Large-scale Synchronous/Asynchronous Collaborative Distributed Learning in a Graduate-Level Computer Engineering Course

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Abstract

Recent advances in telecommunications and network technology, increasing demand for continuing education for industry professionals, and the general mobility and geographic distribution of the population are forcing major changes in both synchronous and asynchronous graduate education. This paper describes the author's experience in teaching a large section of a graduate-level computer engineering course with synchronous lectures to nine locations in Virginia and the numerous supporting mechanisms utilized for communications among students and with the instructor. Results of a survey conducted with all students in the class are analyzed here. We focus on students' experiences with working on a collaborative group research project involving group members in multiple locations. The author concludes that there is value in providing strong encouragement for student involvement across geographies; however, this is a process that will not typically occur naturally, so it requires both careful planning from the instructor and the appropriate set of tools to make active collaboration possible.

I. Introduction

Recent advances in telecommunications and network technology, increasing demand for continuing education for industry professionals, and the general mobility and geographic distribution of the population are leading to long-lasting changes in graduate engineering education. The most visible changes have been in the development of online (mostly web-based) courses, with several universities today offering graduate degrees that can be earned entirely asynchronously. The same societal pull is also in the process of forever modifying the way we conduct synchronous graduate learning. This is due to two synergistic factors: the requirement to address the needs of a changing and distributed student population and the opportunity to do so effectively by taking advantage of new technologies now available.

This paper describes the lessons learned in teaching a large section (one hundred and forty-nine students) of a graduate course in computer network architectures. The student population consisted of a heterogeneous mix of traditional full-time students, government and industry professionals and active-duty military personnel; they attended lectures in real time from eight locations throughout the Commonwealth of Virginia. The main concentration of students occurred at the main campus in Blacksburg, VA (64%) and at Virginia Tech's Northern Virginia Center (25%), with the other six locations making up the remaining 11%. The exact breakdown of students per location is shown in Figure 1.

Both synchronous and asynchronous modes of delivery were used for the lectures: two-way video linked nine classrooms across the state in real-time; streaming video was available, in real time, on the web (and archived to serve as reference material); lectures were videotaped, with tapes available at the libraries at the two primary locations.

Collaboration among geographically distributed coworkers is increasingly common in industry, and it requires particular skills: communication at a distance, without the aid of informal cues provided by personal contact; development of a consensus for the distribution of responsibilities; emergence of group leadership. An important component of this course was a final research project carried out in groups of seven to ten students; all groups had participants at multiple locations. A different topic was assigned to each group, and the group was asked to develop a single, cohesive web-based resource relating to the topic. These resources typically contained a collection of student-developed HTML pages and tutorials, annotated list of useful links, simulation interfaces, etc. Each group had access to a particular set of resources for distance collaboration, including email lists, shared folder capabilities, threaded discussion, a chat area and a web-based audio conferencing tool with whiteboard capabilities. Students were challenged to use these in order to effectively replace in-person group activities that were precluded by the distributed character of the group.

In this paper we describe student reactions and feedback to the group project and to the distributed nature and delivery of the course, provided both informally and through a survey developed in collaboration with Virginia Tech's Institute for Distance and Distributed Learning (IDDL).

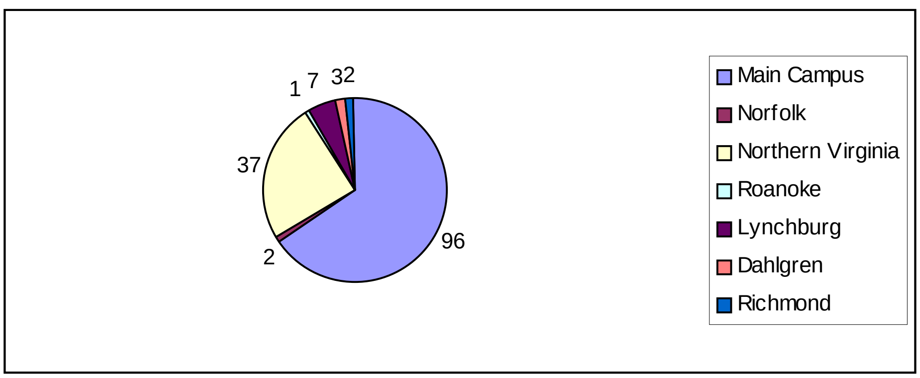

Figure 1 - Geographic distribution of student population for ECPE 5516 - Computer and Network Architectures II at Virginia Tech in the fall of 2000.

II. Course delivery and collaboration requirements

The course being discussed in this paper, ECPE/CS 5516, is a first graduate-level course on computer networks that can satisfy degree requirements for the Electrical Engineering, Computer Engineering, Computer Science, and Information Technology programs, among others. The course is intended to provide students with a deep understanding of fundamental concepts in networks and protocols. Widely deployed network protocols and technologies, such as IEEE 802.3, IEEE 802.11, ATM, and the TCP/IP suite, are studied in detail.

This course was part of Virginia Tech's Commonwealth Graduate Engineering Program, where courses are delivered in real time to multiple locations in Virginia. The primary mode of delivery is real-time two-way video, allowing students to interact live with the instructor from any of the locations. All lectures are also tape recorded, with tapes made available at the library at some of the locations. In the Fall of 2000, for the first time all lectures were also available via streaming video live on the web; the streaming video was archived and could be accessed at any time by students.

The course was taught once a week, in the evening, in two one-hour and fifteen-minute blocks separated by a fifteen-minute break. This schedule is dictated by the requirements of part-time students in the program, who work during the day and for whom coming to class more frequently than once a week would impose excessive overhead due to traffic, etc. The instructor generated 75% of lectures from Northern Virginia and 25% from the main campus in Blacksburg.

Typically, enrollments in graduate-level courses delivered under this program fall at much lower levels than in this particular case. The extreme popularity of the subject matter for this course, combined with a larger-than-usual first-semester Electrical and Computer Engineering graduate student population in the fall of 2000, resulted in the unusual class size. The large class size prompted us to search for new solutions for interaction between instructor and students, performance assessment and collaboration among students.

It is well known that distance delivery of courses imposes additional logistics for distribution of assignments, grading, proctoring of exams, general communications, etc. [1]. We see these as a minimal set of requirements, insufficient to ensure the success of the course. The real challenge resides in building an effective learning community. Flugrad *et al.* [2] suggest some techniques for achieving this in a distributed learning environment. In this course, we adopted an approach of strongly encouraging interaction during and after class and requiring students to collaborate across geographical boundaries, utilizing the appropriate technologies to enable this collaboration. In the next sections, we will discuss our experience and students' reactions.

III. Assessment of student feedback

The author developed a survey, with assistance from faculty at IDDL, to assess student reactions to the delivery mode for the class, as well as to the distributed nature of the final project. Numerical results presented in this paper are taken from that survey; subjective feedback was obtained both from comments to various questions in the survey as well as from informal discussions with students during and after the course.

The survey was web-based and available to all students during the week prior to the end of classes. Participation was voluntary and anonymous; a small incentive for participation was provided in the form of a modest amount of extra credit (a list of students who participated in the survey was provided to the instructor, without any links to individual responses). Return rate on the survey was 96.6%, providing high confidence that the opinions of this group of students were well represented. The return rate compares very favorably to those reported in similar surveys of students' perception of asynchronous learning methods [3]. The breakdown of participating students according to location and to full-time versus part-time status is shown in Table 1.

Blacksburg	66%	Full-time students	73%
Northern Virginia	24%	Part-time students	26%
Other locations	10%		

Table 1 - Student representation in the survey results.

The mix of traditional full-time students (mostly at the main campus in Blacksburg) and non-traditional students, who typically held full time jobs, provided a unique opportunity. It has been observed [4] that this type of population mix can enhance the overall learning experience, with each group contributing with its own strengths. Non-traditional students typically bring a higher level of maturity, work ethic, and in-depth knowledge of practical implications of the subject; full-time students tend to have fewer time constraints and therefore are better able to focus on the tasks at hand, and are generally more familiar with theoretical and analytical methods. The risk exists, however, that when both on-campus and remote students are present in the same course, one of the groups may feel disenfranchised and therefore have a much less positive view of the overall course than the other group, as reported in [5]. The challenge is to take advantage of the potential for mutual learning among the entire student population while minimizing any resentment about the extra level of effort required to overcome the additional obstacles. In an attempt to maximize interaction between the two groups (which are, for the most part, geographically separated), the final project for course required mixed groups, with members in multiple locations.

The survey had two main groups of questions: one dealt with the technology used in the course delivery and the other with experiences in distributed group collaboration. The next two sections discuss the lessons learned on each count.

IV. Lessons learned: course delivery

The delivery of this course employed a number of synchronous and asynchronous methods: traditional live lectures, live streaming video of the lectures on the web, VHS tapes of the lectures available from the library, archived streaming video of all lectures, a very active listserv, online posting of all notes, assignments and solutions. One reasonable question to ask is: do students tend to attend class less often when all these are made available? Not so, seems to be the answer in this case. Although roll call was not taken and attendance was not mandatory, 79.7% of the students reported attending 80 to 100% of the lectures live, 15.7% reported attending 50 to 80% of the lectures, and only 4.6% reported attending fewer than half of the lectures. Although it is difficult to assess the reliability of self-reporting on this question, these results seem consistent with informal observation. The instructor also observed an increase of attendance at whichever site he was lecturing from on any particular evening.

Both full and part time students attributed great value to the web-based video streaming of the lectures, used both to make up for missed lectures and for the purpose of reviewing key concepts.

Whenever they missed classes, most students reported using video streaming as a substitute, as shown in Figure 2. In a separate question on the survey, students were asked whether they referred back to the streaming video to review or consolidate concepts, even when they had been present during lecture: 58% of students did so, with varying frequencies.

Our original expectation was that part-time students would be the primary audience for newer technologies such as streaming video. Several of the off-campus students told the instructor that they received the lectures through the web while away on business trips. Somewhat surprisingly, the survey indicates that full-time students made use of some of these resources even more frequently than part-time students.

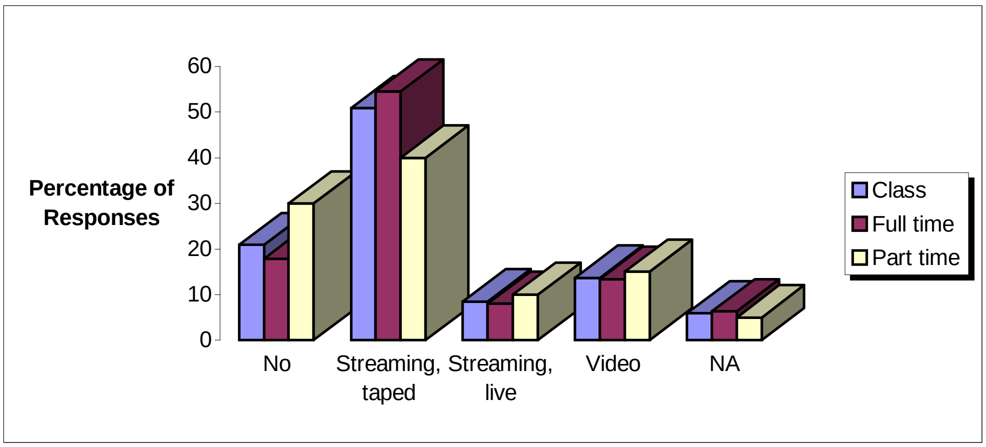

Figure 2 - Responses to the survey question: "Whenever you did NOT attend lecture, did you watch the taped lecture or the streaming video on the web?" Students who attended all lectures chose the "Not Applicable" category.

Several asynchronous mechanisms were used for communication between the instructor and the teaching assistants and the students. These included:

- Course web site - contained all lecture slides, homework assignments and solutions, project assignments, previous and current exams and solutions, and links to other resources;
- Online gradebook - contained individual grades for homework assignments, projects and exams;
- Listserv - was extensively used for general announcements, answering questions about lecture content and homework problems;
- Email - there was no limitation on the number or frequency of email messages the students were allowed to send to the instructor. This was the preferred method for addressing specific technical questions, administrative procedures, discussion of individual grades, etc.

It was clear from the results of the survey as well as from informal feedback that students valued each of these aspects of the course. Their view of the effectiveness of each of these mechanisms is shown in Figure 3.

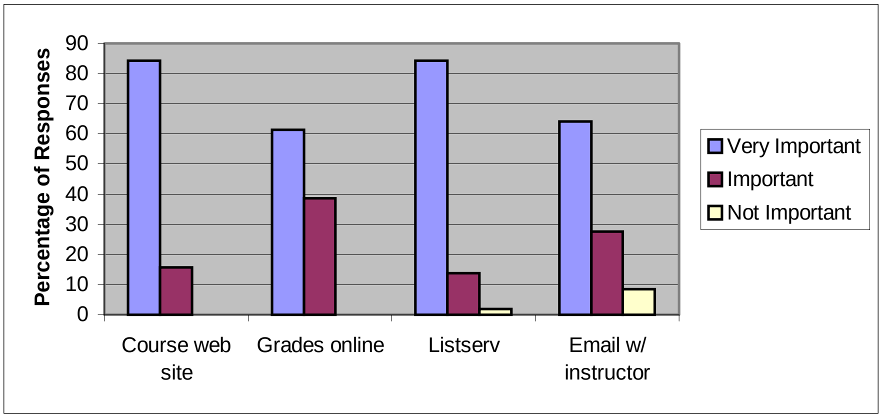

Figure 3 - Students' responses to asynchronous technologies used in the course.

V. Lessons learned: group collaboration

Students were required to participate in a semester-long group project, accounting for approximately one-third of the final grade. The project consisted of creating a web-based resource in one of eighteen topics in computer networking; these resources included a tutorial, annotated list of research links, and in-depth reports on various subtopics. Students were encouraged to express their preferences of topics, and the instructor assigned groups of seven to ten students, based on these preferences. A common characteristic of all eighteen groups was that each included students in multiple locations. Some of the learning objectives were:

- To gain expertise in topics of current relevance in computer networks (web caching, voice over IP, ad-hoc networking, security, etc.);
- To develop a web-based resource that would be useful to researchers and professionals interested in these topics;
- To foster interaction between full-time and part-time students;
- To hone skills in distributed collaboration and group work.

There was a clear difference in attitude towards group projects between students on the main campus and remote students. As shown in Figure 4, on-campus students strongly preferred group work versus individual projects, while off-campus students were almost evenly divided on the question. Two main factors can explain off-campus students' reluctance towards group projects: very constrained work schedules make it more difficult for part-time students to deal with the overhead involved in group work (scheduled meetings, coordination, division of tasks, etc.); and since off-campus students were the minority in all groups, some felt they had little control on decisions.

There was consensus on the idea that students would be likely to encounter this type of distributed group collaboration in their future professional lives. When asked whether they expected to face this type of work in the future, 88.4% of students responded that would be very likely or somewhat likely, 11% responded that would be somewhat unlikely, and a single student believed it was very unlikely.

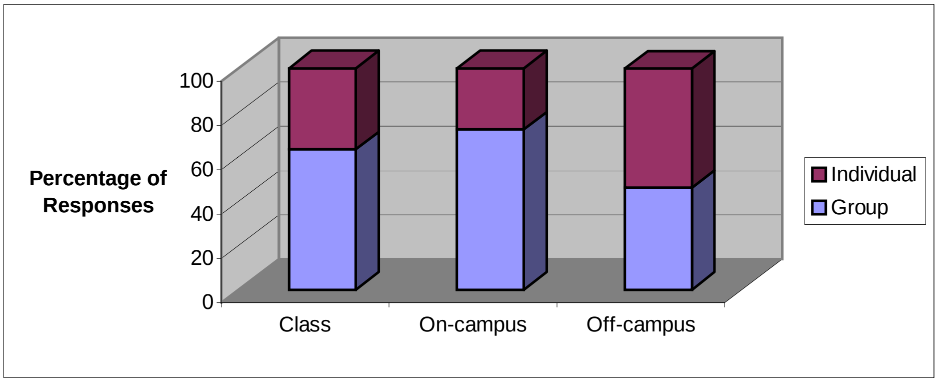

Figure 4 - Students' preferences for group versus individual project work.

There is no question that this type of group work imposes new challenges to students. These were large groups that ultimately had to produce a seamless web-based resource; there was the need for careful planning and integration of content produced by multiple students. Nevertheless, the majority of students felt they were able to work well in a group (Figure 5a).

Each student was asked what was the biggest obstacle they faced in completing the project. The distributed nature of the work was the most common response, closely followed by lack of communications among group members. A small percentage of the class referred to inappropriateness of the tools for distributed collaboration as the biggest obstacle (most of the tools used were well received; however, it was clear from student feedback that the chat tool adopted, did not live up to expectations). The breakdown of responses is shown in Figure 5b.

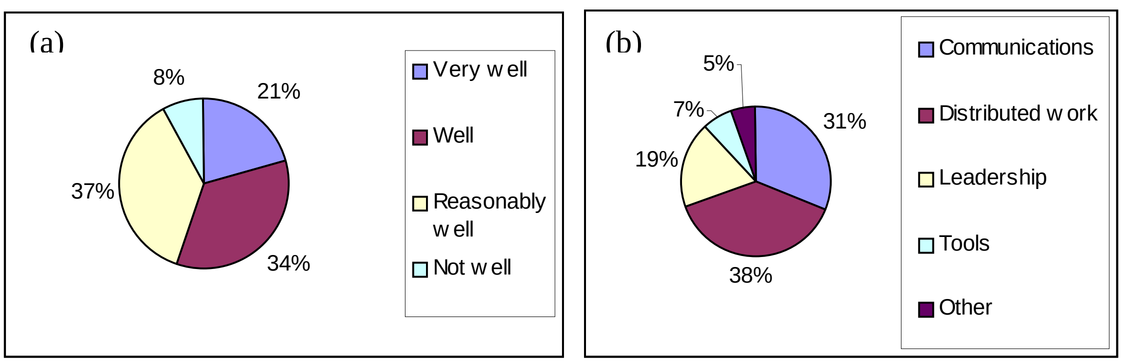

Figure 5 - (a) Students' impressions of how well they worked in a group; (b) biggest obstacle for their group work.

We encouraged students to comment on any difficulties they may have encountered in the project. We found that these free-form comments were split more or less evenly between difficulties due to the distributed nature of the project and difficulties that are likely to arise in any group endeavor, even in a more traditional classroom setting. Examples of the former included difficulties created by psychological distance among group members, which made it harder in some instances for leadership and a strong sense of motivation to emerge; examples of the latter include challenges in coordinating schedules for a large number of group members and difficulty in gaining familiarity with the subject.

As for what worked in communications among group members, the lesson was to "keep it simple." Plain old electronic mail appears to have been the most useful tool for communications, followed by in-person meetings at each site (see Figure 6). We believe a more robust chat tool would have helped, although with large groups and heterogeneous student profiles scheduling for any real-time activity becomes a major obstacle.

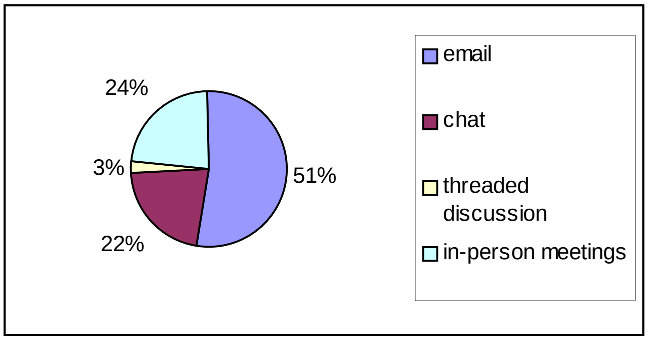

Figure 6 - Responses to the question: " Which of the following was the most useful for group communications?"

Although the groups were assigned by the instructor, there was no instructor interference in how each group managed its work. In particular, no group leader was explicitly appointed. According to students, in most cases (56%) group members shared duties evenly, while in 29% of cases a clear group leader emerged and in 15% of cases there was one group leader in each location.

When asked whether they felt they played an integral part in all group decisions, 82% of the students responded that they did. However, these responses did show correlation to geographical location: only 11% of students on the main campus felt left out of the decision making process, compared to 35% of students in other locations. These results are consistent with informal interaction with the groups throughout the semester: since most off-campus students were in the minority in their groups, they sometimes felt they had little influence on group decisions. In the few instances when the instructor was asked to intercede, it was to resolve disputes between on-campus and off-campus students in the same group. In many of these cases, a few comments from the instructor via email or in class was enough to attenuate the polarization between sites; however, we suspect that in some groups the "us versus them" mentality persisted. Clearly, this kind polarization is undesirable; it is, however, not unusual in professional group endeavors (for instance, between headquarters and remote sites of a company, among partnering companies, among different departments in the same company, etc.).

We recognize that the distributed collaboration in this classroom set-up does not mirror exactly the types of distributed work that often take place in the industry. In industry, it is likely that the group members (or, at the very least, leaders from each location) would occasionally meet and interact in person. In order to at least partially make up for this, we instituted the "name with a face" experiment, initially suggested by one of the students. We reserved the first half hour of one of the lectures for introductions from each of the students; it was the first time that some of the students saw some of their group mates, some of whom lived and worked two hundred and fifty miles apart. The experiment was well received by the majority, and it was well worth the time. In the future, as web-based video conferencing becomes more widely available, it will fulfill the role of allowing group members to be able to associate faces to the names of their colleagues.

The survey results indicate an overwhelmingly positive overall experience with the group project, as indicated in Figure 7. This is a very encouraging result, given the additional obstacles that had to be overcome by students likely translated into additional hours put into the project.

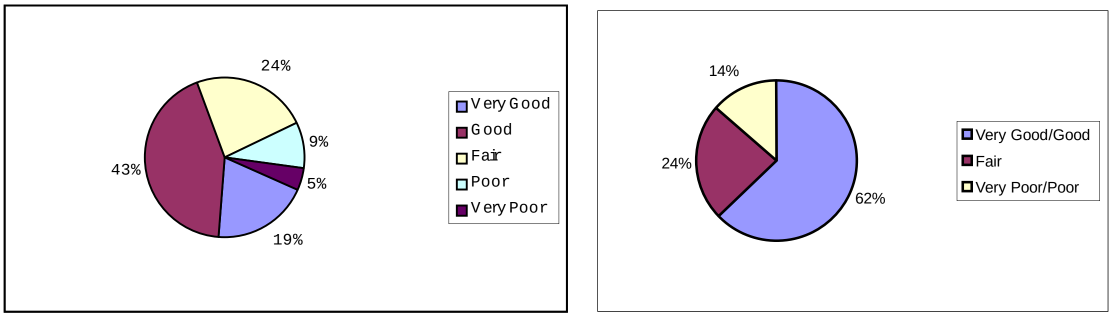

Figure 7 - Student perceptions of how well they were able to work in groups.

For the evaluation of the projects, students were required to submit material in two phases. Phase 1, due a little over halfway into the semester, consisted of a checkpoint where a skeleton of the project and some limited initial content was to be present. Phase 2, due on the last day of classes, consisted of the full final project. The instructor provided comments to each of the eighteen groups in between the two phases, with directions that each group should incorporate those comments into their final projects. At Phase 1, several of the projects looked like a patchwork of largely disjoint contributions that were gathered under the same web page; students were informed that they were to integrate individual contributions in a seamless fashion. The results at Phase 2 were quite impressive: several of the web sites looked professionally developed, material was well integrated and exhibited both breath and depth of knowledge. These projects can be reached by linking from [6].

VI. Final Remarks

In our experience, students embraced the wide range of technologies made available with very little need for guidance as to how to employ the technology. It must be said that this was a very computer-literate group of students, mostly composed of graduate students in Computer Engineering, Electrical Engineering and Computer Science. As such, they are likely to be more receptive of new technologies than some students in other disciplines.

The reactions and opinions expressed in the survey were all quite positive. Clearly, both on-campus and off-campus students had to make a special effort to adapt to the distance learning model. On-campus students had to sit through longer, once-a-week lectures and had less access to the instructor during in-person office hours; off-campus students had to coordinate schedules with those on-campus for synchronous group activities. That both groups emerged with an overall positive view of the process can be seen as a major accomplishment.

Final grades for the course were comparable across geographies. While there was greater occurrence of lower grades in the off-campus sites, as shown in Figure 8, we do not believe this to be a result of the distance learning format: since most lectures originated in Northern Virginia, on-campus students can be considered "remote" in this case. The occurrence of some lower grades off-campus may be explained by two factors: most off-campus students work full time, and therefore have strong competing demands on their time; and there seems to be a different attitude towards grades among off-campus students, who tend to place more importance on the usefulness of the subject being studied than on the final grades.

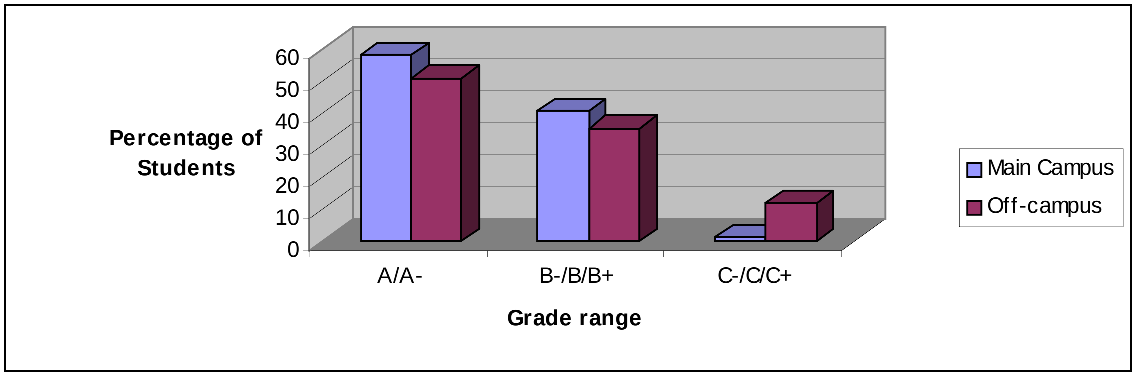

Figure 8 - Final grade distributions per geography.

We believe that the variety of opportunities for interaction among students and with the instructor helped mitigate the feelings of emotional distance that are sometimes associated with distance education. The instructor, while primarily located in Northern Virginia, lectured from and held office hours at the main campus about 25% of the time. Questions and answers during lecture were actively encouraged and, with time, students seemed to become more confident with the technology and with the prospect of asking a question "on TV." And finally, the distributed group work requirement forced all to expand their horizons beyond their locality. This is not to say that all obstacles have been conquered, but the increase of interactions is a move in the positive direction for both learning outcomes and student perception of the value of the course.

As technology progresses, we will be able to more efficiently incorporate increased collaboration among remote students and between those and students on-campus. Both groups have much to gain from this interaction, resulting in a much richer education experience.

VII. Acknowledgements

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