Multi-institutional Collaboration in Delivery of Team-Project-Based Computer Graphics Studio Courses

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Abstract. Effective use of computer graphics for technical and artistic exploration often requires the participation of multiple teams representing specific knowledge domains though these teams may be separated by both geography and time zones. This paper reports on the introduction of a project organized by four academic institutions oriented around collaborative technical and visual problem solving among non-co-located students. The project was developed to match the curricular requirements of existing courses. Participants included undergraduates at two U.S. universities and U.S. students studying in Western Europe, as well as a group of U.S. high school students. This paper specifically details the organizational issues, curricular alignments, and employment of affordable information technology for both workflow coordination and communication among team members. The results indicate that the project economically utilized course time, contributed to learning objectives aligned with work force trends in the animation industry, and levied commonalities of existing computing infrastructure along with commodity computing services for positive effect.

1 Introduction

Information technology enables collaboration among world-wide project participants, including the delivery of visual computing related courses and projects. Students pursuing education in visual computing fields are likely to eventually contribute as domain-area specialists to projects involving distant collaborators separated by both physical distance and time zones. Effective multidisciplinary collaboration includes the ability to communicate synchronously and asynchronously between individuals and among groups. Effective collaboration also requires organizational components such as scheduling, workflow coordination, and specificity of data types and information to a degree of shared understanding significantly beyond the requirements of individual work or group projects among co-located team members.

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As educators with the goal of preparing students for the world outside of the academy, we want to expose students to the issues surrounding distance collaboration. We want to provide them with an understanding of the differences between working in the physical presence of our collaborators and using technology to allow us to work at a distance [1]. We want to broaden the students' exposure to the thoughts and ideas of both students and instructors at other programs. We also want to take advantage of the commodification of information technology by broadening opportunities to practice cross-disciplinary collaboration across institutions.

This paper focuses on the organizational components and technical infrastructure required to extend participation in group projects beyond students at a single university. Collaborative projects provide opportunities for students to learn from one another and contribute their knowledge and skills to a larger goal than is possible in independent projects. When structured as a reflection of industry practice, collaborative projects also create a fluency for students about processes and considerations that are important to future employers. This project focused on how a group of institutions can partner with one another for the benefit of their respective students through exposure to distance collaboration and creative problem solving with distant partners. In this paper we show that multi-institutional collaborative student projects can be managed effectively without significant changes to curricular or infrastructure requirements. We assume that the effectiveness of the existing courses is already validated. The results include specific organizational requirements, technical requirements, and expectations for faculty and student participants. We have defined the conditions through which remote collaboration projects can be setup that match conditions within a targeted industry, and provided the students with an experience that promotes fluency with issues they are expected to encounter in their careers following formal education.

Our approach differs from other uses of distance education in that the students are participating as area specialists with non-co-located partners. The project did not consume the entire calendar for each location. The work was coordinated to include overlaps and periods in which there was little or no overlap. We also used existing commercial technology to facilitate the IT requirements of the project. This project brought together academia and industry to address the issue of how creative problem solving is facilitated among non-colocated team members. Industry participants, acting in an advisory role, included artists, engineers, and managers from Lucasfilm Ltd., DreamWorks Animation, ReelFX Creative Studios, Digital Domain, and Adobe Systems. These companies are interested in this project because it directly addresses issues they face in the global market of development of technically and creatively complex products and intellectual properties. Educators and administrators at each institution are interested in the project due to the potential to extend the reach of creativity enhancing and technically challenging curricula outside the brick-and-mortar classroom.

2 Prior Work

2.1 Collaborative Projects

The studio approach for instruction in undergraduate computing-intensive courses has been used in practice for only about 20 years, as documented by Tomakyo at Carnegie Mellon University in 1987 [2]. Cooperative learning environments are able to achieve significantly better student performance through peer-to-peer mentoring [3], and high levels of collaborative learning increase student satisfaction with a courses [4]. Identified benefits of the studio approach for computing-intensive work are the extension of the skill set of the group, the capacity to employ technology attuned to the individual needs of groups members, and ownership of responsibility for outcomes assumed by the group members [5].

In 1990, Rensselaer Polytechnic Institute in Troy, New York, instituted change across the curriculum embracing studio-style instruction [5]. Such substantial change was undertaken to both improve the educational experience in science and engineering, and to adapt a model for delivery of education that was extensible through distance learning. Among the conclusions drawn from the experience was the importance of highly interactive computing and communication tools [6]. The embrace of studio-style learning for computing-intensive subjects follows over 100 years of studio-style education in art and design and repeated empirical analysis of the connection between studio learning and creative thinking [7]. However, information technology is changing the way studio courses are taught, both in computing and design [1]. Rapid integration of new technology is required if educational institutions intend to continue to supply skilled workers to industry and maintain effective delivery of computationally intensive education experiences for growing numbers of students.

2.2 Technology Development for Synchronous Collaboration

Studio style learning in is dependent upon tight communication and cooperation among participants. When collaborators are not co-located the success of their partnerships can be in large part determined by information technology. Participants in large projects who are not co-located rely on both synchronous and asynchronous exchanges of information. Verbal interaction is recognized for its superiority over asynchronous information exchanges such as email and message boards for both efficiency and qualitative reasons. Awareness of a collaborators progress and intentions, as supported by verbal exchanges, are critical to successful collaboration. Tools that provide awareness through visual means have been shown to promote efficiency, increase accuracy, and contribute to qualitative improvements when used over time [8]. When partners are problem solving using visual imagery, synchronicity of verbal communication and collaborative viewing of the imagery is essential. [9] developed a video architecture facilitating synchronization of video presentation through the use of a video server, several video clients, an autonomic controller, and a common communications infrastructure. [10] developed a web-based system for collaborative virtual science lab environments using Java applets within the open source tool Easy Java Simulations.

3 Our Contribution

The primary focus of this project was the enhancement of undergraduate learning in undergraduate design studios that require both artistic and technical problem solving. The design of this project reflects a project management issue faced by many companies in the animation industry where high levels of technical and visual creativity and collaboration are required from a global workforce. Our approach is fundamentally dependent upon solving administrative, technical, and pedagogy delivery issues to facilitate the participation of students from multiple learning institutions. In this arena we have produced findings that are instructive both in terms of the conditions that promoted our primary objective of enhanced student learning and some issues that interfered with enhancement of learning. Our findings are grouped in three sub-topics discussed in detail below: (a) institutional organization, (b) alignment of pedagogy, and (c) technology.

3.1 Project Funding

Significantly, funding to facilitate the technology support for the project was very low relative to the standards for computer graphics oriented projects. To execute the project described in this paper expenditures on technology totaled 696 USD. Later in this paper differentiation will be made between technology specific to this project and technology already existing at the collaborating institutions. This project was phase one of a three year investigation funded by the National Science Foundation's CreativeIT Program within the Division of Information & Intelligent Systems (NSF Award #0855908). This program explores cross disciplinary research in creativity, computer science, and information technology with a particular focus on creative problem solving. Funding from NSF, in addition to supporting the Principal Investigator's work on the project, included support for a graduate student at the PI's institution, and travel assistance funding for the faculty and industry advisors to gather at a professional conference prior to the initiation of the project.

3.2 Institutional Alignment

In the Spring of 2010, faculty from four academic institutions embarked on a joint effort to engage students at each location with partners at each of the other three institutions in the development and execution of short animation projects requiring cooperative problems solving in both aesthetic and technical issues. Prior to the initiation of this project, the four institutions involved were all connected in some way not directly related to the project to the institution initiating the project. Formal planning and organization for the project began approximately five months prior to the first day of participation by the students involved.

This project initiated within the Department of Visualization at Texas A&M University (for clarity hereafter called AU). AU is a state funded research-oriented university in College Station, Texas, U.S.A. that serves a large population of both undergraduate and graduate students. Initiating and participating in projects of this kind is an expected contribution for faculty at AU. The curricular goals of this project match the learning outcomes expected for undergraduates pursuing the Bachelor of Science in Visualization degree, a studio-based program that mixes equal parts of math, science, and logic competency with art and digitally composed visual media competency.

The European participants were students participating in a study abroad program sponsored by AU but administered by the Academy for International Education located in Bonn, Germany and managed by German educators (hereafter called EU). The main campus for EU is approximately 8,200 km (5,100 miles) and six time zones ahead of AU. EU custom designs programs to provide international experience, cross-cultural competence, and professional skills. EU is not-for-profit and coordinates with multiple US-based universities to conduct programs in the academic fields of Business, Liberal Arts, Language and Cultural Studies, Film and TV, Theater, Political Science, Engineering, Architecture, and Landscape Architecture. Participation in a project of this kind is uncommon for EU, but falls within the expectations of responsible partnership toward curricular goals that EU and its faculty share with their affiliated US-based institutions.

The other US-based university participating in this project was the University of Texas at Dallas (hereafter called BU). BU is also a state funded research-oriented university located in Richardson, Texas U.S.A. It is in a separate university system from AU. The two campuses are roughly 300 km (190 miles) apart, but in the same time zone. Students participating from BU were enrolled in the Arts & Technology undergraduate program that focuses on the intersection points of art, design, technology, and science. Participation in projects of this kind is an expectation for faculty at BU.

The participating high school was the Design and Technology Academy (hereafter called HS), a community funded school located in San Antonio, Texas, U.S.A. HS is roughly 260 km (160 miles) from AU and 450 km (280 miles) from BU and shares the same time zone. HS has a four year (9th through 12th grade) magnet program focused on design and technology. Participation in projects of this kind is uncommon for faculty at HS, but falls within their scope of responsibilities for contributing to the currency of the academic program and contributing to outreach and external profile of the institution.

Initiation of this project required the interest and agreement of the faculty members directly involved at each institution as well as the administrators of the academic programs in which the student participants were enrolled. An important feature of the project setup is that no additional resources were expected to be required by any of the participating institutions. This did not prove to be precisely true (as is discussed in the Technology portion of this paper) but remained true in large part. The participating faculty taught the courses and course load they would have normally taught even if the project did not exist. However, the scheduling of weekday and meeting times of the classes at AU, BU, and EU were coordinated to provide overlapping times when all students would be in class simultaneously.

Unfortunately, the scheduling of classes at HS did not permit a course time overlap. The absence of course time overlap with the participants from HS led to an unexpected and significant lack of coordination between the work of students at HS and the work of students at AU and BU. The factor was not felt as heavily between HS and EU since students from EU contributed primarily at the beginning of the project workflow and students at HS contributed primarily at the end of the project workflow. The term, or semester, calendars at the four locations did not line up precisely. The greatest negative impact of imperfect alignment stemmed from the fact that the students at EU were primarily responsible for the first phase of the project pipeline yet were the last group to begin the school term. The difference was only a matter of one week, but within a 15 week semester the impact was significant.

In the five month period prior to the first day of student involvement, the faculty collaborating on the project held one face-to-face meeting at a professional conference. This meeting also included the project's industry advisory board. At this occasion the general goals and organization of the project were discussed and a variety of technical solutions were considered for further investigation. Following the face-to-face meeting, and approximately one month prior to the start of student participation, the faculty participated in a group conference call. During this call the final details for the calendar of the project, roles of participants, and outstanding technology questions were addressed. Email was used by the faculty and graduate assistant on the project to plan, discuss, share documents, and determine solutions for issues that did not get answered during the face-to-face meeting or conference call.

3.3 Curriculum Alignment

In the case of AU, BU, and EU, the project was conducted as a part of existing regularly taught courses. For HS the project replaced a professional study, or internship, component of the curriculum that is a requirement for graduation. As such, the project was new in the form in which it was delivered, but did not increase curricular requirements. At each location students were informed about the project prior to the start of the term in which the project took place and were offered alternative curricular equivalents if they did not wish to participate.

This project involved four institutions and four courses with separate, though related, course requirements and expected learning outcomes. A primary goal in organizing the project was to preserve the existing curricula at the participating locations. We reasoned that if this project succeeded in creating a connection between courses at the participating institutions, the significant impact of the project would be greatest if the courses were part of the existing curricula. The academic programs involved in this project at each institution are aligned with the study of topics in computer graphics that have application to the technical aspects of animation, visual effects, and video game development. As such, the workflow of this project was organized to roughly match processes and disciplines found in the production of 3D computer graphics animation. Within each academic program the learning objectives for students include awareness of industry practices, skills specific to the generation of computer graphics imagery, visual design problem solving, programing and technical problem solving.

In the preparation time prior to student involvement in the project, the faculty determined the scope of the project to be undertaken and how the work would be divided among the collaborating locations. It was determined that the students would be divided into two teams at each location with each team responsible for producing a 3D animated short of approximately 30 seconds in length. Each project was required to include two characters, one or two environments, and one or two effects such as fire, smoke, sparks, or an explosion. The specifications for the project did not include title design or sound design. Division of work was based upon discipline responsibilities and workflow common to the animation industry. The work was divided between the schools based upon the learning objectives of the specific courses at each location.

Contribution of the students to the group project was arranged so that the time required did not consume the full 15 weeks of the semester. See Table 1 for the project calendar. This created time within the semester to concentrate on topics and projects that were not directly tied to the group project. For example, students at AU began story and concept development beginning on their first day of class (Week 2 for the project). For much of the Week 4 and Week 5 they were exploring general topics related to scripting languages, motion, control, and deformation systems through lectures and short experimental projects. In Week 6 through Week 12 they were deeply invested the collaborative project. In Week 13 through 15 they worked on individual projects that were unconnected to the group project. Similarly, at BU the students were not heavily involved in the group project for Weeks 1, 5, 6, or 7. The students at EU completed their work on the project in Week 7. A positive effect of this schedule is that the overall project was large in scope for a 15-week schedule yet did not consume all of the time in any of the courses. A drawback to this schedule is that the students ranged between being intensely connected to the project and being disinterested. Their investment in solving problems related to the project was directly related to the calendar. For example, the students at EU and AU, whose work contributed near the beginning of the project, were intensely engaged in the Story and Look Development pitches for which all participants were to take part. Conversely, the students at BU and HS, whose primary responsibilities to the project did not occur until later were not as engaged in the Story and Look Development pitches.

3.4 Student Participants and Team Structure

In total, 42 students took part in this project. There were 18 undergraduates spread between the two US institutions (AU & BU), 16 students at the European-based program (EU), and eight high school juniors at the participating high school program (HS). English was the native spoken and written language for all of the students. The undergraduate students were all already proficient in the use of computing technology including both the software required to perform tasks to contribute to the project delivery and email, which was required to communicate with team members at the other locations. Students in the high school program spent a significant portion of the semester learning software leading up to their direct contribution to the work.

At each location the students were divided into two teams. For purposes of this paper we will call them *Team A* and *Team B*. Each team, therefore, was composed of 21 members: eight members from EU, four members from AU, five members from BU, and four members from HS. During the Story Development and Pitch phase of the project, each team at each location developed and pitched

Table 1. Calendar of collaborative project activities during the 15-week semester

Week	Activities	Locations
Week 1	Course & project introduction	BU
Week 2	Course & project introduction	AU & HS
Week 3	Course & project introduction	EU
	Story development begins	AU, BU & EU
	1st virtual meetings between student team members	AU, BU & EU
Week 4	Story ideas pitched	AU, BU & EU
	Story ideas selected via voting	All
Week 5	Modeling, layout & visual style development begins	EU
Week 6	Development of anim. control & deformation systems begins	AU
	1st virtual project review: rough models, layout & vis. dev.	EU & AU
Week 7	Character animation tests begin	AU
	Mid-project virtual meeting of instructors	All
	2nd virtual project review: final models, layout & vis. dev.	AU, BU & EU
	Modeling, layout & visual development completed	EU
Week 8	Effects animation tests begin	HS
	Surfacing begins	BU
Week 9	Animation control systems work completed	AU
Week 10	3rd virtual project review: rough animation	AU & BU
	Lighting tests begin	BU
Week 11	4th virtual project review: surfacing & lighting tests	AU & BU
	Animation review	AU & BU
Week 12	Animation completed	AU
Week 13	Continuation of lighting	BU
	Compositing tests	BU
	Continuation of effects animation	HS
Week 14	6th virtual project review: final lighting	AU & BU
Week 15	Final review	AU, BU & EU

a story idea. Other than this phase, the participants on each team worked collectively on the same project. The teams were purposefully organized with no clear leadership structure. No location was specified as the lead on the project and no individual was identified as the director by the faculty. During email exchanges and virtual project reviews strong opinions emerged, but the students were left on their own to devise solutions to the conflicts. In the end there was some deference to the opinions of the originators of the story pitches, but each location internally solved the problems over which they had local control as they deemed fit. This could have resulted in something akin to the *telephone game* in which a secret is whispered into the ear of a succession of children and by the end the secret that is told by the last child bares little resemblance to what the first child initially said. However, perhaps surprisingly, both team projects emerged from the production process baring a significantly strong correlation to the original story pitch, including visual style and emotional tone. Even without defined leadership the collaborators accommodated differences of opinion and managed to successfully stay on course.

3.5 Technology

Each academic institution involved in this project had both commonality and differences in their respective approaches to information technology, hardware, and software. Overall, there was more commonality than differences. One does not have to look very far into the past to find a time when the prospect of connecting students at different schools together on a computer graphics related project would have been extremely difficult due to the significant differences between levels of computing and incompatibility between systems and file formats. One of the driving forces behind embarking on this project was recognition that the capacity to connect electronically has exceeded our knowledge and skill at doing so for collaborative effectiveness. Another goal for this project was to minimize the universality requirement between collaborators. Universality is the degree to which workflow -systems, directory structures, software, interface setups, naming conventions and file formats, is consistent. In commercial production universality is a key factor in contributing to or impeding productivity. Universality within a single project and as teams move from project to project is desirable feature. A high degree of universality is possible in top-down structures such as commercial production where technology and artistic leads jointly determine workflow standards. Education, particularly when multiple non-affiliated institutions are involved, has many features that prohibit top-down driven universality. To develop the technology requirements for this project we divided the issue into two separate areas: communications technology and production technology. Collectively, these two areas comprise the project's information technology (IT).

3.6 Cross-Site Tool and Workflow Alignment

This project was structured so that students at each location would contribute a specific portion of the work making up the completed 30-second short animation.

Such a workflow requires that data from preceding portions of the production pipeline can be loss-lessly incorporated by the succeeding pipeline steps. Specific to our project, models and camera scenes from EU were used by AU, BU, and HS; animation from AU was used by BU and HS; lighting from BU was used by HS; and effects animation from HS was used by BU. We also worked to keep the pipeline as open as possible to software and workflow preferences at each location. Forcing the use of a specific piece of software potentially dictates pedagogical and budgetary decisions. To facilitate the lossless transfer of data this project we determined that all models would be delivered in *.obj* format. We determined a unit size and global orientation standard within 3D software packages, for example: *1 unit = 1 foot*; and all character models should face down the *positive z-axis*, for example. These guidelines were distributed to all students at the beginning of the project. As it turned out, Autodesk's Maya 3D animation software was the preferred choice of all of the students at each location. Maya is a standard tool within animation and visual effects. At BU Maya was already licensed by the academic institutions and available for the students to use. Students at AU, EU, and HS took advantage of Autodesk's free trial opportunity available only for students.

Computing power and connectivity varied from location to location among the participating schools. At BU and HS students performed their work in computer tutorial classrooms on graphical workstations provided by the institutions. These machines were connected in a local area network and possessed, optimally, 1 Gbps ethernet connection to the outside world. Students at AU performed their work in a studio classroom, not specialized for computing, using personal laptops or personal desktop machines. They communicated to the outside world using a VPN controlled wireless network with approximately 54 Mbps connections. Students at EU also worked in a studio classroom using their personal laptop machines. They connected to the outside world either through 18 Mbps data ports or 3 Mbps wireless connections. At EU the institution purchased higher performance routers once the administrators recognized the extent to which connectivity was going to play a role in the execution of the course and project.

3.7 Cross-Site File Sharing

Sharing large files containing models, animation, and image sequences among a large team is a hallmark of animation production. To facilitate this facet of the project we utilized a cloud-based service with controlled access provided by Dropbox. Published by Evenflow and made publicly available in 2008, Dropbox offers cross-platform compatibility for Windows, Mac, and Linux. Users place files into a designated folder on their own machine and synchronization with the Dropbox cloud server occurs automatically when changes are detected. Basic 2 GB service is free and each student on the project set up his or her own Dropbox folder. A home folder for the project on server partition at AU provided a 50 GB file storage location for which Dropbox charged 99 USD for a year. Access to the files on in Dropbox folders is password protected. A one-month revision history is included in the service. The file structure in the primary project folder was originally left to the students to organize. By mid-project however, there was a great deal of confusion over where the latest versions of files were located and what file naming convention should be used. With agreement of the faculty the graduate assistant instituted a file structure and attempted to enforce its use throughout the second half of the project.

3.8 Synchronous and Asynchronous Communication

To provide synchronous viewing of visual media and verbal communication between team members at different locations we combined the use of two commercial software applications: cineSync and Skype. The former is a synchronized media player permitting control at multiple locations. CineSync includes drawing and text annotation capabilities. It is built on the Apple QuickTime player. Media files can be constructed into a playlist and played back in perfect synchronisation at any location invited to participate in the review session. A particular advantage of cineSync for animation review is frame specificity and control. CineSync is downloadable for Mac and Windows. The cost for five users for six months was 597 USD. A version with additional features, including support for Linux, is available at a higher price but was not required for this project. Though cineSync includes audio support for verbal discussions we chose to use Skype running alongside cineSync. Skype utilizes VOIP technology and is free to non-commercial users. In addition to VOIP Skype offers instant messaging. This feature was highly useful to the faculty and graduate assistant on the project for quickly sending small snippets of information while organizing cineSync virtual reviews (dailies) between locations.

To provide a mechanism for detailed communication we provided three project specific email accounts: one was an overall project email and was intended for students to be able to contact the faculty and graduate assistant with questions about the project. The other two email accounts were team specific. Everyone on Team A was connected to one account while everyone on Team B was connected to another. We used Google's mail service, *gmail* because it was free and, significantly, it was not the domain of any of the institutions involved. For a variety of reasons, including security, institutions are reasonably averse to providing email accounts and access to individuals who are not either faculty, staff or students of that institution. The use of an outside email service avoided this bureaucratic problem. At the beginning of the project the lead institution created a publicly accessible website for the project. On this website initial instructions for getting started on the project, such as how to setup a Dropbox account, were posted. Following initial setup the majority of communication was handled through email.

4 Conclusion and Future Work

This project succeeded in bringing the faculty and students of four academic institutions together to execute a large scale collaborative project while preserving curricular autonomy. The workflow employed followed standards in the animation industry, however the collaboration did not introduce any special IT requirements that had a significant impact on existing resources. The programs involved and their students are all left-brain/right-brain engaged. They are straddling the division between the art of computer graphics and the science of computer graphics. It is conceivable that this project could have been organized to include participation from students in programs that are either strongly computer science oriented or strongly art and design oriented. It is our opinion that because each location shared responsibility for both technical and aesthetic problems there was a shared empathy and understanding among the student participants and faculty regarding time, resources, knowledge and skills required. We intend to pursue the project further through augmentation of the IT used to maintain synchronous communication among the participants.

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