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Distance Education: Realizing its Potential*

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Recent advances in computing and communication technology have made distance education a reasonable alternative to traditional on-campus instruction. However, many faculty believe that a University should not be involved in providing this alternative. They assert that (1) the off-grounds students are not as good as those in the on-grounds program, and (2) TV cannot be as good as live instruction. In this paper, we describe the distance education program available from the School of Engineering and Applied Science at the University of Virginia (UVa). Focusing on a particular course, we trace changes in the environment for distance learning over a decade, and show how most of the early problems with this environment have been resolved. Then, we discuss the above two claims based on our experiences with televised instruction. Finally, we speculate on the necessary conditions for a successful distance education program.

TELEVISED INSTRUCTION AT UVa

TELEVISED courses began at UVa in the fall of 1983 with offerings in Materials Science and Civil Engineering. Initially, there was only one receiving site at Virginia Commonwealth University in Richmond. Our early experience with this medium, and that of many other pioneering schools, is represented in the compendium assembled by Greenberg and Biedenbach [1]. We now offer Master of Engineering degrees in seven fields (Chemical, Civil, Electrical, Mechanical, Nuclear, and Systems Engineering and Materials Science), and a Certificate Program in Manufacturing Systems Engineering (MSE) through our televised program. Eight courses each semester originate from the University of Virginia. Students in our programs may also take courses from Virginia Tech., Virginia Commonwealth University, Old Dominion University, George Mason University, and others, although the bulk of the courses originate at UVa and Virginia Tech. These courses are broadcast in the late afternoon and early evening to maximize participation by students from industry. Currently we have two broadcast studios in UVa's School of Engineering and Applied Science and a number of classrooms which receive televised courses from other schools. We also have a small room for teleconferences with two-way visual and audio.

These courses are transmitted to sites around Virginia, but may be received throughout North America. We have had students in Pennsylvania, Michigan, New York, New Jersey, Illinois, Texas, Iowa, Minnesota, Tennessee and California. Most courses have their major enrollments at UVa remote sites within Virginia (Richmond, Tidewater, Roanoke, Lynchburg, and Northern Virginia) and various industry sites. Nearly half of the 50 receiving sites are located at industries. Students receive the course as a normal satellite TV broadcast, but they can interact with the instructor via a two-way audio link. An on-grounds class is always present in the studio as the lectures are being broadcast and recorded. All classes are videotaped, and those tapes are available to the students.

Tables 1–4 provide a statistical overview of the UVa portion of the Virginia Commonwealth Graduate Engineering Program. Table 1 shows total course enrollments for each of the eight time slots for the 10 semesters from Fall 1991 to Spring 1996. The large enrollments for the 6:30–7:45 p.m. time slot reflect both the convenience of this period for students from industry and the popularity of the two programs occupying these slots. The 5:00–6:15 p.m. period is the second most popular.

Table 2 shows how the percentage of off-grounds students varies by discipline and time. Courses offered by Civil, Mechanical and Aerospace (MAE), and Materials Science (at the Master's level) draw mostly off-grounds students. Table 3 shows how enrollments vary by discipline over the 10-semester period. A careful examination of this table reveals no consistent trends in the data. There are jumps and drops in course enrollments in most disciplines but no overall tendency for enrollments to systematically increase or decrease.

While MAE/MSE enrollments are generally high, they do drop off for three semesters (Fall 1993 through Fall 1994). The MAE/MSE row of Table 3 includes both manufacturing courses and

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Table 1. Course enrollment as a function of discipline and time slot (entries are totals for 10 semesters)

Time	M, W	T, Th	Totals
3:30–4:45 p.m.	Nuclear 250	Systems 460	710
5:00–6:15 p.m.	Electrical 390	Materials Science 600 471	861
6:30–7:45 p.m.	MSE/MAE 621	Chemical 585	1206
8:00–9:15 p.m.	Civil 356	Materials Science 700 274	630
Totals	1617	1790	3407

more traditional mechanical engineering courses. The six semesters with the large total enrollments are all core courses for the Manufacturing Program. Comparing the first four semesters (Fall 1991 to Spring 1993) with the last two (Fall 1995 and Spring 1996) reveals an important trend. Our on-grounds enrollment in the manufacturing courses has declined, but the off-grounds enrollments remain high. On-grounds enrollments depend on department admissions decisions, which limit students in the various areas.

Table 4 shows the number of instructors involved in the TV program from each department and how many of them have taught on TV three or more times. At UVa, the TV teaching load is carried by only a few instructors. Of the 74 faculty who have taught on TV, 27 have done so only once, 16 twice, and 31 three or more times. Most engineering faculty have never taught on TV; overall only 42% of the faculty have. In some departments only a few faculty participate, while in others almost all the faculty have taught on TV.

Table 5 summarizes the enrollment data for one particular course, MAE 665. In this course, we are reaching more sites in Virginia and increasing our enrollments at some sites. The trends evident in Table 5 hold for all of the courses in the Manufacturing Systems Engineering Program.

Computer Aided-Engineering and Design

One particular course, Computer-Aided Engineering and Design (MAE 665) has attracted over 70 students each time it has been offered on television. It is one of four core courses in our Masters Program on Manufacturing Systems Engineering and is offered every year on-grounds and every four years on television.

Table 2. Percentage of off-grounds students as a function of time slot and discipline (data from 10 semesters)

Time	M, W	T, Th
3:30–4:45 p.m.	Nuclear 0.61	Systems 0.49
5:00–6:15 p.m.	Electrical 0.50	Materials Science 600 0.72
6:30–7:45 p.m.	MSE/MAE 0.79	Chemical 0.52
8:00–9:15 p.m.	Civil 0.85	Materials Science 700 0.59

This course introduces geometric modeling schemes, computer graphics, 3D modeling and visualization, finite-element analysis, mechanical dynamics, group technology, quality tools, design for production, and expert systems for design. The students must learn a 3D computer-aided design program, and then use it to complete four sets of assigned problems. Initially, they model a specified set of objects. Later, they must generate their own symbol libraries, assembly models and unique designs.

The field of CAD has been in constant transformation for over 30 years. Many of the dreams of 1985 were reality by 1990. The content of the course has continuously changed, and the computing environment has been radically altered over the past decade.

EVOLVING COMPUTER ACCESS

In 1987, we used the Medusa CAD program, and PATRAN and ANSYS for finite-element analysis. All ran on Prime minicomputers, and computer access for off-grounds students was difficult. We invited students from remote locations to visit UVa on weekends, and managed to arrange computer access through several industrial sites and at a high school in Tidewater Virginia (New Horizons School in Hampton, Virginia). To demonstrate the software during class, we had to record a terminal session in the CAE laboratory and play it back in the studio.

By 1991, personal computers were widespread and most of our receiving sites had computer labs. We distributed the CADKEY program to each of the sites. Many of the students now had access to other CAD systems (Intergraph, ANVIL, Unigraphics). However, industry level 3D modeling was still not widely available for PC's, especially at prices our students could afford.

In 1995, powerful personal computers were widely available and relatively inexpensive. Most of our receiving sites were connected to UVa on the Internet, and we had a license for the SilverScreen geometric modeling program. Most of our students had E-mail access either from home or work, and most of the communication problems from the earlier years vanished. Since we have a computer in the classroom connected to the University's network and thus to the Internet, we can easily demonstrate the use of CAE software live during class.

In all three offerings of this course on TV, we have permitted students to use any CAE programs available to them for homework and projects. Thus, this year, we had students using Intergraph, IDEAS, Pro Engineer, and AutoCad 13, as well as SilverScreen.

Table 3. Enrollments in UVa televised courses by discipline over 10 semesters

	Fall 1991	Spring 1992	Fall 1992	Spring 1993	Fall 1993	Spring 1994	Fall 1994	Spring 1995	Fall 1995	Spring 1996	Totals
MAE/MSE											
On-grounds	12	16	17	18	12	20	7	12	5	6	125
Off-grounds	62	55	65	65	24	27	18	49	69	62	496
Civil											
On-grounds	5	7	8	4	2	3	9	6	2	7	53
Off-grounds	33	20	28	19	28	37	48	29	35	28	305
Chemical											
On-grounds	14	24	20	10	2	23	21	50	74	20	281
Off-grounds	38	31	32	25	29	23	32	32	38	24	304
Electrical											
On-grounds	17	25	38	30	21	11	13	15	18	7	195
Off-grounds	18	14	30	15	31	21	22	21	17	6	195
Systems											
On-grounds	40	22	33	30	23	17	24	12	15	17	233
Off-grounds	32	21	27	20	6	17	38	13	27	26	227
Nuclear											
On-grounds	8	11	5	7	8	23	11	12	7	6	98
Off-grounds	19	18	17	25	20	17	11	7	8	10	152
Materials Science 600											
On-grounds	18	16	19	13	20	9	16	6	8	8	133
Off-grounds	18	30	63	44	30	39	27	20	38	29	338
Materials Science 700											
On-grounds	13	13	15	14	15	4	15	15	4	4	112
Off-grounds	17	20	10	15	33	24	8	11	14	10	162

LOGISTICS: COMMUNICATING WITH STUDENTS

In dealing with students at many sites, coordination has been a problem. Materials must be prepared and distributed well in advance. Even when the lectures are broadcast in real-time, a great deal of advance preparation is necessary. The lectures must be planned and scripted; materials must be assembled; and software must be selected and distributed. At least a month of advance effort is required to get ready for a TV course and each lecture requires much more preparation than in a typical on-grounds class.

Table 4. Number of faculty involved in teaching on TV by department

	Total faculty in department*	Total number of instructors teaching on TV	Taught on TV 3 or more times
Civil	15	7	4
Chemical	10	12	2
Electrical	21	12	5
MAE	28	10	3
Materials Science	17	14	9
Nuclear	6	6	4
Systems	12	13	4
Totals	109	74	31

* These numbers are approximate; they change every year. Some faculty have retired or left UVa; others are listed in multiple departments. Not all departments teach on TV.

Since all lectures are videotaped, attendance at a particular place and time no longer matters. The learning environment has become asynchronous. This provides several options for offering the course. It can be made available on demand and under unusual circumstances. For example a small group of students could take the course using the videotapes and view them anytime: during the summer, an off semester; or during a condensed time period (for example, they could complete an entire semester in 2 weeks of full time effort). Four years ago, one of my students was assigned to a Navy ship. She took copies of all the videotapes, and a personal computer and the necessary software to sea with her. This year, several students were transferred to new job locations in the middle of the semester. Using videotape, they were able to complete the course. The use of videotapes also allows professors to cover their own class when they are not available in person.

Telephone office hours are established for each televised course. Faculty are expected to be available several hours each week for calls from students. The goal was to facilitate personal interaction between students and faculty. It worked. During the first two offerings of my course on TV, I was inundated with calls. They came all hours of the day—from before 8 a.m. until 9 or 10 p.m. The students were not constrained by the official office hours. Indeed the posted office hours were the least

Table 5. Enrollment information for MAE 665 by year

	1987	1991	1995
Number of students			
On-grounds	27	12	5
Off-grounds	54	62	69
Number of sites			
In Virginia*	9	13	12
Out of State	0	2	3
Enrollment at largest sites			
UVa	27	11	5
Telestar	11	17	21
Lynchburg	15	11	22
PGEC	15	9	3
VCU	8	7	5

* Includes UVa.

likely time for students to call. Some students even called me at home—especially on weekends. The peak period for calls was just before class. Of course, this makes sense when you trace student work patterns. Students need help when they are actually working on the course. They do assignments just before they are due, they work in the evenings and on weekends. This last year, everything had changed! The Internet has transformed how we interact with students. E-mail is as reliable as the phone service, and it is available from anywhere; thus, I can respond to it while away from the office and my students can contact me even when they are traveling. I no longer receive complaints about my 'inaccessibility'. Students who send e-mail get a reply as quickly as possible.

As I review the experiences of the last 9 years, I am amazed at how computing and communication technology has improved. In addition, we have learned to use it more effectively. The Internet is now an integral component of distance education. The class Home Page permits the immediate distribution of assignments and materials, newsgroups facilitate broadcasting answers to frequently asked questions, and e-mail allows a level of personal interaction between faculty and students. The rapid development of computer and communications technology has allowed a level of interaction and timeliness unavailable a decade ago.

TWO FUNDAMENTAL ISSUES

Many faculty condemn televised teaching without having experienced it directly. They claim that it can't possibly provide the same 'atmosphere' and level of personal contact provided at the university. Some faculty fear that we are somehow weakening our program by letting students take courses on TV. I don't agree with either claim.

Are the TV students as good as those on-grounds?

In our graduate program, the audience is different for the TV classes than for the same classes on-grounds. The TV students are engineers working full time in industry. They want courses which relate to their jobs and career goals. They are less concerned with theory and more with application. They want to see the relevance of what they are learning to real-world problems. The audience is certainly more diverse—in interests and abilities. They are, however, more motivated than many on-grounds students.

The sample of students in our on-grounds program represent a restricted range of abilities. All had excellent undergraduate records and most proceeded directly from one university to another. They are selected for their promise as research scientists. Students from industry are different.

Table 6. Grade distributions by discipline for on vs off-grounds students

	MAE	CIVIL	ChE	EE	Systems	Nuclear	MS600*	MS700*	Overall averages
A+ On-grounds	0.06	0.04	0.04	0.07	0.06	0.03	0.05	0.04	0.05
A+ Off-grounds	0.07	0.03	0.03	0.08	0.03	0.02	0.07	0.04	0.05
A On-grounds	0.42	0.42	0.33	0.27	0.27	0.22	0.24	0.28	0.31
A Off-grounds	0.41	0.24	0.35	0.21	0.19	0.28	0.15	0.10	0.24
A– On-grounds	0.19	0.28	0.22	0.25	0.30	0.18	0.24	0.26	0.24
A– Off-grounds	0.10	0.25	0.20	0.11	0.22	0.18	0.15	0.12	0.17
B+ On-grounds	0.09	0.11	0.17	0.14	0.18	0.21	0.26	0.23	0.17
B+ Off-grounds	0.09	0.14	0.11	0.18	0.20	0.18	0.21	0.20	0.16
B On-grounds	0.17	0.13	0.16	0.10	0.11	0.16	0.17	0.14	0.14
B Off-grounds	0.19	0.17	0.16	0.17	0.17	0.19	0.23	0.25	0.19
B– On-grounds	0.01	0.02	0.06	0.06	0.06	0.05	0.01	0.03	0.04
B– Off-grounds	0.04	0.05	0.07	0.09	0.06	0.03	0.08	0.15	0.05
C On-grounds	0.02	0.00	0.02	0.09	0.03	0.12	0.03	0.03	0.04
C Off-grounds	0.02	0.03	0.05	0.08	0.04	0.04	0.08	0.13	0.06
F On-grounds	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
F Off-grounds	0.00	0.01	0.00	0.03	0.00	0.01	0.01	0.00	0.01
IN On-grounds	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN Off-grounds	0.08	0.08	0.03	0.04	0.08	0.06	0.02	0.01	0.05
Average discrepancies	0.02	0.05	0.02	0.05	0.04	0.03	0.05	0.08	0.03

* Materials Science has two time slots, and regularly offers courses at both the Master's (600) and Doctoral (700) levels.

They are self-selected based on their interest or need for knowledge or skills. Even those with relatively poor undergraduate records often perform very well in our graduate classes. A few years in industry often changes one's perspective on learning and can lead to maturity and focus.

Table 6 compares the distribution of grades for on-grounds versus off-grounds students by discipline for the five-year period since Fall 1991. Each column contains two frequency distributions—one for on-grounds students and the other for off-grounds. If the distributions of grades were identical, the numbers in each cell would match. These percentages are averages over all the courses for each area. They ignore differences due to instructors and particular courses. However, since we are addressing a general issue, pooling the data seems the most reasonable strategy.

If we examine the *overall averages*, we see somewhat more A's and A–'s for the on-grounds students and slightly more B's for those off-grounds. For most of the columns in Table 6, the two groups are generally comparable: grades for off-grounds and on-grounds students are fairly close. The off-grounds population often has both the top and bottom students in a class—the best performers and the worst. However, the numbers of top students (A+'s) and worst students (C and below) don't differ much. The MS700 column is the exception: these courses have far more A's for on-grounds students and more B's and C's for those off-grounds. In all disciplines, there are more 'incompletes' for the off-grounds students. These findings support and provide more detail to previous evaluations of the Virginia Commonwealth Graduate Engineering Program [5, 6].

The bottom row of Table 6 shows the average discrepancies between the two groups of students for each discipline. The courses in Mechanical and Chemical Engineering have the least difference, while Materials Science, Civil, and Electrical Engineering show the most. Because there were differences in Materials Science due to course level (MS600 vs MS700), we decided to see how many 700-level courses were offered in each discipline. The results are shown in Table 7. Mechanical, Chemical, Systems and Nuclear offer predominantly Master's level courses, while Civil, Electrical, and of course Materials Science offer more advanced (Doctoral level) courses.

In 1987, I wrote: 'The TV classes have a much wider range of student abilities and expectations than our other classes. For example, some students were already expert CAD users, other were barely computer literate. Some wanted a survey course, others a management overview, and others a how-to-do-it introduction to CAD programs. We do not often realize how homogeneous our usual sample of students is.'

In 1995, the range of abilities seems to have narrowed: most students at remote sites were every bit as bright as our on-grounds students, and many were more motivated and goal directed. Of course, we could structure our classes so that on-grounds students have an advantage or vice versa. But with planning and foresight, we can insure that the overall performance does not differ between the two audiences [2, 3].

In the Manufacturing Systems Engineering Program, we have designed our assessment procedures to insure equivalence of on- and off-grounds students. We give lots of graded homework, assign projects and give take-home exams. We strive to get as much work from our students as possible, and we use it all to determine grades. The more measures of performance we have available, the better our grading system will be. On all my exams, the students are asked to rate the exam on length, difficulty, fairness, representativeness, and value; and to respond to a series of questions about the course, materials, and instruction. This feedback allows us to detect and address problems and concerns from both on- and off-grounds students.

Is televised instruction as good as the alternatives? That depends on what the alternatives are and who the audience is. Is this the best way to teach? No! But it may be the best we can achieve given current social realities. A good solution would be to have enough faculty to allow all classes to be limited to 15–20 students. Faculty could travel to remote sites and offer instruction in person whenever there is sufficient demand. The optimum teaching situation is one-on-one tutorial instruction. Neither of these ideal situations is likely to occur again.

Is televised instruction any less personal than a

Table 7. Frequency of course offerings by department and level

	Frequency of Master's Level courses	Frequency of Doctoral Level courses	Total number of TV offerings	Number of distinct courses	Number of courses with multiple offerings
Civil	23	9	32	19	8
Chemical	25	1	26	11	8
Electrical	17	9	26	15	7
MAE	25	1	26	12	8
Materials Science	35	16	51	13	12
Nuclear	16	2	18	8	6
Systems	26	0	26	12	6
Total	167	38	205	90	55

single instructor addressing an auditorium filled with over 500 students? Or even a class of 50? Once a class exceeds a certain size (about 30 students), the perspective of the instructor changes. The class is seen as a group, not as a collection of individuals. At that point, teaching becomes performance. The performance serves to motivate and guide the students, to provide a context for learning, and to highlight the important ideas. A professor who can do those things well in a large class is likely to do them well in a TV studio.

In some ways, televised instruction can be better than our usual modes of teaching. We can do things on TV that are difficult to accomplish otherwise, such as video plant tours, special lab demonstrations, computer visualizations and simulation [7]. With videotapes, the students can review classes, repeat segments and pace the presentation of material. We find that even our on-grounds students make extensive use of the videos. The medium has rich capabilities which we can exploit to improve teaching and learning. On TV, the instructor is usually better prepared; this results in a clearer, better organized class, and usually more material is covered. In addition, viewing one's own videotapes often leads to improved performance as a teacher [4].

Several authors [8, 9] have demonstrated the potential of multimedia and the World Wide Web for engineering education. Is there a role for lectures in the asynchronous, Web-based learning environment we see evolving? Should the 'virtual university' include lectures and formal classes? Lectures can be powerful instructional and motivational vehicles [10]. A good lecture organizes and presents knowledge from the perspective of an expert in the field. It guides the students in their studies and highlights important ideas. Ideally, our students should have access to the best instruction *and* the best of multimedia modules and Web-based materials.

The Virginia Commonwealth Graduate Engineering Program has expanded its range—from limited coverage in Virginia in 1983 to national availability in 1996. We are still primarily serving Virginia industry. Our national audience has developed through existing connections of students to UVa. However, we can now offer advanced educational opportunities to students anywhere in the country.

CONCLUDING REMARKS

The two issues raised above are really indications of a much deeper concern. Distance education is alien to most university faculty because it violates their view of a university. They see education as *exclusive* rather than inclusive. Admissions policies are designed to exclude those students who don't show sufficient commitment to scholarly ideals. Distance education seeks to be *inclusive*—to provide access to instruction to a wide audience [11].

Most engineers working in industry are not committed to the academic ethic; they want knowledge and skills which can be applied to real-world problems (their problems). They may wish to take a course or two to upgrade their professional competence, or they may chose to enter a degree program. Our admissions procedures will need to become more flexible and open in this new environment. Rather than selecting students *a priori* based on their *promise*, we might admit them after they have successfully completed half a dozen courses. Admission would be automatic based on satisfactory *performance*.

We are entering a new era of competition among universities—perhaps even an international competition. There is a very large potential audience for distance education, and industry is willing to pay the bills. But now it is more essential than ever to view the student as a customer. These students are not a captive audience; they can choose from a large number of potential suppliers. To compete, we must give industry and its employees what it wants and needs, and provide better programs than anyone else. For universities, this means instituting better quality control for its products and committing the resources needed to produce exceptional televised courses. The university is represented (and will be evaluated) by what it puts on the air; it must provide the best professors and the highest level of technical quality for its courses. This will require careful screening of who delivers televised instruction and the allocation of sufficient technical staff to ensure excellent programs.

To realize the potential of distance education, we need committed and proficient teachers, exceptional technical and administrative support, and innovative admissions and marketing strategies. As we recognize the importance of lifelong learning and seek to accommodate rapid advances in knowledge and technology, distance education is an essential component of the 21st Century University.

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REFERENCES

1. J. S. Greenberg and J. M. Biedenbach, *Compendium on Uses of Television in Engineering Education*, American Society of Engineering Education, 1987 CPD Division TV Compendium.

2. James L. Davis, Computer-assisted distance learning, Part II: examination performance of students on and off campus, *Journal of Engineering Education*, Vol. 85/1, Jan. 1996, pp. 77–82.
3. B. Daily and M. Daily, Effectiveness of a multimedia televised distance education program for engineering majors, *Journal of Engineering Education*, Vol. 83/4, Oct. 1994, pp. 383–387.
4. L. G. Richards, Lights, Camera, TEACH! *ASEE Prism*, Vol. 6/6, Feb. 1997, pp. 24–27.
5. Mary W. Stout, The hidden curriculum of the video teleconference (VTC) classroom and its implications for the university of the 21st Century, Ph.D dissertation presented to the faculty of the School of Education of the College of William and Mary in Virginia, Spring, 1995 (UMI Number: 9530360).
6. State Council of Higher Education for Virginia, *Evaluation of the Virginia Cooperative Graduate Engineering Program*, Richmond, VA: State Council of Higher Education for Virginia, 1989.
7. R. J. Ribando, D. M. Snyder, and G. L. Cahen, Jr., Effective transfer of computer graphics to video format, *Journal of Engineering Education*, Vol. 84/3, July, 1995, pp. 299–302.
8. B. Oakley, *Using the Internet in Undergraduate Instruction*, satellite broadcast, June 4, 1996, National Technological University, Fort Collins, Colorado.
9. J. R. Bourne, A. J. Brodersen, J. O. Campbell, J. M. Dawant, and R. G. Shiavi, A model for on-line learning networks in engineering education, *Journal of Engineering Education*, Vol. 85/3, July, 1996, pp. 253–262.
10. M. U. Hosain, Personal view: three E's of teaching: Enduring, Effective and Entertaining, *International Journal of Engineering Education*, Vol. II, No. 2, pp. 83–86, 1995.
11. W. R. Spence, *Innovation: The Communication of Change in Ideas, Practices and Products*, London: Chapman and Hall, 1994.

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