Digital Visualization Tools Improve Teaching 3D Character Modeling

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ABSTRACT

Many Universities are building interdisciplinary programs that overlap engineering and fine art departments that focus on games, special effects, animation and other forms of interdisciplinary efforts. With increasing demands for education linking the Engineering Sciences and Fine Arts, fueled by the competitive nature of the industries that recruit graduates, educators need to become more efficient and effective in their task of educating engineering and art majors in cross-disciplinary courses.

CS3650 at the University of Utah is a digital character production course. This course is interdisciplinary and draws from several disciplines including computer science, graphics, anatomy, sculpture, art, and entertainment. It is a prerequisite for our machinima class, which immerses students into 3D game engines. Visualization tools are used in the course to help students learn to create better digital models.

Presented in this paper is an experimental comparison between traditional visualization tools and digital visualization tools, which are less expensive, easier to distribute, arrange/procure and transport than the traditional tools. Traditional visualization tools include lifelike skeleton reproductions, wooden body mass structures, actual live human models, and anatomy drawing books. The digital visualization tools that are contrasted in this paper are: a layered anatomically correct, digital human model (skin, muscles, masses and some bones adapted from several sources) and a VisTrails version of a properly produced human figure (interactive animation). The digital tools are used to replace the traditional visualization tools used in the same educational curriculum, which teaches students to design, model and produce digital characters for games, machinima, and animation. The quantitative experiment demonstrates that digital visualization tools help to improve a student’s understanding of the complex software packages used to produce characters, helps to improve specific techniques used to model 3D characters, and it helps to improve understanding of 3D form, more than the traditional tools within the context of this educational curriculum.

Categories and Subject Descriptors: K.3.2 [Computer and Information Science Education]: Computer Science Education, Curriculum.

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1. INTRODUCTION

Many universities and colleges are building interdisciplinary programs that overlap engineering and fine art departments allowing a focus on games, special effects, animation and other similar interdisciplinary efforts [1][2][3]. Just recently New York University created the NYU Game Center [4]. In 2007 we began our Entertainment Arts and Engineering (EAE) program [5]. This new academic emphasis was created partially due to the digital entertainment industry’s demand (including both game and animation) for new employees that are trained in disciplines from both the engineering and fine arts and partially from the extremely strong draw the program has on a diverse set of interested students [6]. A key to a successful program (according to our industrial colleagues) is that students graduate as either excellent computer scientists or excellent artists with the additional skills of having worked extensively with “the other side.” These interdisciplinary classes form the heart of bringing the two sides together.

Typical cross-disciplinary classes include CS1 that focuses on games and graphics [7][8][9] and beginning drawing for non-art-majors. Both curriculums are usually designed to alleviate anxieties associated with “walking to the other side of campus.” The classes are also designed to fast track students to a beginning level of competency and to help promote understanding and communication between the two areas. At the University of Utah we have designed a series of two classes that are equally based in knowledge and practices from both the engineering and fine art fields of study. The first is the Digital Character Production Course (CS3650) that feeds into the second, a Machinima [10] class (animation shorts created using a 3D game engine). Both classes are evenly split between art/design principles and engineering/technology principles.

CS3650 provides an extraordinary applied learning experience for students [11] by combining learning concepts that are not commonly taught together. The curriculum is designed to teach students complex problem solving by learning to breakdown the extremely difficult problem of creating a digital character into manageable segments. This promotes understanding diverse
concepts that range from computer graphics fundamentals to sculptural ideology and from graphic algorithms to 3D design elementary concepts and most importantly algorithmic thinking. It is a process that provides a direct view of the correlation between many technical concepts and the application of the concepts that solidifies essential knowledge. It also allows for engineers and artists to gain an appreciation and understanding of each other’s roles in and contributions to entertainment arts and engineering production, hence, improving teamwork.

The Digital Character Production Course is taught in a guild-style. Guild-style education is project-based and incorporates multiple disciplines and areas of study with the goal and focus of inducing an exceptional learning experience while producing an important and complex product. The learning objectives and outcomes of CS3650 course include teaching students the production pipeline for CG character development, introducing students to the applications for computer graphics used in the game and animation industries, and introducing students to algorithms used in specific modeling techniques including smoothing, polygon decimation, vertex merging, edge loops selections and edge loop inserts. Other learning objectives are to help students: improve their understanding of form, structure, and anatomy of anthropomorphic characters; understand proper contour design for 3D models; learn the critical elements of digital figure modeling that distinguish levels of sophistication in character modeling; learn to translate design concepts into physical representations (paper, words, images and clay); and finally the translation into a digital representation for input to gaming engines and animation tools.

The curriculum is based on techniques for modeling the anatomically correct human figure. All lectures, examples and demonstrations are taught using the human figure as a representation of anthropomorphic characters. This choice was made because the human figure is complex and requires a tremendous understanding of form, structure and visual relationships. Also, most students can tell the difference between accurate human models and non-accurate human models. Even with characters that have extreme proportions (such as characters in “The Incredibles”) an understanding of visual human anatomy is essential to make characters that we as viewers want to relate.

A final project assignment is included which accounts for 80% of the student’s final grade. The project is to produce a digital character. The students are shown how to break the task into manageable parts that begins with designing a character of the student’s choosing with drawings, clay sculpture and words as devices for working out designs and representing design ideas. The next stages include using Adobe's Photoshop, a 2D software program, and AutoDesk’s MAYA, a 3D software program. One of the learning objectives of the course is to teach the students to take the abstract ideas of a chosen character and realize them into drawings and clay sculptures as a learning process, and then to translate the drawings and clay into digital characters. This applied process creates strong intellectual connections between the two disciplines allowing students to solidify important engineering principles.

Courses that are similar to this digital character course are typically taught using traditional visualization tools. Visualization tools provide opportunities for understanding and involve cognitive functions such as recognition, learning, and memory.

When objects or characters are visualized, they are easier to understand because they become more tangible in the mind [12]. Typical traditional visualization tools are shown in Figure 1 and serve as 2D and 3D references for aiding the students in producing anthropomorphic characters that have the physical qualities that promote the viewer’s ability to relate to the character with sympathy. These tools permit exploration of complex physical relationships of the human figure and also provide concrete examples of comparisons of form, structure and mechanics from 2D to 3D. Digital character classes also require a large amount of one-on-one time with teachers and students, which can limit the number of students in a class.

![Figure 1: Traditional visualization tools—half-sized skeleton, block figures of anatomical masses, anatomy books and live models.](image1.png)

Recently there has been work completed on digital visualization tools at the University of Utah that seem suited to improve the learning experience in our digital character production course. The Human Reference Model [16][17] (HRM) is a virtual representation of the human figure that allows students to interactively reference it from MAYA. The HRM is a 3D layered anatomically correct, digital human model (bones, skin, muscles, masses and some bones). The model was adapted from the University of Pennsylvania’s Digital Figure Modeling Course and anatomical models from a commercial modeling firm. The second tool is a VisTrails [15] MAYA version of a properly produced human figure/character that enables interactive animation (figure 2). This version allows the student to visually review exactly how a model is constructed by following the exact steps taken by an instructor as they work on a sample model. An important advantage is that the student can proceed interactively through the steps of the sample model at any rate they choose.

Our hypotheses is that using digital visualization tools as a replacement for traditional visualization tools will improve the students learning experience without reducing the quality of their final character projects. We also believe that the students who use the digital visualization tools will be able to demonstrate improvement in their understanding of the complex software packages used to produce characters, improvement in specific techniques used to model 3D characters and improvement in understanding of 3D form/visual relationships, more than the traditional tools within the context of this educational curriculum.

![Figure 2: HRM Muscle layer reference screen shot (left) VizTrails—Head Interactive Animation screen shot (right).](image2.png)
2. STATEMENT OF PROBLEM
The Digital Character Production course curriculum at the University of Utah is designed, in part, to help students learn MAYA, a complicated 3D design tool from AutoDesk Corporation that is considered an industry standard for 3D graphics software, for the purpose of producing an anthropomorphic, digital character. The task of creating a successful 3D digital character can be divided into four skill sets: the vision and understanding of the original character, the understanding and ability to control the MAYA software system, the understanding and ability to apply particular techniques to well-organized character models, and the understanding of anatomical form and structure of an anthropomorphic character. The learning objectives for the course are partially derived from the goal for students to acquire the necessary skill sets to produce a successful 3D digital character.

The new digital visualization tools developed at the University of Utah hold great promise as replacements for more traditional tools typically used in digital character production courses.

Within the context of interdisciplinary 3D digital character production courses, the specific questions being addressed in this study are:

- Are the VisTrails—MAYA plug-in and the HRM better than the traditional visualization tools for instructing students to attain the skill set of understanding and ability to control the MAYA software for character production?
- Are the VisTrails—MAYA plug-in and the HRM better than the traditional visualization tools for instructing students to attain the skill set of designing and manipulating contours for well-organized models?
- Are the VisTrails—MAYA plug-in and the HRM better than the traditional visualization tools for instructing students to attain the skill set for understanding the anatomical form and structure of an anthropomorphic characters?
- Are the VisTrails—MAYA plug-in and the HRM better than the traditional visualization tool based curriculum for instructing students to produce 3D digital characters?

3. METHODOLOGY
An experimental methodology was used for this study. The methodology measures include:

- All participants were assigned a term-long modeling project of a character of their own choosing. During the semester the students learned how to use MAYA for polygonal character modeling, how to design and organize contours on character models, and how to model anatomically based forms adapted to their characters. They were also taught to shape the entirety of their character model. They were informed that they would be graded on the overall quality of their models and that would include: their ability to use MAYA to make their model, their ability to organize contours on their model, and their ability to adapt the anatomical forms to their model. The length of the project alleviated the potential stress from short, timed exams (Figure 6).
- All participants were assigned an end-of-term technical exam of a MAYA modeling exercise. The exam was to model a wooden duck. It was different from the humanoid form and structure of their project characters. At the time of the exam, the students were shown an example of a well-done model (Figure 3) and the actual wooden duck that they were to use as a physical reference. Each participant was given a project folder that included photographic and drawn references. They were given exactly ninety minutes. There was no communication between students or proctors during the test. This exam provided a different enough challenge from the final anthropomorphic character project to assess the depth of learning of the students that would be required for extension to a different model. It also mandated an exact time control on the assignment.

- Pre and Post Drawing tests were assigned to all participants to help qualify student’s understanding of complex forms, relationships and structure. At the first of the semester the students drew five drawings in one hour: a front-view of a human figure in prone position (from memory), a side view of a human figure in prone position (from memory), a front view of a human head (possible for some reflection in monitor), a side view of a human head (possible for short glimpses of fellow students), and a hand drawn in any position (could use own hand as reference). There were no references allowed except those that naturally occurred with the hand drawings and possibly glimpses of other student faces during the assessment. The instructions were given that they would have an hour to do their very best drawings of a realistic representation of a human. The students were told that they would be graded on effort. At the end of the semester they were given the exact same instructions.

Figure 3: end-of-term technical exam example.

4. PARTICIPANTS AND STRUCTURE
A restricted self-selecting sampling method was used to populate the sample pool. Section 001 was held on Tuesdays at 3:45 to 6:20PM with Lab from 6:30 to 9:00PM and section 002 was held at the same times on Thursdays. By the flipping of a coin, section 001 was assigned the digital visualization tools (Digital Group) and section 002 (Traditional Group) was assigned the traditional tools for the independent variable. The classes and labs were kept completely separate and virtually identical except for the difference in visualization tools. Both classes met 15 times independently and once together for the final presentations of character projects. Each group was randomly assigned 17 engineering majors and 3 non-engineering majors.

The same instructor and two teaching assistants taught the classes. The curriculum included lectures, demonstrations and one-on-one instruction. The only differences at all in the classes were based on the visualization tools. For instance, the Traditional Group was provided with anatomy books, skeleton models and a fieldtrip to the Body Worlds Exhibit and the Digital Group was not. Also the
Digital Group was provided with VizTrails examples and HRMs for references and the Traditional Group was not.

Instruction in the class began with a simple start to the body that lets the students become familiar with many of the MAYA and modeling concepts. Next, the hand is a type of algorithmic instruction. It is step-by-step and all students follow the exact procedures. This teaches techniques by repetition and replication. After that, the face starts off similarly with algorithmic instruction for the nose, but the eyes and lips are one step removed from step-by-step approach. They are more like “here is an example of how to do it, now apply that to your particular eyes and lips.” This allows the students to use their newfound modeling skills and mix them with their own creativity and ingenuity. This gives them the ability to figure out complex modeling problems with less help. Then finishing off the head is a chance to learn new techniques and review several approaches already taught. At this point the students finish the details on the body and complete the character at the level expected for the class.

5. RATERS

Three individuals that have relative academic, and professional industry experience rated the projects, technical exams and pre-post drawings. These raters had no relationship with the participants in the study. Every precaution was taken to assure the raters had consistent viewing experiences and importantly, there was no way for the raters to determine group assignment.

The raters were given additional instruction on the areas of criterion measurements. For the project, each rater was required to give a grade between 0 and 100 on four different criterions: (1) MAYA proficiency, (2) contour design and manipulation, (3) form description, (4) and overall character model. This was the same for the technical exam. For the pre-post drawings, each judge was required to give a grade between 0 and 100 on each of the five different drawings and also a grade on the overall drawings combined for each participant. The raters also compared the first set of drawings to the second set. They graded each drawing for improvement by comparing each participant’s pre drawing with the same participant’s post drawing. The five drawings completed in the hour exam were: (1) front body, (2) side body, (3) front face, (4) side face, and (5) hand from any angle.

The grades from the raters were subjective. To measure legitimacy of the grades, a Spearman Correlation was completed comparing each grading criterion for all three judges. The nature of the correlation coefficient is to indicate the relationships of the ratings of the raters. The correlation coefficient ranges from -1 to 1. A correlation of 1 signifies that all grades were rated exactly the same, whereas, a correlation of -1 signifies a negative correlation. A 0 correlation signifies no correlation at all. In educational research, an intraclass correlation coefficient of .6 is considered strong enough for reliability. For comparison, highly trained professional Olympic judges for gymnastics usually have an intraclass correlation coefficient of nearly .9. For this study, the expectations of intraclass correlation coefficients are greater than .6 for each criterion. Because of this correlation, we can average each grade from the three raters for the analysis.

6. RESULTS

The first comparison analyzed was the overall final projects. The Digital Group’s N = 20 with a mean score of 79.03, a standard deviation of 9.27, and standard error mean of 2.07. The Traditional Group’s N = 20 with a mean score of 69.26, a standard deviation of 12.56, and a standard error mean of 2.81. The independent samples t-test was t(38) = 2.79, p = .00805 and a mean difference of 9.76 (Figure 4). The Digital Group’s scores were significantly higher than the Traditional Group’s scores in the Overall Character Model category. The MAYA proficiency category average scores, the contour design and manipulation category average scores, and the form description category average scores were similar to the final projects. They also had significant t-tests.

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<th>Overall Model Averages</th>
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Figure 4: Final Character Model Statistics.

The second comparison analyzed was the end-of-term technical exam. In the MAYA proficiency category, the Digital Group’s N = 20 with a mean score of 64.27, a standard deviation of 11.79, and standard error mean of 2.64. The Traditional Group’s N = 20 with a mean score of 51.22, a standard deviation of 12.36, and a standard error mean of 2.76. The independent samples t-test was t(38) = 3.41, p = .00150 and a mean difference of 13.05. The Digital Group’s scores were significantly higher than the Traditional Group’s scores in the MAYA proficiency category. In the contour design category, the Digital Group’s N = 20 with a mean score of 65.83, a standard deviation of 10.81, and standard error mean of 2.42. The Traditional Group’s N = 20 with a mean score of 49.67, a standard deviation of 11.87, and a standard error mean of 2.65. The independent samples t-test was t(38) = 4.50, p = .00010 and a mean difference of 16.16. The Digital Group’s scores were significantly higher than the Traditional Group’s scores in the contour design category. In the form description category, the Digital Group’s N = 20 with a mean score of 66.55, a standard deviation of 10.79, and standard error mean of 2.41. The Traditional Group’s N = 20 with a mean score of 50.85, a standard deviation of 11.39, and a standard error mean of 2.55. The independent samples t-test was t(38) = 4.47, p = .00010 and a mean difference of 15.70. The Digital Group’s scores were significantly higher than the Traditional Group’s scores in the form description category. In the overall model category, the Digital Group’s N = 20 with a mean score of 66.10, a standard deviation of 11.22, and standard error mean of 2.55. The independent samples t-test was t(38) = 4.50, p = .00010 and a mean difference of 16.16. The Digital Group’s scores were significantly higher than the Traditional Group’s scores in the overall model category [18].

The third comparison was the pre/post drawing assessment. There was no significant difference found between the two groups in this comparison; however, it was interesting to note that both groups improved at similar rates (Figure 5).
Our motivation for this study was influenced by our desire to extend and improve the digital character production course. We wanted to open it to more of the students that were requesting it. We also wanted to extend it further by figuring out how to teach this subject to individuals who wanted the learning experience without attending my classroom. To accomplish this goal of handling more students or helping students to learn the subject using distance learning, there are many obstacles that are hard to overcome and still give the students the same level of learning experience. We focused on one practical obstacle—the physical visualization tools that we use in the classroom to enhance the learning of the students. They work well for classes with limited enrollment of a dozen or less; however, lose their effectiveness as enrollment increases due to their physicality and costs.

In future research, we want to make a comparison between CS students who have taken this course and who go on to take our advanced CS graphics programming class with those who are in the advanced CS graphics that didn’t take this course.

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Figure 5: Pre/post Drawings similar rates of improvement.

Figure 6: Sample of final projects from engineering students