch or diagram" (Kelley, 2002, pp. 61-62). This interactive and active ideation phase can be seen as the anchor of the traditional design culture, where design thinking occurs before implementing that idea into further stages in the design process and creativity flows freely from every step. With CAD added to the equation, the new generation of engineers is more likely to change the traditional model to resemble more of a four-step process (Figure 2).

CAD's role eliminates the stages of sketching and redesigning that are seen in the traditional model. If students use CAD without first working through the conceptual stages, they run the risk of deciding on an idea and spending time on creating the virtual model of something that, in the end, could potentially not be viable for many reasons. IDEO, one of leading design firms in the world, has built its legacy on its creative approach to design. It is unique in the way it has preserved the traditional approach to product design in the industry. In many ways, its style and attitude parallel those held by faculty in Stanford's design and engineering departments, many of whom have worked closely with IDEO over the years. Simon Leach, an IDEO prototyper, commented on how IDEO believes that CAD should be used "much further into the design process, where a product's form is much more tightly defined" (Dean, 2009), stressing the vital nature of the collaborative conceptualization process in order to maximize potential creativity. As product design student and mechanical engineering teaching assistant Matt Coleman (2009) said, "if a student jumps into [CAD] too soon and forgets low-fi prototyping, they're losing their ability to innovate." The sketching and rapid prototyping stages allow students to flush out possible kinks and rethink their concept before committing to model that they'll develop.

Although CAD can be seen as taking away from the creative process if students immediately use CAD after coming up with an idea, there is a

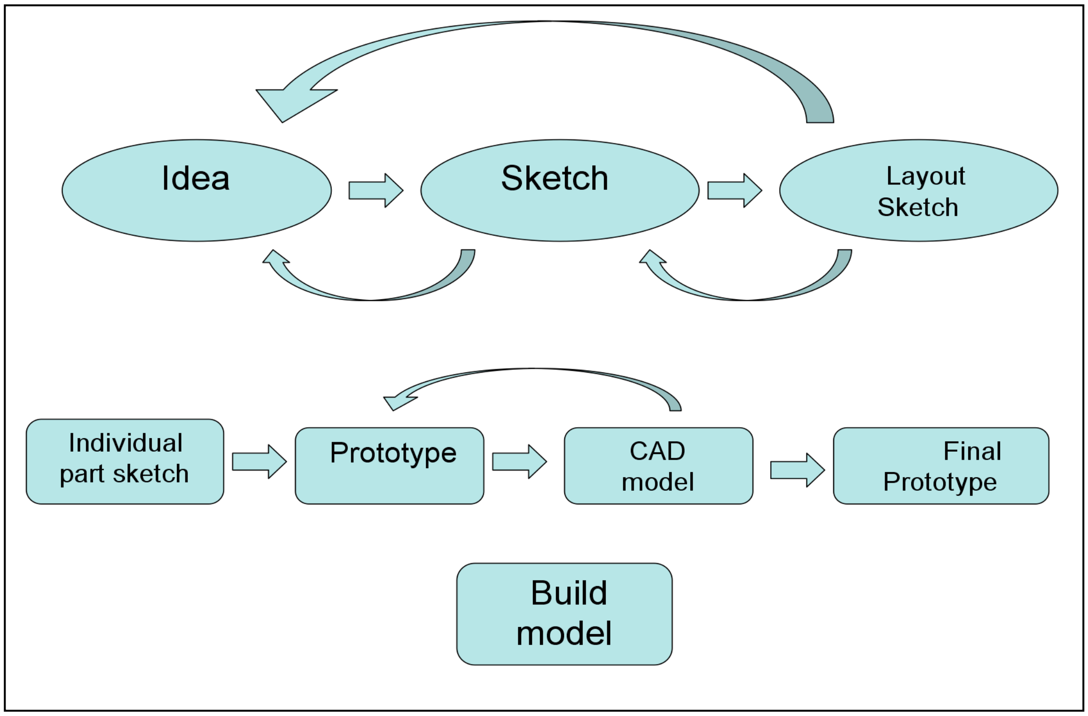

FIGURE 3. Design process that incorporate both traditional methods and CAD (Millroy, 2009).

middle ground besides the pre-CAD and post-CAD models of design that maximizes potential creativity and execution (Figure 3).

In this model, "the use of CAD technology can deepen the student's understanding of final form, structure, and performance of a product," for without the initial conceptual stages, "the student and teacher do not have access to a simple overview of all the development process traditionally a set of drawings in a layout pad with a complimentary range of sketch and appearance models" (Unver, 2006, p. 323). With all the stages in place, the students can use CAD as a detailed problem-solving tool to finalize a clean, scaled model that they can then base their modeling on. CAD also eliminates the need for students to spend time on issues such as the stress analysis for the object and can allow them to use more of their energy on creativity. IDEO Design Engineer Max Bielenberg sees CAD as part of the bigger picture of designing, acting as an added tool for designers to create and represent their best ideas. Bielenberg (Dean, 2009) believes:

> It's a piece of the toolbox but the tools don't define how we innovate. It's just one of the tools, depending on what the project is and if it's suitable for that particular project, or not…. It's part of a suite of tools. Part of which is just your brain and your creative thought that you use in the innovation process, which goes from thinking and creating, sketching – generally, communicating ideas as fast as you can. That could just be verbally in a brainstorm, it could be pencil sketching, but as it gets more detailed, you have to use more sophisticated tools. 3D CAD is a sophisticated tool that you use further on down the line in the innovation process.

Another element of the designing process that has also changed since CAD is the role of the designer when it comes to prototyping. With advanced CAD technology, once a model is built to scale using the software, students can essentially print their model to a 3-D printer and have the completed prototype within a matter of hours, depending on the speed of the printer. While this is convenient, cheap, and efficient, the students are losing the experience of working with their hands and having a close relationship with the product they are creating. By making students make initial prototypes that are "quick and dirty," as the Stanford mechanical engineering department puts it, students gain a sense of what it will feel like to hold the object, work with various materials, use different machines, and have a greater understanding of their product as a whole. Coleman (2009) believes, "Good designers have a good intuition for the physical thing, and CAD can't replace that intuition." IDEO's Bielenberg (Dean, 2009) would agree that it's importing for students to learn, "hand prototyping and trying things out - literally doing things with sticky tape, plasticine, cardboard." He said, "I think people are very keen to get into 3-D CAD because it makes people think things are much more defined than they really are - because it looks impressive" (ibid). Working with your hands and "learning by doing works because it teaches implicitly rather than explicitly" (Hare, 2004), and also helps communicate your ideas with your peers and gauge the reactions of your peers. IDEO CEO Tim Brown stresses the importance of quick prototypes. To him, prototypes are "rough, ready, and not at all elegant, but they work. The goal isn't to create a close approximation of the finished product or process; the goal is to elicit feedback that helps us work through the problem we're trying to solve. In a sense, we build to think" (Brown, 2007). Cutting out the initial prototyping diminishes their role as a thinking designer.

CAD's Role in the Training of Engineers in Academia

The final divide between the generations of engineers is illustrated by how each views the educational approach to using this technology. Because this technology has influenced designers not only on an individual level, but also on an academic one, institutions of design education "should regard the use of computers as a socio-cultural rather than merely a technical issue" (Cil and Pakdil, 2007, p. 125). The difference in the academic training of the two generations can be seen as a source of tension when it comes to students and teachers clashing over their approach to design training. Fundamentally, however, the pre-CAD generation feels strongly that the importance of creativity and design should not be lost in academia in the future, especially given the technological advances that have infiltrated the students' lives. Gary Lee Downey shadowed the CAD lab and CAD curriculum at Virginia Tech, where he is a professor in anthropology and engineering, and head of the STS department. While studying Virginia Tech's CAD curriculum, he observed the tension between the students and teachers and studied how the two groups view CAD and the CAD introductory courses. As Downey recounts, Dr. West, an engineering professor who taught a CAD course to undergraduates, "had often struggled for language to explain that [CAD] would never fully automate the human process of engineering design… [his] project objective [was] to achieve a design, not just to figure out what the CAD system is good for making. Only then will you find out what the CAD system is good for or not" (Downey, 1998, p. 199). David Kelley, founder of IDEO, tenured professor at Stanford, and head of Stanford's d.School, echoed Dr. West's desire to stress the importance of the human process in design. Kelley so strongly believes "creativity is as important in education as literacy" (Brown, 2007), that he has even been in close contact with Stanford's president, John Hennessy, to make "creative confidence" a requirement for all undergraduates.

For their part, students believe CAD is the entire future of engineering because they see it at the forefront of their future in the design industry. Professors, however, are looking at CAD from an academic perspective, focusing solely on how it is used to train engineers. As a result, there is often miscommunication about preparing students for the real world without compromising their education. After observing students and teachers, Downey (1998, p. 208) reflected, "Everybody knew that industry was charging headlong in [CAD] technology and that any demonstration of understanding could be a ticket to a job. The legitimacy for teaching [CAD] was there, but the theoretical strategies for integrating it into established practices of engineering education were not." Due to students' notions that CAD must be mastered entirely in order to have any hope of breaking into the industry after graduation, tension arises when students want to strictly emphasize their work in CAD instead of appreciating the technology it offers but also realizing it isn't the only means to creative design. As Downey discovered, students see CAD as a technological hurdle between them and success in the industry, and believe they must excel as a CAD user in order to feel accomplished as a designer. Dr. Smith's introductory CAD projects "brought to a head the tension in the CAD/CAM course between the instructors' desire to have students appreciate simultaneously the opportunities and limitations of CAD/CAM technology and the students' desires to control or use it" (Downey, 1998, p. 163).

Because teachers see CAD as an element of design instead of the answer to design, their generation is often less proficient in CAD. As a result, the Introductory CAD courses often have both a lecture and lab component to give the professors time to talk about design theory in addition to handing out CAD assignments that their TAs design. As Downey witnessed, however, the lectures often have at least one third of the class missing on any given day. This lack of attendance is because students realize that their final grade is based solely on their CAD assignments, which they learn to do on their own through the CAD manuals or by going to see TAs during the lab hours. Downey spoke with one student, Sandy, who had just finished the class. She left the course with "the good grade she wanted but without a strong of sense of achievement or pleasure, or even a desire to continue and learn more… rather than celebrating, wondering, questioning, or otherwise engaging … [she] sold one of her books and her journal simply ended with a bare description of the final exam" (Downey, 1998, p. 191). Instead of thinking about how she developed her skills as a creative designer, Sandy remembers "she had sat repeatedly for hours at a time trying out all sorts of pathways until she could find something the computer would accept" (ibid). The concept that a student spent countless hours on a project hoping to find a design that "the computer would accept" rather than an idea she accepted herself exemplifies how CAD can interfere with the educational development of a student in this field.

One effort to bridge the gap has been made by the Development of the College CAD/CAM Consortium, also known as "The 4Cs." The 4Cs is a nonprofit organization that is funded by the National Science Foundation. The 4Cs works with its partner universities to fund curriculum development to better introduce and integrate CAD into the academic environment. In the 1980s, the 4C faculty teams from the member schools "developed courses, curricula, and software using the emerging technology of computer graphics to teach engineering concepts" (Riachards, 1985, p. 19). Today, the universities in the consortium work "to promote the integration of CAD/CAM into their engineering curriculum," which is intended to lead to more highly focused efforts in making CAD an efficient and, more importantly, educational tool in the overall training of the future engineers.

The effect of the revolution of CAD on product design education demonstrates that, although this technology has transformed the process of engineering on a technological level, the broader social implications that have resulted have profoundly changed the culture of design. CAD's influential role will only increase over time because "the increasing use of computer technology is evident, not only in the CAD and practical design modules, but also in the theoretical and cultural aspects of education" (Unver, 2006, p. 325). CAD's technological advances appear to have dramatically enhanced the market-side of manufacturing and design. However, CAD can also affect different social infrastructures in different ways. Research on the influences CAD has had on the academic environment and the role it will play in the future of engineering demonstrates that universities must recognize the power of CAD not only as a scientific tool but more importantly, as a social one.

What draws so many intelligent and curious minds to the world of design and engineering is the culture that implicitly comes with it. The notion of these dynamic minds coming together to solve a problem in the most imaginative and inspired way is an exciting and unique culture. This notion needs to be preserved and promoted for the future engineering students. IDEO's offices in Palo Alto, CA epitomize design culture at its finest:

> Ideo's headquarters look like a cross between a cool Montessori school and a crash pad circa 1970. There are tubs of markers and easel pads of paper everywhere; Post-it Notes litter the walls of conference rooms. A gum-ball machine, xylophone, and Tickle Me Elmo lie nearby, critical elements in the latest company prank, a global Rube Goldberg contraption, which began with a coin drop in Palo Alto and bumped and rattled its way, with occasional electronic leaps, through the company's seven other offices. A vintage Volkswagen bus has been converted into a meeting area, complete with beach chairs on the roof (Brown, 2007).

An academic environment that will produce the best engineers is one that preserves the spirit of the kind of design culture that IDEO has adopted and that provides its engineers with the necessary tools and approaches they need to be as innovative and creative as possible. Schools should instill the traditional skills every engineer should have while also implementing the latest technologies to help them maximize students' potentials to communicate and develop their ideas. Jean Thilmany (2006) put it well when she wrote, "No one has any doubts that CAD does help the bottom line," but, as Matt Coleman (2009) has observed, educationally, CAD is "great for execution, not for learning."

Too great a reliance on technology in the design world will create an environment that is a dramatic change from the freehand, ingenious collaborative and dynamic work environment that makes designing what it is. As Downey (1998, p. 142) observed when entering the CAD Laboratory at Virginia Tech, it was, "like entering a different world indeed… it felt as though one were becoming part of a closed environment, constructed by some faceless authorities looking to the future rather than to the past or present." This environment is the opposite of the one in which a student's minds will unfold and grow. Implementing CAD in a student's curriculum should be encouraged, but in the manner that preserves and builds on the fundamentals of engineering. In this way, new technology can become an element of the creative culture of design interaction and help engineers become the best thinkers they can. As Tom Kelley, General Manager (2002, p. 13) of IDEO believes, "we all have a creative side, and it can flourish if you spawn a culture to encourage it, one that embraces risk and wild ideas and tolerates the occasional failure."

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