The Art and Science of Digital Production Arts

T. A. Davis[1] and D. H. House[1]

[1]Clemson University, Clemson, SC, USA

Abstract

As its name implies, digital production arts incorporates both technical and artistic aspects. The challenge of any program in this discipline is to balance these two components in such a way that each enhances the other – the technical aspect provides new tools and techniques for artists to explore, while the art aspect drives digital technology in new directions. Students interested in digital production arts require both generalized and specialized education in each field, with additional emphasis on synthesis of both. The Digital Production Arts program at Clemson University strives to accomplish this goal through an interdisciplinary program with major components in art and computer science. Graduates of our program seek to apply their skills in special effects and computer animation in the rapidly expanding field of film, television, and gaming.

Categories and Subject Descriptors (according to ACM CCS): K.3.2 [Computer and Education]: Computer and Information Science Curriculum.

1. Introduction

Art and technology are often perceived as existing at opposite ends of the knowledge spectrum; however, such a categorization is merely the product of modern society, as these disciplines have traditionally been more closely tied. To illustrate this point, one need only look at the ancient Greek words for art (τέχνη) and technology (τέχνgoloία) to discover they share a common root. Digital production arts not only reveals this connection, but *requires* it in order to meet the goals of modern visual imagery, specifically in terms of computer animation and special effects production.

To satisfy the appetites of audiences with increasing demands for sophisticated imagery, movie studios require talented individuals with the creative and technical ability to produce elaborate special effects. While such effects were limited mostly to science fiction films in the past, most of today's films contain post-production effects, such as virtual set dressing, to reduce costs in terms of time and money. Commercial television advertising also takes advantage of eye-catching effects to market their products. Add to that the graphical demands of interactive gaming, and the fact that digital production is a hot and continually expanding field becomes obvious.

Accordingly, the effects industry requires an increasing number of trained individuals to meet the demands described, and many students, anxious to work in this cutting-edge field, are pursuing programs to prepare them for such a career. Unfortunately, educational programs and curricula by and large have not matched this pace. To add further to the deficiency, the digital arts field is not only large, but ever expanding. The educational goals and requirements for digital artists vary widely and tend to change dramatically over short spans of time. About 10 years ago, we began a new graduate program, Digital Production Arts (DPA), at Clemson University to train students in this field [Dav06]. Upon completion, graduates are awarded the terminal degree of Master of Fine Arts in Digital Production Arts.

Though the impetus to develop the program originated in the computer science department, the department was not suited to cover all of the topics necessary, even with the addition of several new courses. Accordingly, the program was established as interdisciplinary, with major components in computer science (CPSC) and art (ART), and additional influences from theater (THEA), computer engineering (ECE), psychology (PSY), music (MUSC), and graphic communication (GC). The program has recently undergone a major curriculum overhaul which has transformed it from a somewhat disparate collection of courses into a tighter, more integrated, educational experience, with a high graduate placement in the industry.

The focus of this paper is to describe our efforts in creating a curriculum to fulfill the needs of this interdisciplinary program, with the hope that our experiences will be helpful to others who may face similar challenges (see [CKLW05] for a treatment of a gaming curriculum). Section 2 describes the origins of the program, while Section 3 covers the revised curriculum. From our work so far, we have achieved some results, which are enumerated in Section 4. We cite lessons learned and conclude in Section 5.

2. Early influences and initial curriculum

As part of our planning process to develop a new curriculum in Digital Production Arts, originally termed MFAC (Masters of Fine Arts in Computing), we consulted experts in the special effects industry for advice and guidance. The overarching message of their input emphasized their desire not for an artist with some technical skills, nor a computer scientist who dabbled in art, but for both an artist and a computer scientist in one person. They desired someone who could sketch storyboards, then turn to the computer to write script for a particle simulation without missing a beat.

To address this need, we attempted to design a program containing components from both art and computer science. We also included instruction from psychology, performing arts, philosophy, music, and electrical engineering to broaden the experience. As the creation of a new program at a state-funded institution often involves aspects of bureaucracy and politics, we were motivated to minimize the cost and implementation of the program, making the case that we could essentially establish it using existing courses with the addition of just a few new classes, all of which, except one specialized studio course, could be taken by students in other curricula. Despite this cobbling together of somewhat disparate courses, the resulting program was effective in producing the type of split-brain individual production companies seek.

3. Current curriculum

Within the last year, we have implemented a new curriculum for the DPA program that affords students new avenues of study and more freedom to pursue individual projects. Since the program has been successful on several levels, both to students and the university at large, we feel justified in adding new courses aimed specifically at enhancing the learning experience for DPA students.

At present, the degree requires 60 credit hours, 12 of which are devoted to Digital Production Studio (ART/CPSC 860), wherein the student participates in group production work; and six of which are devoted to Graduate Research Studio, where students may choose to continue work on a team project, or pursue an individual project or production. Of the remaining 42 hours, 15 must come from the Core Courses (Figure 1), six from the Master's Thesis (ART/CPSC 891), and the remainder from Electives (Figures 2 and 3) or Foundation Courses.

Studio Methods Core	
CPSC 807	3D Modeling and Animation
CPSC 815	Digital Compositing
Technical Core	
CPSC 606	Digital Image Manipulation
CPSC 607	Rendering and Shading
Artistic Core	
THEA 687	Stage Lighting I
ART 821	Visual Narrative

Figure 1: *Core courses*

3.1 Foundation courses

Foundation Courses are intended for entering students who, due to insufficient background, are not prepared to begin graduate level work in either art or computer science. Up to two foundations classes may be required as directed by the admissions committee upon examination of the student's portfolio and record of coursework. Students requiring more than two foundations courses are asked to resolve any extra deficiencies before admission.

The Technical Foundations courses (DPA 601 and 602) include introductions to the algorithmic and mathematical bases of computer graphics. Courses provide students with practical experience in Python/C/C++ programming, scripting, linux/unix operating systems, spatial data structures, mathematics for graphics, and interactive graphics API. As part of the sequence, students complete a series of visually grounded programming projects. Teaching introductory computer concepts through graphics projects has also been explored in [WN05], [AR98], and [DGMW04].

The Visual Foundations courses (DPA 603 and 604) include introductions to observational drawing and clay modeling, color, principles of composition and design, and photography. Courses incorporate the studio method, involving students in hands-on work and the critique process, and stress examples from the history of art.

3.2 Studio methods core

Once such foundation knowledge has been acquired, students can turn their attention to the core courses (Figure 1), which form the kernel of topics that must be mastered for study in digital production arts. The Studio Methods Core includes 3D Modeling and Animation (CPSC 807), typically taken in the first semester, which covers the production pipeline (modeling, animation, rigging, lighting, texturing, and rendering). We currently use Maya as our main production package; however, the specific tool is not as important as the understanding of the underlying principles. The other core class, Digital Compositing (CPSC 815), focuses on developing skills to seamlessly blend imagery of the virtual with the real. As such, students must develop a keen eye for color, as well as become skilled at recreating phenomena such as atmospheric perspective to match photographic elements.

3.3 Technical core

The Technical Core is composed of two courses: Digital Image Manipulation (CPSC 606) and Rendering and Shading (CPSC 607). In the former, students hone their programming skills by writing code for various image processing tasks. In the process, they also learn underlying mathematical bases involved in manipulating images, such as filtering, color theory, and compression. The Rendering and Shading course also includes programming, in terms of writing shader scripts, but primarily explores the interaction between light and surfaces. Algorithms and their mathematical foundations are presented for ray tracing and global illumination.

3.4 Artistic core

The Artistic Core courses provide opportunities for students to learn and apply artistic skills related to digital production. Stage Lighting (THEA 687), a theater course in performing arts, is the only core course that is not designed specifically for DPA students. In this course, students learn how to use light to focus viewer attention and to convey mood or emotion. In addition to creating and implementing light designs for theater performance, students also participate in light charades and storytelling, whereby ideas and short narratives must be conveyed through light only. The other Artistic Core course, Visual Narrative (ART 821), explores storytelling through imagery directly related to storyboarding. Here, students apply fine arts skills to a discipline directly related to digital production, while gaining insight into the process of creating and visualizing a coherent story.

3.5 Artistic and theory electives

The artistic and theory electives provide an introduction to the analysis and conceptual foundation of visual presentation. Although only one course is required, an additional course may be chosen towards the Open Electives requirement. All students must complete one of the courses listed in Figure 2.

3.6 Open electives

The Open Electives provide an opportunity for students to either develop a special expertise, or broaden their backgrounds to support studio and thesis work. Further, students may tailor their degrees to specialize in a field that is not specifically targeted by DPA, such as gaming, but that shares foundational skills. In this way, we can accommodate more students with diverse career goals without formally offering all possible degree options.

An additional Core Course or an additional Artistic and Theory Elective may be used towards this requirement. Other courses may also be considered, but all students must complete at least four Open Electives from the list given in Figure 3.

3.7 Digital production studio

The Digital Production Studio (DPA 860) is the primary synthesis course of the program, providing the student with opportunities to apply artistic and technical knowledge to the creation of a team-oriented production project from concept art to final editing. Typically, these projects take the form of two to three-minute computer animations, or short films with effects work. Through the process, students develop visual problem solving and teamwork skills, which closely match a professional production environment.

Students begin the studio sequence by taking the course for one credit each semester of their first year. This familiarizes students with the team process pipeline, while allowing them to develop core skills and knowledge through coursework. After the first two semesters, students work on a team project for two consecutive terms, either summer-fall or fall-spring. Up to six hours of credit for the course may also be obtained through an approved summer internship at a professional production studio.

Digital Production Studio includes regular class meetings under faculty supervision, providing the vehicle for planning, critique, and presentation of ongoing project work. Although a large majority of studio work is undertaken outside of class meetings, active participation in class is crucial to a successful studio experience, and is required.

3.8 Graduate research studio and thesis

After students have successfully worked within a team to produce an artistic goal, they are prepared to pursue more intensive study in a particular area. Graduate Research Studio (DPA 880) provides students with the opportunity to complete a major project or projects, under the supervision of a faculty advisor, in a direction supporting their personal goals and aspirations. Such work may be team-oriented or produced individually, and may be of a primari-

AAH 630	Twentieth Century Art I
AAH 632	Twentieth Century Art II
ENGL 650	Film Genres
ENGL 651	Film Theory and Criticism
ENGL 853	Visual Communication
PHIL 845	Aesthetics

Figure 2: *Artistic and theory electives*

Artistic Electives	
ART 605	Advanced Drawing
ART 607	Advanced Painting
ART 609	Advanced Sculpture
ART 611	Advanced Printmaking
ART 613	Advanced Photography
ART 617	Advanced Ceramic Arts
Technical Electives	
CPSC 605	Computer Graphics
CPSC 611	Virtual Reality
CPSC 614	Human and Computer Interaction
CPSC 616	2D Game Engine Design
CPSC 617	3D Game Engine Design
CPSC 805	Advanced Computer Graphics
CPSC 809	Physically Based Animation
CPSC 863	Multimedia Systems and Applications
Studio Methods Electives	
DPA 808	Advanced Animation
DPA 819	Visual Special Effects
General Electives	
ECE 847	Digital Image Processing
GC 801	Process Control in Color Reproduction
MUSC 604	Electronic Music
PSY 823	Human Perception and Cognition
THEA 697	Scene Painting

Figure 3: *Open electives*

Figure 4: *Sample image from a student thesis project investigating techniques for focusing attention through stereoscopic radial blur.*

ly technical or artistic nature, but typically strong aspects of both sides are involved.

Following the completion of graduate research studio, students are ready to perform thesis work (DPA 891) to elaborate and refine a theme that they had begun to explore in the elective coursework and the production and research studios. The thesis project is developed to a refined degree, articulated in the form of a written document, and presented orally in a thesis defense, evaluated by an advisor and thesis committee.

The M.F.A. thesis can follow one of several routes, all of which contain an original idea, implementation, and review by a third party. The first type of thesis project focuses on creating a new technique or process for digital production. This type of project usually involves implementation in a high-level language, such as C or C++, with proof-of-concept results as well as incorporation in a short piece that shows how the technique could be employed to realize an artistic vision. Additionally, the technique must be submitted to a conference or journal in the form of a paper, poster, or other applicable submission. A sample thesis project of this type (Figure 4) produced a published work for the student [RFD09].

The second type of project is the creation of an individual animation or effects piece. Beginning with an original idea, a student must perform all steps of the pre-production, production, and post-production pipeline using both technical and artistic skills. The final product must be submitted to an animation or film festival for third-party review.

The final type of project allows a student to use the arsenal of digital tools at his or her disposal to create an artistic exhibit or installation. Ideally, this series of works should demonstrate how digital techniques can be used to produce unique artistic works that would be otherwise difficult or impossible to accomplish. Naturally, the final piece(s) would be submitted for exhibition.

Our goal for all thesis projects is the integration of the artistic with the technical to advance the broad range of visual imagery. All work should result in a final product that is complete enough to be evaluated, but not necessarily

Semester 1		
CPSC 807	*3*	*3D Modeling and Animation*
CPSC 606	*3*	*Digital Image Manipulation*
THEA 687	*3*	*Stage Lighting I*
DPA 860	*1*	*Digital Production Studio*
Semester 2		
CPSC 607	*3*	*Rendering and Shading*
ART 821	*3*	*Visual Narrative*
THEA 697	*3*	*Scene Painting*
ENGL 650	*3*	*Film Genres*
DPA 860	*1*	*Digital Production Studio*
Summer 1		
DPA 860	*6*	*Digital Production Studio*
Semester 3		
CPSC 805	*3*	*Advanced Computer Graphics*
CPSC 815	*3*	*Digital Compositing*
ART 613	*3*	*Advanced Photography*
DPA 860	*4*	*Digital Production Studio*
Semester 4		
CPSC 616	*3*	*2D Game Engine Design*
DPA 808	*3*	*Advanced Animation*
DPA 880	*6*	*Graduate Research Studio*
Summer 2		
DPA 891	*6*	*M.F.A. Thesis*

Figure 5: *Sample course of study*

accepted, for public display. In this way, we hope to prepare our students in the best possible way to contribute to both the artistic and technical communities involved in digital production.

3.9 Sample course of study

Each student brings a different collection of strengths and weaknesses to the program, and an appropriate course sequence must be tailored to both the individual's needs and course availability. A typical course sequence is shown in Figure 5.

4. Results

As no general guidelines for digital production arts curricula or assessment currently exist, we measure our effectiveness against several yardsticks: successful placement of students in the industry, acceptances of work created in the program, and student applicants.

The first measure of success for our program is the placement of our graduates in the film industry. Our students are working or have worked, for many of the best companies in the industry, including Pixar, Industrial Light and Magic, DreamWorks Animation, Moving Picture Company (MPC), Rhythm & Hues, FrameStore, Disney, BlueSky Studios, EA Games, and Tippet Studios, among others. These studios have confirmed that the blend of

Figure 6: *Alumni Rachel Drews holding team Oscar.*

computer science and art that our program requires has been a key component to the success of our students in the industry. One of our alumni is shown in Figure 6.

At the same time, DPA team animations have enjoyed a measure of success in terms of acceptances and awards in national and international venues, such as the Charleston International Film Festival (with a 2009 "Audience Favorite" award), the Eurographics Animation Theatre (with a 2005 "Best Independent Animation" award and two Pixar Award runner-up's), the SIGGRAPH SPACE program (with several Honorable Mention's), and the Flix on 66 Digital Animation Festival (with first and second place wins), among others. Screen shots from some of our student works are shown in Figure 7.

The pool of student applicants, however, is an area in need of improvement and a well-designed strategic plan. We hope to remedy this deficiency in coming years.

5. Lessons learned and conclusion

Given the broad range of knowledge required to produce a capable digital artist, we have attempted to design a program that will educate and prepare students to meet the demands of the production industry. With each passing year, we continue to learn more about the field and how best to provide a balanced education of art and technology. We hope that other programs with similar goals will gain insight from our experiences.

The following details some lessons learned:

- The differences between the professional cultures of art and computer science cannot be easily dismissed. Some fine arts faculty do not consider digital production arts to be "real" art, while some computer science faculty do not deem it to be "real" computer science. Additionally, misunderstandings and conflicting priorities often arise as faculty from the two fields, given their independent development over many years, strive to unite under an interdisciplinary program.
- Student applicants often believe that the desire to work in such a field will equal competency in the field. Many students have applied to our program without skills in either art or computer science, believing that their interest or passion for movies and games will propel them to success. Unfortunately, this situation often concludes with negative results.

Figure 7: *Project images.*

- Any program of this nature must develop a student culture where the older students instruct the new students not only in matters of artistic and technical education, but also in professional conduct with regards to coursework and interaction with faculty.
- Many programs, ours included, may sometimes err in providing instruction and training in the core areas of the field without synthesis. That is, courses in both art and computer science may be offered, and classes that straddle the areas may be taught, but lacking specific instruction on the application of the technical to the artistic results in a non-cohesive, and therefore incomplete, education in digital production arts.
- Students (and faculty for that matter) must not confuse the importance of the artistic goal with knowledge of the tools. The goal of digital production arts study should emphasize a desired end result and techniques to achieve that end, rather than knowledge of specific packages, such as Maya or Final Cut Studio. Production companies, such as DreamWorks Animation, have commented that prospective employees tend to stress skill in commercial software over resulting imagery. As mentioned previously, 3D packages are merely tools for the artist to use in realizing a creative vision, not an end unto themselves.

Digital production arts dilutes neither art nor computer science. In fact, both fields are enhanced by the other: art is afforded new tools and techniques, while research in computer science is driven forward. Through the DPA program, we have broadened the roles of computer science and art at our university. With this foray, however, we are constantly challenged with discovering the best ways to teach such an interdisciplinary program in an effective manner.

6. References

[AR98] ASTRACHAN, O., RODGER, S. H.: Animation, visualization, and interaction in cs1 assignments. *SIGCSE Bulletin*, 30(1), 1998, pp. 317-321.

[CKLW05] R. COLEMAN, R., KREMBS, M., LABOUSEUR, A., WEIR, J.: Game design & programming concentration within the computer science curriculum, *SIGCSE Bulletin*, 37(1), 2005, pp. 545-550.

[Dav06] DAVIS, T. A.: Graphics-based learning in first-year computer science, *Computer Graphics forum*, 26(4), 2006, pp. 125-129.

[DGMW04] DAVIS, T. A., GEIST, R., MATZKO, S., WESTALL, J.: τεχηί: A first step, *ACM SIGCSE Bulletin*, 36(1), 2004, pp. 125-129.

[RFD09] RAMASAMY, C., HOUSE, D., DAUGHERTY, B.: Using eye tracking to analyze stereoscopic filmmaking, *SIGGRAPH Posters*, 2009.

[WN05] WICENTOWSKI, R., NEWHALL, T.: Using image processing projects to teach cs1 topics, *SIGCSE Bulletin*, 37(1), pp. 287-291, 2005.