Evaluation of Students' Skills in Remote Collaboration for Creative Problem Solving in Computer Graphics

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Abstract

Use of distributed teams of artists and engineers is becoming more prevalent in computer graphics oriented industries. Developing the skills required to work as a team through the complex sequential development and production process of animated films, visual effects, and commercial productions is a part of many academic programs that focus on computer graphics. However, the development of the skills required to communicate and coordinate this kind of work across a distributed team is currently a rare curriculum feature, and may not even be recognized as a separate set of issues from localized collaboration. This paper reports on an effort to assess this problem through pilot projects that focus on discovering how adept students are at working as members of distributed teams. We tightly controlled the tools of communication -email, chat, and video-conferencing- to determine the impact of each modality on creative problem solving while teams of students from four locations attempted to coordinate their work to produce short 30-second computer animations. Assessment by industry professionals of the originality found in the aesthetic and technical results of the student projects suggests that the students, overall, are deficient in two areas that are essential to successful creative collaboration: communication that contributes to awareness among distant partners, and communicating in ways that build consensus and solves problems. Though these issues also exist for co-located teams, their significance is likely heightened in distance collaboration projects. These issues might also impact the manner in which companies that use distributed teams incorporate various modalities of communication technology into their production pipelines.

Categories and Subject Descriptors (according to ACM CCS): H.5.3 [Group and Organization Interfaces]: Computer Supported Cooperative Work—Collaborative Computing

1. Introduction

A review of production credits of computer animation and visual effects projects reveals that geographically distributed teams of artists and technical directors are being used to produce the imagery for many large-scale and even some small-scale projects. These distributed groups cover the range of artistic and technical responsibilities found in the production of computer graphics intensive movies, episodic series, and commercials. These teams labor under the burden of time zone differences and incompatibility of tool sets and processes that is not faced by teams that are co-located at a single studio facility. That these teams can be successful is evidenced by the acclaim given their resulting projects by the industry. Between 2006 and 2010 13 of 17 (76%) films nominated for Best Achievement in Visual Effects by the Academy of Motion Picture Arts and Sciences were produced through multi-studio collaborations. In the same time period two of the 17 (12%) nominees for Best Animated Feature Film were produced by distributed teams [osc12] [imd12]. How these distributed teams coordinated their efforts to successfully resolve the creative artistic and technical problems of the production is a matter that is difficult to discern beyond anecdotal post-action interviews in trade publications. Yet, it is obvious that, at least at some level, communication technology played a role in coordinating the work.

In this paper we report on an effort to assess the skill level of students in the use of communication technology for creative technical and artistic problem solving with distant teammates. Our goal includes identification of the communication technology modalities that students use to contribute effectively to creative technical and artistic problem solving. To accomplish our intentions we adopted a product goal and workflow distribution of responsibilities among teams that mirrors, on a smaller scale, a distributed development project in the visual effects and animation industries. Our hypothesis was that university and high school students, as digital natives, would prove to be adept at using technology to communicate and coordinate action. Based upon this hypothesis we assume that there is no need for specific curricular objectives that focus on developing remote collaboration skills. To test our hypothesis we conducted two tests, each test involved two teams of students. Team members were distributed between four geographic locations, with three in the U.S. and one location in Germany. We tasked each team with the concept development and production of a 30-second computer animated short subject project within a period of 15 weeks. We limited the communication tools available to group email and video conferencing in the first test. We added chat to the available modalities in the second test. The frequency, modality, and subject matter of the students' communications was recorded. After all four teams completed their work the resulting animations were evaluated by professionals from the animation and visual effects industry. While each team succeeded in completing their projects the professional evaluations noted underperformance overall and that there were clear differences in the quality of the technical and artistic accomplishments between the projects. When these qualitative assessments were aligned with the data record of how students communicated with one another we found defined indications that the students struggled to communicate in clear and concise terms and that chat appears to have had a positive influence on outcomes.

This study highlights the need for exposure to opportunities for remote collaboration for students in computer graphics intensive programs. The industry, both for artistically driven and technically driven projects, is expanding in the use of distributed teams. Computer graphics production requires communication modalities that can capture both quantitative and qualitative issues. How, when, and where these issues are communicated is an issue that is driven both by the competency of the individuals involved, and by the communication technology available and the way that it is incorporated into the team environment.

2. Background

2.1. Foundations from Professional Practice

Creative problem solving among teams is not a new phenomenon in visual effects and animation production. In the 1930s Disney animators developed the "sweatbox" wherein artists would gather to review work, make suggestions for improvement, and record their progress [TJ81]. In the days when the majority of visual effects were created on live action stages production artists and technicians gathered together around miniature models, motion control cameras, and gimbals to collaboratively discuss problems and determine solutions [Ric07]. Everyone involved in determining and executing a solution witnessed the problem synchronously and had the same access to critical feedback.

As the digital age of visual effects and animation production dawned in the mid-1990s the work of creating imagery moved to graphical computing workstations and the conversations shifted to email. The iterative and relatively lossless capacity of digital production afforded economical advantages that overcame losses due to moving teams off the stage and into rooms filled with clusters of digital artists. During this period, due to both the limited bandwidth of external connectivity and culture, work continued to be produced at single locations [CVD96].

In the early- to mid-2000s the capacity of commodity computing and the spread of high bandwidth connectivity led to geographical expansion of the locations of visual effects and animation production studios to areas with lower costs and broader access to artistic and technical talent. Team structure reflected a distribution of work in which responsibility for discrete portions of the production pipeline was parsed to specific studio locations. By the late 2000s a handful of large studios, notably Rhythm & Hues in visual effects production, DreamWorks Animation in feature animation production, and Lucasfilm Animation in serial animation production, began to fully and tightly integrate the work of teams distributed across locations. Video conferencing, asset management tools, production tracking tools, and efforts to promote universality of production tools and methods were brought into the production environment.

2.1.1. Professional Peer Assessment of Success

Throughout this time of change in production methods and team organization the use of peer review, in the form of awards given by industry professionals, has remained in place as the standard measure of success. The annual Visual Effects Society awards and the Annie Awards parse recognition for visual effects and animation, respectively, into categories based upon the venue where the work was shown, such as features or television, and the specific artistic area, such as effects animation, compositing, or character animation. The Academy of Motion Picture Arts and Sciences' Academy Awards, commonly referred to as the Oscars, treat achievement comprehensively by simply awarding a Best Achievement in Visual Effects and a Best Achievement in Feature Animation. While box office success and critical acclaim are standards by which the public measures success, the Academy Awards, VES awards, and Annie Awards are recognized by the practitioners as the honors most reflective of high achievement in their fields.

2.2. Foundations from CSCW

Computer supported cooperative work (CSCW) is a broad area of research. For the purpose of this study we have narrowed our focus to research that deals with distributed teams, teaching/learning environments, variance in communication modalities, and where creativity is a factor in measuring outcomes. Developing computer graphics for visual effects and animation is a complex process involving teams of people from varying disciplines contributing toward a common goal. Tran & Biddle [TB08] studied a similar environment, the development of computer games, and identified four key factors that contribute to collaboration: (1) team awareness, (2) social atmosphere that promotes openness, (3) shared knowledge and situational awareness, and (4) shared organizational goals and methodologies. Their work involved observations of co-located collaborators. When teams are not co-located the factors contributing to collaboration begin to break down [SB08] and the distance over which teams are separated can affect both the frequency and the quality of communication [BM02]. However, the capacity to communicate effectively remains, and even in text-only communication team members who are able to choose the use of words to defend their own positions and critically review those of others are deemed to be both better collaborators and more likely to have their ideas move forward [TS07]. Even the capacity for "cheap talk", communication that is not strategically important to the collaborative activity, can have a positive impact on the capacity for cooperation among remote teams [Fie09].

Beyond the human aspects of collaboration, the tools themselves have a significant impact on distributed teams. Farooq et. al., [FCG08] looked at the capacity of communication tools to support creative problem solving in remote collaboration and determined that they must (1) support divergent thinking, (2) support the development of shared objectives, and (3) support monitoring and evaluation of progress. For example, chat, as a communication modality, provides a record of conversation that can be decomposed by current users as well as those who return to the conversation at some later time. Video-conferencing, on the other hand, supports the development of shared objectives, but does not leave a record that can be dissected and critically reviewed unless specifically recorded. Jensen [JFDK00] found that voice communication prompted the highest level of cooperative activity, followed by text-to-speech and chat; though simply being aware of what others are doing –as through status updates, acknowledged presence in a chat room or a change on a task list –has been shown to improve creativity within a group [FC11].

3. Approach

Our primary interest was to test the hypothesis that college and high school students are naturally adept at using communication technology to communicate and coordinate action. Our vision was the development of both an assessment of the students' skill level and an assessment of the technology. To accomplish this task we developed a visual effects and animation oriented computer graphics project for teams of students to undertake. We ran the project on two separate occasions (Test 1 and Test 2), with each test composed of two teams (Team A and Team B) and labeled their results as T1A, T1B, T2A, and T2B, respectively. The students were given roughly 15 weeks to complete the project. The projects were delivered as part of the standard curriculum at each institution. Most students were enrolled in three or four other courses at the same time, so participation in this project was only a portion of their overall academic commitment. Each team was tasked with developing and producing a 3-D computer animated short film, 30 seconds in length, featuring specific components that required technical and artistic problem solving: one or two environments, two articulated characters, at least one effects animation (fire, smoke, sparks, or water), a minimum final frame resolution of 720 pixels in the short dimension, and a playable frame rate of 30 frames per second.

Using the cascading structure of project development common to animation and visual effects production, responsibilities for delivering specific components of the project were divided by location. This provided periods of independent work at each location as well as periods of overlap as one group handed off their work to the next group. For Test 1 both Team A and Team B were limited to group email and group video conferencing as the only means of communication with their distant teammates. For Test 2 we provided both teams with access to group chat, in addition to group email and group video-conferencing. The arrangement of teams and their limited modes of communication was intentionally set to reflect practices common in the visual effects and animation industries where specific tasks within the production pipeline are often distributed to separate locations, and team members can only use company approved communication tools to discuss the project.

3.1. Project Team Participants and Locations

Two undergraduate programs (TAMU and UTD), and one high school program (DATA) in the U.S. took part in the project. The three institutions were no closer to one another than 260 km (160 miles) and no further than 450 km (280 miles). They all shared the same time zone (U.S. Central Standard Time, UTC/GMT -6 hours). The European participants (AIB), composed of students from the U.S. participating in a study abroad program, were approximately 8,200 km (5,100 miles) from the U.S. students and seven hours ahead (Central European Time, UTC/GMT +1 hour). All four institutions shared the curricular goals of developing student competency in the art and technology of digitally composed visual media.

In Test 1, a total of 42 students (28 male, 14 female) took

Table 1: *Distribution of production tasks by discipline among the collaborating schools and with the number of students per team at each location.*

Task	Location	Test 1	Test 2
Story Development	AIB, TAMU, UTD	17	21
Visual Development	AIB	8	9/10
Modeling	AIB	8	9/10
Set Layout	AIB	8	9/10
Camera Animation	AIB	8	9/10
Rigging	TAMU	4	6
Animation	TAMU	4	6
Surfacing	UTD	5	6/5
Lighting	UTD	5	6/5
Effects Animation	DATA	4	3
Rendering	UTD, TAMU	9	12/11
Compositing	UTD, TAMU	9	12/11
Final Editing	UTD	5	6/5

part in this project, 21 students per team. In Test 2, a total of 48 students (28 male, 20 female) took part in the project, 24 students per team. **Table 1** describes the distribution of tasks and number of participants per location for each test. 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 15-week schedule of each test period learning software leading up to their direct contribution to the work.

3.2. Technology Universality

A key issue that made this project viable was the capacity to connect electronically at a level that permited the exchange of large files such as hi-resolution imagery and movie sequences. One of the sub-goals for this project was to gain a better understanding of the degree to which the universality requirement between institutional collaborators can be minimized. 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 contributing to, or impeding productivity. Universality within a single project, and as teams move from project to project, is a desirable feature. A high degree of universality is possible in top-down structures such as commercial production where technology and artistic leadership jointly determines workflow standards. Education, particularly when multiple non-affiliated institutions are involved, has many features that prohibit top-down driven universality. A similar situation exists when production companies in visual effects and animation that have not previously worked together are placed in the situation of collaborating to produce projects.

3.3. 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. This cascading, or waterfall, workflow requires that data from preceding portions of the production pipeline be loss-lessly incorporated by the succeeding pipeline steps. Specific to our project, models and camera scenes from AIB were used by all three other locations -TAMU, UTD, and DATA; animation from TAMU was used by UTD and DATA; lighting from UTD was used by DATA; and effects animation from DATA was used by UTD. 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 and offers both discounted licenses to academic institutions and free trials available for students. Sharing large files containing models, animation, and image sequences among a large team is a hallmark of animation production. Connectivity varied among the participating institutions, ranging from 3 Mbps wireless connectivity to 1 Gbps ethernet connections. We therefore utilized a commercially available cloud-based solution, Dropbox, which permitted the upload and download of files of varying sizes. The organization of the shared file folder structure was established and managed by a graduate teaching assistant.

3.4. Team 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. Media files were constructed into a playlists and played back with frame-accurate synchronicity and shared control at each location invited to participate in review sessions. Though cineSync includes audio support for voice communication we chose to use Skype running alongside cineSync. Skype utilizes VOIP technology. In Test 1 we used Skype and cineSync for communication between only two locations at a time. In Test 2, multiway calling using Skype was available and used for this project. Video conferencing sessions only occurred at set meeting times and were managed by the project instructors and graduate student assistants.

Group email was established for each team using a multicast email list-serve approach whereby a single sender could send a message that would be received by everyone on the team. Person to person, dyadic, email was not permitted between distributed team members but was permitted among co-located team members. In Test 2 we continued using the multicast email approach and added the capacity for person-to-group online chat. The chat tool used was Campfire by 37 Signals. Campfire is web-based (i.e. non-platform-specific) and centered around administrated "rooms" to which users can be invited. Campfire includes the functionality of sending images along with text. Similar to our email structure, we set up chat rooms for both Team A and Team B. Students were given unlimited access to both email and chat throughout the duration of the project with minimal intrusion from the project instructors or staff. All communication modalities were recorded.

3.5. Methods of Analysis & Measuring Results

At the conclusion of each project we analyzed the records of communication between the participants (email logs, chat logs, and video recordings of video conference sessions), along with feedback from participants in the form of a survey. The communication records were analyzed to determine the communication modality(email, chat, or video conference); frequency of communication per location, and per tool; who communicated based upon location; and the subject of the communication (quantitative, qualitative, or social). In order to gain a measure of the achievement level of the student projects we mirrored the use of popularity (ticket sales) and professional society awards (Academy, Annie, and Visual Effects Society Awards) by surveying visual effects and animation professionals. Both groups viewed the completed projects and provided simple assessments of quality.

4. Results

4.1. Qualitative Review of Student Work

Our first level of qualitative evaluation of the student projects was provided by five professional artists and technicians. This group had an average of 15 years of experience in the visual effects and animation industries. Across the four projects, the professional reviewers rated Test 2, Team B's project (T2B) the most successful, scoring it a 2.65 on a 4-point scale where 1 = little or no evidence of originality in problem solving and 4 = extraordinary creativity in problem solving. The three other projects scored, in descending order: Test 1 - Team A (T1A) = 2.15; Test 2 -Team A (T2A) = 2.06, and Test 1 - Team B (T1B) = 1.5. See **Table 2** for complete results including scores for creative problem solving per area of production: modeling, animation, surfacing & lighting, and visual effects. The creativity expressed in the artistry and the creativity expressed in the technical achievement of effects animation received significantly low scores in T1A and T1B due to the fact that the completed work from the DATA team was not included in the final composites. This was caused by a communication breakdown between locations.

Table 2: *Evaluations of the visual and technical creativity exhibited in projects on a scale of 1 to 4; where 1 = no evidence of originality and 4 = extraordinary evidence of originality. The evaluations were provided by visual effects and animation industry professionals.*

Question	T1A	T1B	T2A	T2B
Visual Creativity of Models	2.8	1.8	2.4	3.3
Technical Creativity of Models	2.5	1.4	2.3	2.9
Vis. Crtvty. of Animation	2.5	2.0	1.4	2.8
Tech. Crtvty. of Animation	2.2	1.5	1.6	2.5
Vis. Crtvty. of Surfacing & Lighting	2.6	1.8	2.2	3.3
Tech. Crtvty. of Surf. & Ltg.	2.6	1.3	2.1	2.8
Vis. Crtvty of Effects Animation	1.0	1.1	2.3	1.8
Tech. Crtvty. of Effects Animation	1.0	1.1	2.2	1.8
Mean Score	**2.15**	**1.5**	**2.06**	**2.65**
Standard Deviation	0.73	0.34	0.36	0.59

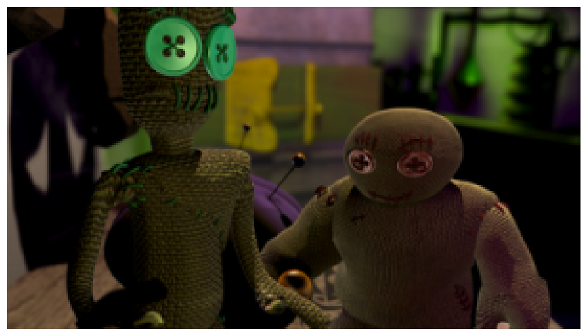

Figure 1: *Example image from the short animation produced by Test 1, Team A (T1A)*

4.2. Students' Capacity to Collaborate Effectively

4.2.1. Communication: When, Where & What

Communication of timely and appropriate information was a key factor in the success of each team's final result. As discussed previously, teams had unlimited access to email and limited access to live video conferencing. Teams in Test 2 also had unlimited access to synchronous chat. Communication using each of these mediums was logged by team and location and categorized as either qualitative or quan-

Table 3: *Number of communication exchanges by modality and type.*

Type	Email	Chat	Video
Qualitative	141	461	745
Quantitative	561	590	342
Social	N/A	183	N/A

Figure 2: *Example image from the short animation produced by Test 1, Team B (T1B)*

Figure 3: *Example image from the short animation produced by Test 2, Team A (T2A)*

titative in nature. Communication was considered qualitative if it concerned subjective issues such as aesthetics or storytelling aspects of the production. Communication was labeled quantitative if it concerned numerical or logistical topics such as file versioning, naming, location, and editorial timing. With the addition of chat in In Test 2, we found instances of "cheap talk", communication that was neither

Figure 4: *Example image from the short animation produced by Test 2, Team B (T2B)*

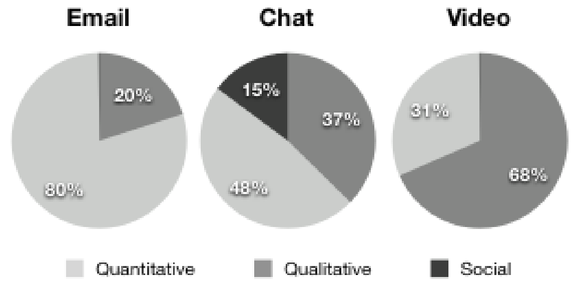

Figure 5: *Nature of Communication by Modality*

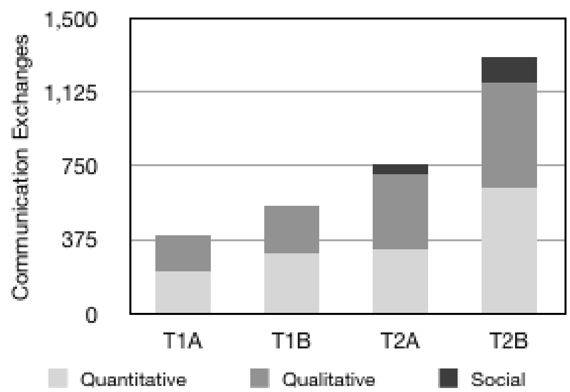

Figure 6: *Communication Volume by Type*

qualitative or quantitative but served a social team-building function. In both Test 1 and Test 2, the social "cheap talk" was negligible within the modalities of email and videoconferencing.

5. Discussion

5.1. Student Capacity for Distance Collaboration

Overall, the student teams were not very effective at collaborating for creative problem solving with remote teams. Though some projects were judged to be more successful than others, the overall quality was not considered high by the professional evaluators. It's important as educators not to get too caught up in short term student achievements. As

Table 4: *Number of communication exchanges by test and type.*

Type	T1A	T1B	T2A	T2B
Qualitative	117	228	383	535
Quantitative	167	309	326	634
Social	N/A	N/A	50	135

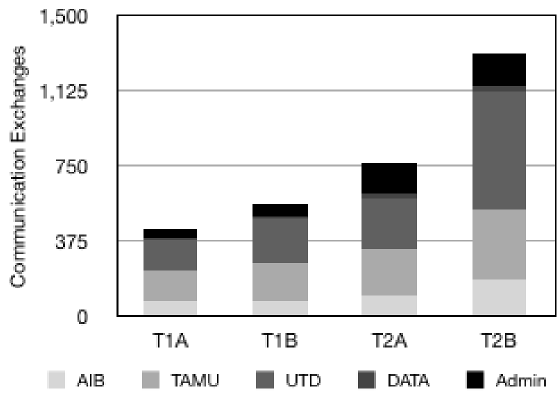

Figure 7: *Communication Volume by Location*

Table 5: *Number of communication exchanges by team and location.*

Location	T1A	T1B	T2A	T2B
AIB	69	72	100	177
TAMU	157	190	229	354
UTD	155	221	255	585
DATA	7	13	29	32
Admin	42	57	144	154

Greer & Barnes [GB] state, the "key to engendering higher levels of collaboration and creativity is to focus on the learning process of students participants rather than the end product." As educators, we have confidence that the exposure of the students to the issues of remote collaboration has contributed to the development of their skills and knowledge even though the projects themselves do not offer significant visual proof.

It is interesting to note that T1A, the team that communicated the least overall, was judged to be the second most creatively successful. This would appear to counter the idea that collaborative creativity requires significant support for group reflection [FCG08] while the highest performing team, T2B, had by far the highest volume of communications and the highest volume of social "cheap talk". It may be the case that T1A was able to effectively resolve differences and left fewer issues open-ended. Oliveira et. al. [OTP11], using measures that included qualitative assessment of results, found that teams that spent more time manifesting differences were less successful than teams that used explicit communication to solve problems. A sum of the the evaluation scores from Test 1 (T1A + T1B = 3.65) compared against a sum of the scores from Test 2 (T2A + T2B = 4.71) may indicate that the use of chat in Test 2 improved results. Perhaps this effect was due to the introduction of both a social "cheap talk" aspect to communication and through promoting awareness. This result may be confounded by growth in expertise –some students had the advantage of witnessing Test 1 before taking part in Test 2 –or by the increased experience of the instructors with this course delivery. Students were given no formal guidance about how to use the communication tools in terms of dividing their sharing between quantitative, qualitative, and social, yet they appear to have naturally made use of the affordance of email for sharing knowledge, the affordance of video conferencing discussion for discussion, and chat for promoting awareness.

Though this study was primarily focused on observing the natural capacity of the students to make use of various modalities of tools for communication, there is the opportunity to create a more formal learning and instructive delivery. Ocker, et. al. [OKH*09] developed a training system for users of online collaborative environments and found that the introduction of training materials significantly impacted participant reports team performance, trust, and perceived competence of remote team members. A key ingredient that should be added is the capacity for team members to record feedback and progress. Feedback systems are standard components of production environments and Geister [GKH07] found that feedback systems significantly improve performance, motivation, and satisfaction for virtual teams.

5.2. Impact on Industry

The visual effects and animation industries are in the process of restructuring production pipelines to take advantage of high speed connectivity and the world-wide distribution of talent. Their approaches very widely based upon the type of work, artistic challenges, the capacity to develop custom tools, and historical methodologies of the studios. This study may provide a small measure of evidential basis demonstrating how various modalities of communication technology are used by teams involved in artistic and technical problem solving. Our findings suggest that though email has served as the backbone of communication for project teams its effectiveness is limited. Other tools that can support status awareness and shared understanding more effectively, such as asset management and production tracking tools, are likely to replace email.

6. Conclusion and Future Works

This paper reported on an effort to inform both educators and computer graphics professionals about the need for better understanding of student capacity to collaborate for creative problem solving as part of distributed teams. To gain information about this issue we developed a pilot project involving geographically distributed teams of students involved in the production of computer animated short features. Our findings suggest that educators should seek more opportunities to provide students with distance collaboration projects due to the facts that (a) they are likely to face those challenges in the professional industry, and (b) though they are part of the digital native generation they are not as skilled at communicating effectively with distant collaborators as might be expected. There is also a broader impact to consider for industry. The studio environment relies on creative problem solving to achieve both aesthetic and technical goals. Our findings suggest that two factors that are essential to successful creative collaboration: awareness of others and clear communication, are significantly affected by both the modality of communication –email, chat, and video conferencing, for example –and the communication skill of the collaborators. These issues are not unique to distance collaboration, but their impact is heightened. In our pilot tests we tightly controlled the modality of communication to determine the impact of each on creative problem solving, and provided only limited guidance about what to communicate and when to communicate. Though limited in scope, our results suggest that producing the next generations of digital artists and engineers requires that educators pay greater attention to the skills and knowledge required for effective creative collaboration among distributed teams. In the near future these teams of students will be responsible for collaborating from a distance to solve the artistic and technical problems inherent in the production of films, television shows, and commercials. It is important that educators recognize the factors involved in engendering student skills for cooperation, engagement, and problem-solving among distributed groups.

Our future plans for this work include a broadening of the periods of overlap between the participants and increasing their capacity to maintain awareness of one another. Our goal is to create a high degree of fluidity for where, how, when, and by whom work is done while at the same time increasing collaboration and generating higher levels of both aesthetic and technical creative problem solving.

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