Issues in Computer Graphics Education

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Abstract

In spite of a booming industry, most 3D graduates have tremendous difficulty getting even entry-level jobs. Animation programs, the most common source of 3D education, are analyzed to reveal why their students compete less successfully with computer science, design, and other bachelors degree students. The solution is to distinguish 3D from animation by creating a new discipline. This 3D discipline should retain the artistic components of animation but place greater emphasis on problem solving, 3D expression, and computer programming. A new approach would not only strengthen chances of employment for graduates within the entertainment industry but also better enable them to get jobs in other fields like visualization and education. Doing so will empower graduates, broaden societal perceptions of 3D, and provide the next generation of leadership in the digital age.

As anyone who has seen a movie, television commercial, or video game in the last decade can attest, 3D has become the dominant production method for gaming and animated film--even those that look like traditional cel animation. Demand for environment, effect, and character creation have mushroomed from an obscure pursuit in the 1980s to a must-have skill to work in the entertainment industry. What is less well known is that 3D is also used extensively in other fields for flight simulators, industrial and architectural rendering, training and medical illustration. 3D solves the age-old problem of visualizing a difficult concept, and it does so more realistically than any previous form of representation. To that end, programs teaching 3D have sprung up around the world. Students typically learn 3D within animation, a field that has had a formal curriculum for less than 50 years.

Fierce competition exists for all jobs in 3D, and is greatest for the high-profile work in film and gaming. In this industry, the need for the best preparation has become paramount. Yet despite educational programs more structured than ever, most industry grads have tremendous difficulty even getting entry-level jobs. Many never break in at all, much less achieve the top jobs like game designer or visual effects artist. Often these slots are filled by those not trained in an animation program at all but possessing a hybrid educational background of 3D and another discipline, like architecture or science. Many employers find that even for beginner positions, animation applicants fall short of the level of skills needed. The problem is that 3D is not interchangeable with animation, and current animation education is not preparing students for careers in the 3D professions.

The lack of readiness of 3D graduates is not just a problem for the gaming and film industry. Many still consider 3D a boutique artistic profession because thus far there are relatively few jobs compared to other applied arts, such as graphic design, and of those jobs most are in entertainment. However, the question is not how many positions will be affected, but how many people in society at large are influenced by 3D? 3D has permeated our culture in a multitude of hidden ways. To adequately educate 3D artists for the ever-increasing world of digital images, the solution is to separate the disciplines of 3D and animation and create a new curriculum of 3D.

1) The Big Picture of Educating 3D Artists

1a) 2D Animation

The art of animation has lived for ages, but animated film production has existed for about a century, and education for that profession even less. From the 1930s until the 1980s, training was acquired on-the-job. During the 1940s, masters like Ub Iwerks, Chuck Jones, and John Hubley studied painting and drawing at art schools, but learned animation at studios during production. MGM, Warner Bros. and others had in-house animation facilities that drew all-ages cartoons for their releases, while Disney and Hubley founded independent studios. Some of the most beloved animated characters were created in this era, like Warner Bros.' Bugs Bunny, MGM's Tom and Jerry, and Disney's Mickey Mouse. Artists honed their skills drawing hundreds of sheets of celluloid, a.k.a. cels, altering the drawing slightly with each one to create the illusion of movement. To create 1 second of animated film, 24 cels were meticulously drawn, inked and painted. Even with a talented team of artists, production of a 2D animation is an extremely labor intensive art. Creating a 6-minute short took months and a 90-minute feature years. An animator who started as an apprentice would experience the entire process before working his way up to the prime job of animation director.

The demand for movies justified the intensive labor of making cartoons, but television would alter the landscape. As movie attendance at waned in the 1950s, studios like RKO and MGM could barely produce features, much less sponsor their animation studios. Many of them closed in the 60s and 70s. Animations migrated to Saturday morning television, and old favorites like Warner Bros' "Looney Tunes" were syndicated for television. New cartoons were created

strictly for kids, and almost all commercial production of went offshore to low-wage, union-free studios. (It has remained there ever since: traditional cel cartoons like *The Simpsons* have been outsourced for decades.) Older animators retired and future animators had no opportunity to learn. But in the late 70s and early 1980s the public's love of animation was rekindled and production was revived, albeit within a few surviving studios. Unfortunately, the lack of education and experience among the new generation of animators resulted in box office bombs like Disney's *The Black Cauldron* (1985.) Subsequently, Disney created a solution by founding an animation program at UCLA. Pixar's John Lasseter and filmmaker Tim Burton were among its first graduates. This model would be imitated and animation would become another bachelor's degree.

Animation is now learned in departments at colleges and universities. Most 3D is taught in art programs as a progression of traditional cel animation, now using computers with turnkey (a.k.a. off-the-shelf) software. 3D is also taught within host of other disciplines, like architecture and design, as a visualization tool. The actual programming of the computer, the discipline of computer science, is taught at universities and research institutions, but the graduates most skilled in creating environments, characters, and effects in 3D are animation graduates of art schools.

A huge market of gaming, film, television and video has created a need for animators, but contemporary labor costs have made hand-painted cel production economically infeasible. Almost all 2D cartoons are produced on the computer by software that duplicates a traditional hand-painted cel. Even offshore studios have switched to digital production. Moreover, much animation that appears to be 2D is not that at all, but 3D scenes created and then digitally overlaid to look like traditional hand-painted cel art. The clock tower scene in *The Great Mouse Detective* (1986) was the first Disney film to use this technique: every other Disney production since has employed it to some degree. Digital overlay is now a standard practice in all productions in the industry. Viewers remain nostalgic for the cel look, but the reality is that complex scenes and motions can be executed more efficiently in 3D.

Although viewers initially did not like the plastic style of the first computer generated productions, audiences over the last 20 years have become more accepting. *Toy Story* (1995) was a hit despite its obviously digital images because it was such an entertaining film. Children accustomed since birth to cartoons like *Jimmy Neutron: Boy Genius* become less discriminating each year. The latest films like *Final Fantasy* (2002) are bringing 3D closer everyday to photorealism: indistinguishable from live action. Many 3D films like *The Incredibles* (2004) strive for a unique visual style rather than realism. As a result, many in the industry think that the technique of painted cells will disappear altogether in a matter of years.[1]

1b) Development of 3D

Unlike 2D animation, 3D did not originate in the entertainment industry and its close relationship with it is a relatively modern phenomenon. 3D software was developed at research institutions in the 1970s for aerospace, manufacturing and defense industries. One of the first fruits of that research was the flight simulator created by David Evans and Ivan Sutherland at University of Utah. Utah's Computer Graphics program would be the first of its kind and would pioneer much of the technology and people who have shaped the latter 20th century.

During the 1970s, 3D was developed at computer departments like Utah's and used by companies like Boeing, Renault, and Lockheed. Other research occurred at institutions like MIT and Lawrence Livermoore National Labs. The users were as much software engineers as 3D designers and focused on industrial design and defense, with occasional forays into art. It is a testament to the brilliance of these early pioneers that they could actually create moving images, however rough, from the enormous mainframe computing machines of the 1970s. Many of these same individuals would go on to create technology and companies that are now part of modern life. Pixar's Ed Catmull, Netscape's Jim Clark and Adobe's John Warnock all studied at the Computer Graphics Department of University of Utah in the 1970s. (One program at the New York Institute of Technology did focus on art and animation. Their first film was not considered a success, attributed to lack of filmmaking skills, and many of the initial group left the school in frustration.)

In the 1980s 3D was still rooted in heavy industry, but began to move into the film industry as bits of computer animation occurred in commercials and movie effects. *TRON* was a milestone film, featuring 14 minutes of CGI. One of the prototypical programs for today's education was founded by Charles Csuri at Ohio State University. The Advanced Computing Center for Arts and Design (formerly the Computer Graphics Research Group) was founded in 1984 with the focus on creating computer graphics for entertainment.

Up until the early 1990s, only the technical elite practiced 3D. Unlike the present artists, a 3D artist in this era was also a talented programmer because no off the shelf software existed. Even hardware was difficult: computers that could create computer graphics were

[1] Forum, SIGGRAPH '00.

extremely expensive. 3D was created, but only in specialized, well-funded studios like those of Boeing, Lockheed, and Universal. With the advent of hardware like the Pentium chip, CD-ROMs, and Open GL cards in the 1990s, 3D software that was once ran only a mega-machine now possible on a desktop computer. Occurrences of 3D in movies, gaming and television exploded. Better technology enabled artists to reach new heights in 3D imagery. Over roughly ten years, 3D had evolved from 14 minutes of plasticized computer generated imagery in *TRON* (1982) to photoreal dinosaurs in *Jurassic Park* (1993).

Although the movies were the most dazzling example, they were not the only evidence of 3D's growing market presence. Heavy industry continued its usage, but now 3D was accessible to individual artists and users and spread like a pandemic. Local television stations could produce computer graphics in-house. Architectural firms created photoreal renderings in addition to digital blueprints. Small scale industrial designers could utilize off the shelf 3D programs. The gaming industry was able to recover from a post-Atari slump with a series of more impressive games like "Myst."

1C) 3D Education: 1995-2000

With the boom in desktop animation of the 90s, educational programs mushroomed across the country to train artists. Technical, commercial art, and vocational schools fashioned programs that essentially taught software, and the graduates were considered work ready in 6-18 months. In fact, many in the industry disdained the need for any schooling. Buying the right computer and software was all the preparation needed and the result would be an instant 3D artist. Jacqueline Ford Morie remembered an incident in 1990: "A student in my program at Ringling School of Art and Design was convinced by a software salesman…to take his next year's tuition and buy their system--it was all he needed to start his own business."[2] This sort of story was hardly unique during the next few years, and many went to California like would-be starlets looking for their big break. Some even found it: 3D was still so new that many found high-paying jobs in the booming field.

This inflated market would follow the same pattern as the desktop publishing revolution of the 1990s that preceded it (and the dot-com bust that would follow it.) In the desktop revolution, the services of a graphic designer were obsolete: with a personal computer, software and a printer anyone could duplicate a printing house. However, it became clear that the technology did not fabricate legibility and artistry. The business world returned to the talents of graphic designers, who incorporated their experience into digital production.

Ironically, the 3D experience would be almost identical, but the community would be oblivious to the parallel. By 2000, it became clear that 18 months could not even produce a competent user, much less an artist.

Programs have returned to the basic precepts created by past masters, such as Disney's 12 principles of animation. In most course sequences, students are introduced to 2D animation first as a basis for 3D, and then allowed to specialize as they progress further into their curriculum. After a year or more creating 2D cartoons on radically different software, students are expected to evolve to 3D. Even with the changes in technology, careers, etc., 3D is part of animation, and that is a division under the broader heading of film. This can be seen at a variety of schools such as University of Georgia, where the program is a division of the theatre department.

2) 3D Education: 2005

At this time, animation graduates are in fierce competition. The artistic and technical skills expected of a new hire make a formidable list. All are expected to demonstrate abilities in sketching, storytelling, character design, and communication. In addition to proficiency in at least one major commercial modeling and animation package, students are expected to have knowledge of editing, sound, and effects software. The job skills expected of them have risen sharply from the 1990s, and these graduates of animation programs frequently lose out to computer science and film students.

Giant Studios is an award-winning studio that specializes in 3D motion animation for feature films. Having provided content for Hollywood blockbusters like *The Lion, the Witch and the Wardrobe,* Giant is a prime destination of an animation graduate, and their expectations for employment are high. According to Giant's Director of Research and Development Matt Madden, only one third of new hires have an animation degree. The other two-thirds come from computer science, engineering, or video or film production backgrounds. Even entry-level positions are highly technical. Madden commented: "… regardless of the position, we always try to get people who can adapt to new ways of accomplishing our production goals, which usually involves learning to use (or developing) new software that will help improve either the efficiency or quality of our work."[3] The kind of employee described is not a user, but a leader who can draw on multiple levels of experience to complete a project. This degree

[2] Morie, Jacqueline Ford. "CGI Training for the Entertainment Film Industry." IEEE Computer Graphics and Applications 0272-1716/98, 1998 IEEE , vol. 18, no. 1: January /February 1998, pp. 30-37

[3] E-interview, Matt Madden June-July 2005

of proficiency is typical of high and low-end output: 3D skills are but one component of a skill set.

This preferred artist contrasts sharply with the example of Bob[4], a 2003 Bachelor of Arts animation graduate of an arts college. After completing his coursework Bob submitted a portfolio reel to prospective employers believing that he would find a position in gaming. Although it demonstrated a general grasp of software, it failed to show expertise in any specific aspect. After a fruitless job quest, Bob has been working as an auto detailer to repay his student loans. Unfortunately, his situation is all too common among graduates.

If current education is not enough for employment, then where is it falling short? The answer lies in the reality of current 3D curricula: it is considered a variation of 2D animation. But 3D is not a continuation of traditional animation in either practice or product. The answer to graduates' lack of employment lies in the creation of unique discipline of 3D. To create it, the distinctions of 3D must be identified if students are to be truly educated.

2A) The Elephant in the Room: Technology

The biggest distinction must be stated baldly. The technological component of 3D is 100x that of cel animation and other digital media. Students cannot be held to the same timetable of learning 3D as they would be for 2D. Software for 2D animation is far more accessible: it is easier to master and less expensive. Learning most packages of 2D software is a minor hurdle: 6 months of training are sufficient to become competent in the software and then the artist can concentrate on mastery as well as creative content. However, the 3D artist will spend years mastering just a small part of even the most mainstream turnkey packages. Most students require a year of full-time instruction to achieve a minimal level of functionality for modeling and rendering in 3D software. Many times as an instructor, I witnessed students abandon projects in 3D, not because of dislike of the media, but simply because they did not have time to do it adequately. This was especially common as students finished graduation portfolios. These students literally could not afford to spend another semester or more refining their 3D work. They reasoned that a finished 2D body of work, even if it did not reflect their true goals, was better than an incomplete 3D one. Frustration from such dilemmas was high and unfortunately their 2D projects often reflected their second-choice status.

Instead of continuing to model and build upon what they have already learned, students are then moved into character animation. At least another year will be spent learning to animate a character. The art of making creatures move requires a completely different approach from modeling. Animating a character in a believable fashion is a daunting challenge even for industry veterans. The hurdles of learning extremely complex software as well as the nuance of human motion elevate 3D character animation into high art.

There are many other aspects of 3D, such as lighting, effects, or textures, and students who specialize in any one of them face similar challenges. Industry professionals quietly accept that the any of the major commercial software is too broad for any artist to be proficient in all of it: at best the artist hopes to master one aspect. Combined with software that is constantly metamorphosing, the learning curve is steep and never really flattens out.

Hardware for 3D software has always been a challenge. At this time specialized hardware, like 3D body scanners and motion capture rigs, are fundamental for film production but far too expensive for the individual animator. Most schools do not invest in such hardware for a variety of reasons, not least of these is feasibility. Students who are struggling with basic concepts of animation are not ready for such advanced, costly equipment. As a result, a student has little exposure, much less proficiency, with the key tools used in the profession he strives to join.

The issues of learning 3D are unconsciously exacerbated in art programs, where influence of other applied arts like web design, illustration, or graphic design can be felt. This becomes problematic when the same expectations for success and schedules of accomplishment are applied across the board. As stated earlier, the software for 2D creation is far more accessible. Competent students quickly master the software and can spend their senior year as intended: creating content for their portfolios. However, many schools have learned that the timeline for an animation major is far longer, through no fault of the students, than it is for a graphic design major.

The problem with introducing 3D in the latter college years is that it simply does not allow enough time. Mastering an application as complex as 3D and becoming an artist is a lifetime's pursuit, and takes every bit of a four-year program. Unfortunately, most students spend the first portion of their major catching up on the fundamentals. Now that many high schools have eliminated their art courses, students often enter the program needing extensive foundation courses like drawing, sculpture, and visual expression.

Thanks to the Internet, high school students are much more familiar with digital images than at any other time,

[4]Names have been changed to protect the graduate's privacy.

but this familiarity does not equate understanding. Although they may be aware of GIF files, they have no grasp of the distinctions between it and a 3D model. Most of society innocently tends to lump together all aspects of digital content creation. Since they all come from a computer, people assume that web design, etc. and 2D/3Danimation are more or less the same. Part of the fundamentals students need is education in digital media. Ironically, many high schools now offer courses in the same commercial software colleges teach. However, these provide only a cursory understanding of 3D, and rarely can be used for college credit. Students in the major enroll with more exposure to technology but less skill in either software or art.

Once they begin the technical coursework, students barely have time to become functional, and cannot develop a specialty that will get them a job. The time allotted for learning 3D is often squeezed between 2D animation and preparations for portfolio in their senior year, so that many students use time that should be spent refining a portfolio on learning basic operations. Attempting software proficiency while finding their inner artistic voice dilutes the student's energy, making her successful at neither. Given that most of the animation jobs are 3D, the pressure to learn on students is tremendous, and to expect a student to do in 1-2 years is unrealistic. The most successful candidates have already been grounded in art and now pursue the software. This approach allows them to envision their results, and focus on the problem solving approach to achieve the desired result.

2B) Is it Art?

Given the above issues, the 3D student's challenge of mastering the technology *and* trying to create art is formidable. Creating 3D art exerts both left and right brain fully to be successful. However, the most common concern of 3D educators is that students are too focused on learning the software at the expense of art. This issue is an ongoing part of computer graphics. The poor quality of the animations at New York Institute of Technology's pioneering computer graphics school in the 1970s discouraged participants and crippled the program. The critics of early 3D shorts of the 1980s observed they lacked a story and strong visuals. Students often confuse a computer-generated image with art solely on the production hours spent in its creation: any that have taught (including the author) have witnessed this fallacy daily. University of North Carolina-Asheville's Lei Han, assistant professor in Multimedia Arts and Sciences commented that "[students] still have to have basic understanding of aesthetics, composition, and color." [5] This lack of art is a tremendous handicap to getting the premium jobs: a student without strong programming, design, or even artistic skills has little to offer a studio.

The most superficial cause of the lack of artistic value is that students are seduced by creating computer images. In my experience most animation students disliked the sketching phase, and would only do so when required. Many had no artistic background at all, and had entered animation because they loved of gaming and movies and thought this would be a good way to enjoy them. To them, sketching to solidify an idea are at best archaic and at worst a waste of time before producing "real" art. Unlike a sketch, the computer can provide instant results, in 256 million colors. One solution for the above is in hand: re-education of this notion begins from the student's first day of art school. No art school student escapes instruction in foundation drawing and studio art.

The less obvious but far more critical aspect of the problem goes back to the technology elephant. Students are simply stretched too thin in the amount of material they are expected to master to get a job in the industry. Despite calls for increased artistry, the list of required software grows longer each year. Then as now, the whole industry from student to software executive is driven by the mandate "use the most current tools, or be left in the dust." The only solution for this problem is through it: neither art nor technology is likely to get easier. Adding more classes to an already full program of study is not a solution either. Instead, their curriculum must be edited to better integrate both art and technology.

Despite their other employment weaknesses, an art school graduate has one tremendous advantage: their sense of art. This skill is an invaluable asset to a studio, and is a quality simply not found in a computer programmer or software engineer. At all costs, this asset must be preserved and strengthened to sustain not only the graduate but enrich the industry itself. The challenge remains to adjust curricula to better integrate art and technology

2C) 3D, not 2D

In typical higher education, students take a core of general courses like the rest of the student body until declaring their major as upperclassmen. Art schools follow this model, and the general core includes courses in other media. The intent of exposing animation students to other forms of art is a noble one: broad

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[5] Neal, Dale. "Computers are still no substitute for human talent." *Asheville Citizen Times*, June 16, 2005, p.A1

experience with different forms of expression will lead to a richer body of work.

An unconscious emphasis on 2D expression exists in the core curriculum. This represents a bias that is found throughout culture: with computer monitors, television screens, and theatres, it's a 2D world. This approach is adequate for 2D animators, but here the differences between 2D animation and 3D rear their heads. Like traditional animation, the professions of graphic design and computer illustration are generally two dimensional, focused on creating an image instead of shooting a scene.

However, a 3D creation is like sculpture: it must be seen from multiple sides. Art students are encouraged to draw and paint but less to sculpt or model. Even the word cartoon, deriving from the Latin word *carta*, to draw, indicates a whole different medium of art from 3D. Arts programs have often relegated 3D expression to an interesting elective. It is true that non-computer methods of 3D animation, like Claymation and stop motion, are rare in commercial productions because they are even more labor intensive than cel. *Chicken Run (2000)***,** although an excellent film, required 6 years of production[6], an amount of time infeasible for all but diehard animators. 3D media are taught in an adjunct fashion while the most emphasis is put on 2D animation.

Although the profession is beginning to show a return to 3D expression, students need more extensive training in sculpture and modeling. To understand 3D one has to practice working in three dimensions, such as sculpting. As noted earlier, students are already overextended in their courseloads, yet mastery of these skills is as important as that of storyboarding, a staple of every curriculum. Even 2D animators create maquettes, which are clay models of the character. This art was lost in early computer animations early years, as programmers with little art training steered the industry. The results, of flat, disproportionate projects speak for themselves. Graduates of architecture and industrial design build models from the beginning of their training and gain an enormous advantage over animation graduates when seeking 3D jobs.

For many students, a 3D software class is their first instruction in spatial relationships. Only then do many discover that although they are gifted artists, they are extremely weak working in three dimensions. These students do excellent work in cel animation, graphic design, etc. and should be directed to these areas. However, a student who makes this discovery as a junior has already invested a considerable amount of time and money in their education, and is reluctant to change majors in spite of this limitation. Instruction in three dimensions allows them to discover their strengths and weaknesses early in their education.

2D) The Dark Side of Desktop 3D

3D education of the 21st century is driven by off the shelf (also known as "turnkey") commercial software. Turnkey software has been both the blessing and the curse of the modern industry.

Software has evolved considerably from the 1970s when being a 3D artist was synonymous with being a programmer. The blessing is that a new tool, that of turnkey software, made a new avenue of applied art careers available for technophobic artisans. In the past, only hardcore artists were willing to learn programming to create their art. Charles Csuri, an All-American football player and artist, created one of his first pieces "Hummingbird" on punch cards.[7] Lillian Schwartz taught herself computer applications to explore not only art but art history: her analysis of Leonardo Da Vinci's *Mona Lisa* posed the theory that the world's most famous painting is actually a self-portrait. Dedication like that of Csuri and Schwartz produced meaningful results. This willingness to understand the art contrasts sharply the current approach to 3D. A typical animation program teaches little or no programming, relying on turnkey software and Internet downloads. If one must suffer for art, at least the suffering need not entail learning programming.

However, the curse of turnkey software has been in its continuation of a problem that has dogged artists from the beginning of time: separation of the artist from the tools of creation. At one time, artists ground their own colors to make paint, blacksmiths wielded their hammers at the forge, and photographers studied the chemicals of the darkroom. (Undoubtedly, though, someone criticized the Lascaux cave artist for not mixing his own colors but letting his assistant do it for him.) The need for an artist to understand the science behind his medium is hardly a new debate, and its latest iteration can be found with computer software.

What is undeniable however, is that without programming knowledge the artist is at the mercy of others, usually non-artists like software corporations and technical directors. Effects artist Caleb Howard discussed this issue in an editorial he wrote for *Computer Graphics World:* "Yes, it is possible to do a good job…without having a deep understanding of the tools one wields. But artists who gain the greatest recognition…invariably have learned that they must know the deeper mechanisms of their tool sets….*Those*

[6] Ansen, David. "Great Eggscape: Chickens Plot Break from Tweedy's!" *Newsweek*, June 26, 2000. p.59.

[7] *Smithsonian* "Old Master in a New Medium."

who don't remain craftspeople…"[8] (Emphasis added.) At this time, there are not enough jobs to accommodate craftspeople: the market demands multi-dimensional artists. As Giant's Madden noted: "I strongly believe that the more experience [graduates] receive in related fields will no doubt enhance their hiring potential. In fact, that's one of the first things that catch our eye when looking at a resume or CV."[9]

An example of the difference between craftsman and creator can be found in the pursuit of character animation. Successful human motion remains an ongoing challenge: the search continues for a technique that is less prescriptive and more self-guiding than motion capture. An excellent opportunity exists for the 3D artist to become an integral part of this search rather than a recipient of another's results.

Hiring issues fuel one of the most insidious problems of the 3D industry: faith in software instead of their art. In the fluctuating world of entertainment, even 3D masters are one project away from unemployment. Novices dread being, as Howard described, a craftsperson that can be easily replaced by a recent graduate trained in the latest software. Knowing the "right" software is sold as the only thing standing between the artist and destitution. Open any trade magazine to see software makers deliberately play on the fears of 3D artists. According to the advertisements, the only hope is to buy the right tools. Commercial products sponsor a tremendous part of the biggest industry event, the SIGGRAPH convention. Movies feed this monster by endorsing software: the long-awaited *Star Wars Episode 1: The Phantom Menace* featured a prominent kudo to a major software. Considering the film's exposure to the 3D community, such a promotion was like the Ten Commandments from the burning bush. (After all, George Lucas already enjoys the status of a deity in this particular universe.) A student's lack of professional experience makes him particularly vulnerable to this kind of propaganda. The fear of obsolescence is best countered by knowledge: knowledge of programming. Without it, the user is at the mercy of the manufacturer, whose only goal is to sell more products.

Increased technical knowledge will empower the graduate to not only resist the fear-mongering of the industry but also to better enact her vision and be more employable. One example of such can be found in the computer-animated movie *Ice Age* (2002), in a scene featuring corpulent dodo birds. [10] To maintain the illusion of realism (and comic value), the animators wished to have the rolls of fat on the dodo birds jiggle when they walked or ran--an example of the animation principle of secondary motion. The animators tried keyframing the motion, that is adjusting the volume of the body one frame at a time. In spite of the intense effort of animating dozens of birds, the results were unsatisfactory. The most effective solution was to write a script that allowed the blubber to bounce automatically and naturally with each movement. The combination of artistic and a technical prowess resulted in a convincing character.

Learning programming is a substantial expectation to students already challenged by turnkey software, as discussed earlier. Yet it is one that needs to be explored if students are to be more successful. Once again, however, the curriculum must be edited to include this instruction, because the best 3D artist is a successfully integrated artist and user. To reach the top tier of industry jobs, students will be obliged to learn programming for writing solutions to problems.

2E) Problem Solving Through Mathematical Thinking

Programming involves one of the greatest fears of the animation student: math. This aspect comes as a nasty surprise to many art school animation students. As Howard noted, "Digital artists all utilize mathematics, whether they are aware of it or not. Unfortunately, many don't understand the nature of the tools they employ."[11] (Many of my students avoided the math curriculum requirement as long as possible. They delayed their required geometry course until their senior year, depriving themselves of necessary knowledge in 3D volume creation.) 3D is as much an exercise in problem solving as art. A tremendous mathematical problem solving approach is necessary to master even turnkey software. Pure math is used to calculate the speed of a walk cycle or to realistically map a texture to a room. Overall, using a computer requires an applied mathematical approach: if operation A plus operation B equals result C, then what would happen if I perform D instead of B? The above logic is necessary to even operate the software, much less write scripts to enact the command.

Unlike computer science programs, art schools can unconsciously be havens for not only math-phobic students but their instructors as well. Howard wrote that once as a guest speaker he lectured on the connection between digital art and programming. In the middle of his talk, one instructor shouted that he was wrong and stormed out of the room.[12] The reality of 3D, however, is integrating the left and right brain. Giant Studio's

[8] Howard, Caleb. "The Science of Art." *Computer Graphics World*, 1999, p. 24.
[9] Madden, July 2005
[10] Forum, SIGGRAPH 02
[11] Howard, *Computer Graphics World*, p. 24.

Madden commented: "I find that in my job and most others in our industry that you need a fair amount of both 'sides' of the brain to really be most effective."[13] The capacity for problem solving is part of achieving that goal, and one that must become a part of the curriculum as much as art.

2F) Beyond Animation and Gaming

In a field that specializes in myth-making, perhaps it is no surprise that 3D students have equally fantastic job expectations. Almost everyone enjoys the make-believe worlds created by visionaries like Stephen Spielberg, and typical animation students hope to be part of that world. Disillusionment occurs when students confuse hope with entitlement, and discover that their animation degree alone does not provide entrée to these highly prized jobs. The industry overall is not large, and even entry-level positions have extremely high standards. Artists of all ages and experience levels are chasing the same dreams, and the numbers dictate that only a few will prevail. The likelihood of a graduate attaining a job in the top tier of the industry, say at premier effects studio Industrial Light and Magic, is comparable to playing professional basketball. Indeed, someone from some high school team will be talented enough to be drafted, and maybe become a superstar. The entertainment industry is the equivalent of the NBA: there are far more players than positions. (One student once told me, quite earnestly, that he expected to get a job upon graduation in which he would play--not create, program or debug--computer games full-time to critique their content. He said this as if no one else would be interested in the same job, and although he had no so-called professional experience he expected to be paid an entry-level salary of five, preferably six figures.). Some schools encourage unattainable goals, touting that a degree from this program will virtually guarantee a job in Hollywood. When the goal of a school is to enroll as many tuition dollars as possible, unrealistic sales pitches are the norm.

The good news for grads is that there are jobs in other fields that are crying out for leadership from the 3D community. Avenues like visualization, education, and illustration are now part of the world of 3D, and offer more jobs, income, and stability than the entertainment field. One sterling example is educational software. Elementary school students are now as familiar with educational software as they are crayons. The market is enormous, encompassing schools, libraries, and an extensive home usage. This kind of work regularly crosses multiple fields, since even the most venerable programs (like PBS shows) sell learning games featuring their characters. An excellent opportunity exists for 3D graduates to thrive in this media, bringing their visual talents to illustrate difficult concepts.

For inspiration in the educational graphics field, 3D artists need look no further than one of greatest minds in the industry, Jim Blinn. Dr. James F. Blinn has created much of the programming that is used everyday in computer graphics, and is a living legend in the field. (Ivan Sutherland remarked of his student, "There are only a dozen good people in computer graphics and Jim Blinn is six of them."[14]) Among his many accomplishments, Blinn has created a series of videotapes illustrating math for high school students called *Project Mathematics!* As a physicist, animator, programmer and artist, Blinn embodies the merit of bringing multiple disciplines to his work.

Schools of animation that focus on creating entertainment blind students and even faculty to the untapped potential of other fields. Higher education, the place where their horizons should be broadened, must encourage students to move beyond the entertainment job pool. To do so, it is inevitable that 3D must be separated from the relatively limited focus of animation. Instructors are often the worst offenders: having had no experience other than entertainment they often push students in that direction, whether they have the talent for it or not. Not all students want or are capable of creating the next *Shrek*, but may have talents in fields like visualization, education, or motion graphics. With faculty experienced in the myriad aspects of 3D, students can be guided to different career paths.

Each alternate career path requires its own individual skills. It is paramount that the current animation curriculum of one-size-fits-all must be reconfigured as a separate 3D discipline. As noted earlier, students are bombarded with all aspects of 3D, whether they are relevant to their interests or not. Creating a walk cycle is fundamental to the character animator, but is of very little use to the student planning to create design renderings for a living. Instead, that student should be instructed in the technical accuracy of mechanical, industrial, and architectural drawings. Too often, I saw students fail as character animators and then attempt to become architectural and mechanical renderers in the misguided belief that these projects would be easier to produce. They quickly discovered that a different but equally difficult skill set was required. Students within an animation program have little understanding or access to instruction, such as drafting or CAD, that would enable them to get these jobs. (The aforementioned Bob, for example, pleaded with me to

[13] E-interview, Matt Madden July 2005

[14] Rivlin, Robert. *The Algorithmic Image: Graphic Visions of the Computer Age*, Redmond, WA :Microsoft Press, 1986, p. 59

enroll him in a CAD course after graduation just to broaden his skills.) Instead, these jobs go to architects and others in peripheral fields, who often lack the both the artistic and technical knowledge of the 3D artist. Removing 3D from the proscribed courses of animation would be the first step in successfully pursuing other possibilities in the market

The profession of 3D is not ignorant of this problem, but has many voices speaking on the issue from different angles. At a SIGGRAPH 2002 Educator's Forum entitled the "Emerging Computer Graphics Discipline," educators brainstormed what courses should be in the model 3D curriculum. At the end of the session, the difficulty arose not from determining what subjects should be included, but what *shouldn't*.[15] So many courses were deemed necessary that a bachelor's student would have to attend school full-time for eight years before graduating!

3) A New Curriculum Mindset: A School for 3D

The art of 3D is evolving daily, and with each day it diverges further from its cousin 2D animation. To best understand this, one must look at the parallel of photography and painting. In its nascence, photography imitated painting in environments, use of color, and subject matter, in spite of the fact that photography was a completely unrelated technology. As it evolved, the differences between the two became more apparent and photography evolved into an independent medium with its own distinct curriculum. 2D animation and 3D are at this crossroads now

Although 3D needs to become a different discipline, there are numerous elements from 2D animation that can and should be incorporated. Early 3D animators, trained in only in computer science, produced substandard results in their inexperience. Pixar founders Ed Catmull, Alvy Ray Smith, and John Lasseter were among the first to apply the art of animation to computer generated images. These elements, such as drawing and concepting, are fundamental to any successful artistic endeavor.

With the reality of poor job placement, it is clear that the present model of education is insufficient for its graduates. Instead of continually focusing on an industry based on a vanishing technique, it is time to consider other disciplines. Much can be gleaned from studying programs that are neither solely an art nor a technical trade, but a fusion of the two. In schools of architecture and engineering, students are guided from the first freshman courses towards their degree. Although such programs are criticized, rightly, for being single-minded, their students have a more realistic chance of employment from being plunged into their major immediately. Although no one would question the value of learning different media, the evidence is clear that students must be focused immediately in 3D to have the best opportunity for success in their field. Core college requirements yield to major courses, and must be interwoven within a directed schedule. There are considerable parallels between an architecture student and a 3D student, not least because they often use the same software. The biggest is that both require an equally strong input between left and right brain. The artistic requirements are equal to the technical. It is time to realize that 3D animation is neither art nor science but a hybrid and tailor an educational curriculum to match.

3A) The Image Problem

If ever an art suffered from an image problem, animation has been that. From the beginning of the industry in the early 20th century, animation has been perceived as either childish, perverted, or both. Early artists like Fleischer Bros. reveled in bawdy humor with Betty Boop. Traditional folktales are almost unknown in their original context, having been sweetened and served up by Disney. Even classic animations such as the Warner Bros shorts do not enjoy the status of high art or even film. Since the 1970s, animation has become synonymous with juveniles thanks to decades of production geared to that very group. At the other end, the ever-present adult animations like “Stripperella” do nothing to enhance the industry's reputation. Artistic, thought-provoking pieces do indeed exist but are rare and screened at limited venues.

Has 3D's association with animation hindered its standing? Have mainstream schools been slow to embrace 3D because of the cost of software and hardware (indeed prohibitive) or the perception of animation as a lesser art? In this atmosphere, is this why serious students often do not consider a field related to 3D? Creating a new model for 3D will create a new kind of graduate. These graduates will be ambassadors to educate our culture on the greater depths of 3D.

4) A Problem Larger than Computer Graphics

The problems of educating 3D artists might seem to be just another tempest in a computer-generated teapot: it is really a problem for mainstream education? The expense of software and hardware for animation programs limits the feasibility to certain schools, seemingly relative to employment opportunities. Combined with the difficulties of the program of study, it would appear that supply and demand are not disproportionate.

However, the consequences are not limited to individual students, but to our society at large. 3D is bigger than

[15] ACM SIGGRAPH 2002 Educator's Forum: "The Emerging Computer Graphics Discipline."

animation. The 3D industry has changed daily life far beyond our movies and computer games. Everyday communications graphics from email to clip art to cell phones are possible because of technology like the frame buffer, created by 3D artists. Our cars, buildings, and toothpaste tubes are created on virtual drawing boards, and our pilots learn to fly on flight simulators. Our medicine and defenses are created from 3D designs. Every commercial and show on television utilizes 3D, from the obvious special effect to the most insidious forms of digital editing found in electronic media. Can virtual reality, another concept pioneered at Utah, be far behind?

The lack of training will diminish the future leaders of the profession, sending a ripple effect through many aspects of everyday culture. Where are the Ed Catmulls who will be the leaders of the industry? These technologies have made us used to a 3D world, and we now have an appetite for images that vault over language barriers. The clicking an icon has replaced typing a command line for many years, and text messaging and email are truncating language daily. A new generation of leaders in computer graphics will be needed for the next millenium of images.

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