AC 2007-49: DISTANCE LEARNING IN THE GRADUATE-LEVEL OCEAN ENGINEERING CURRICULUM

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Distance learning in the graduate-level ocean engineering curriculum

Abstract

Virginia Tech is an established leader in distance learning with 85% of departments offering some form of electronic courses[1]. The graduate level Ocean Engineering curriculum is fully available to off-campus students, thus allowing professionals anywhere in the world to earn an MS degree. The MS in Ocean Engineering was the first program in engineering at VT to be entirely available online. In this paper the authors present their implementation strategies, successes, and weaknesses in delivering the graduate-level curriculum online, with specific discussion of the pros and cons of synchronous and asynchronous lecture formats. The authors also describe different formulations of a single, on-campus, capstone experience required of all distance-learning students with emphasis upon strategies that lead to greatest student success. Quantitative student perceptions of eLearning in the OE curriculum are presented.

1.0 History of the Online Ocean Engineering Program at Virginia Tech

The roots of this distance-learning program go back to a request from officials at Newport News Shipbuilding (now Northrup-Grumman Newport News) for Ocean Engineering courses through the Virginia Consortium of Engineering and Science (VCES) program at Hampton, VA, in late summer of 1997. The first class was offered in the Spring of 1998.

The Ocean Engineering program at Virginia Tech deals largely with the design of ships. There are only five civilian schools in the country that offer ship design programs. Potential students for a ship design graduate program work at locations spread along the country's coastlines but without a critical mass in any one location to support a local program. Because of this, the potential for a successful distance-learning program in this field existed. In the Fall of 1998, a second site was established at the Naval Surface Warfare Center (NSWC), Carderock Division. At this point, two classes were being offered one night per week using video teleconferencing among three sites; VCES, Carderock, and the Virginia Tech main campus in Blacksburg, VA.

At that time, very few engineering classes – from anywhere – were being offered in a distance-learning mode. The problem was that the resolution of the video teleconferencing medium was too poor to deliver the equation-intensive material in these courses. The instructors would have to write equations in large characters in order to be legible over the TV and were often frustrated by the small amount they could fit on one screen. Students had no way of pointing to or interacting with the mathematical material the professor was presenting. Demonstration of software via video was also very difficult due to the low resolution. With the advent of enabling software, delivery of this type of material via the internet became possible. At first, computers and computer projection equipment at the remote sites were used as a sort of electronic blackboard. Later, delivery was directly to individual desktops.

In the Fall of 1999, a third site was established at Ingalls Shipbuilding in Pascagoula, MS (now, Northrop Grumman Ship Systems' Ingalls Operations). At this point, the success of the program had led to a taxing administrative load. The University did not yet have support services in place for distance-learning students and all of the admission, registration and billing problems for 30-40 students per semester fell to the faculty member supervising the program who served not only as faculty advisor but also as the local agent for the graduate school, the registrar's office and the bursar's office. In 1999, the University established an Institute for Distance and Distributed Learning (IDDL) which began establishing an administrative service network for distance-learning students. It was not until the Fall of 2001, when there was a working administrative system in place, that a fourth remote site was added at the NSWC-Philadelphia Division.

With the assistance of IDDL, the video connection was phased out entirely in the Spring 2003 semester for the Ocean Engineering (OE) program, with courses delivered exclusively over the internet. The delivery mode was designed to take advantage of the fact that a large proportion of any course is lecture based material presented in one direction from instructor to student. This material was split out and delivered through pre-recorded voice-over PowerPoint files that could be downloaded and played at the student's convenience. The interactive portion of the course is accomplished with live sessions on the internet that are digitally recorded for later viewing if necessary. Not only could students take classes from virtually anywhere (one student lived in Paris, France), their time commitment was considerably more flexible since they were no longer tied to a video teleconferencing site for one three hour session each week.

The last several years have seen an explosion of software products for internet course delivery as both the demand for these and the enabling bandwidth have been growing rapidly. The OE program, with the guidance of IDDL, continues to experiment with new technologies and software as they become available with the goal of providing the distance-learning student as high quality a course as possible.

2.0 Technology Summary

Although the OE program has used video classrooms in the past, online education is presently favored to live tv/video conferencing due to resolution issues and excessive physical facility requirements on students. The primary delivery software used are Blackboard[2] (course website hosting), Breeze (voice over presentation recording)[3], and Centra (voice over presentation recording and live-streaming)[4]. These tools were selected due to their suitability for the needs of the courses and University support. This is not to be construed as an endorsement of any single brand or package of software. Numerous other online lecture recording and distribution tools are available, including but not limited to Camtasia[5], Classroom Presenter[6,7], ConferenceXP[8], and DyKnow[9,10].

3.0 The Courses

The following courses have been offered online by the Virginia Tech Department of Aerospace and Ocean Engineering (AOE). Those courses typed in italicized text are required per the core curriculum.

AOE 4064: Fluid flows in nature
AOE 4204: Ocean acoustics

AOE 4214: Ocean wave mechanics
AOE 4404: Applied numerical methods (Math 4404)
AOE 5024: Vehicle structures
AOE 5074: Advanced ship structural analysis
AOE 5084: Submarine design
AOE 5104: Advanced aero and hydrodynamics
AOE 5144: Boundary layer theory and heat transfer
AOE 5204: Vehicle dynamics and control
AOE 5304: Advanced naval architecture
AOE 5305: Marine engineering
AOE 5314: Naval ship system design
AOE 5334: Advanced ship dynamics
AOE 5344: Nonlinear control mechanical systems
AOE 5374: Rationally-based design of ocean structures
AOE 5994: Naval Ship Design Project

This paper focuses upon the experiences and statistics for the courses taught regularly by the full time Ocean Engineering faculty, specifically AOE 5074, 5314, 5334, 5374, and 5994. This paper describes the unique teaching philosophies and applications of multiple individuals. Each of the authors conducts their online course in their own manner. Just as in a traditional classroom, there is no one right or wrong way to teach. The purpose of this work is to put forth a variety of successful online teaching strategies which educators can use as a reference in the development of their own online programs.

3.1 AOE 5074 and 5374– Advanced Ship Structural Analysis and Rationally-Based Design of Ocean Structures

3.1.1 Course philosophy

These courses are entirely web-based -

- No need to come to a common location.
- Students can attend from any location where there is Internet access (home, work, on travel – even on board a Navy ship).
- No three-hour long session on one night.
- Three 30-minute classes, one of which is live (Wed.)
- The other two are Monday and Thursday, at a time of your choosing.
- All three are recorded; students can go back and replay them.
- This is especially valuable for making up missed classes.

3.1.2 Course presentation

One live class per week: On Wednesday evenings, 5:30 to 6:00, there is a "live" class. Each live class is recorded (audio & slides) using Centra software. Because of that, at any time in the future, students are able to log on to the Centra website and "play back" the class on their PC, or on any other PC providing that they first download the Centra software to that PC.

Two recorded-only classes per week: The other two classes are Powerpoint presentations with voice-over using Breeze software. These lectures are recorded and made available on the Blackboard AOE5074/5374 website by noon on Mondays and Thursdays. At any time thereafter students can download and play them. Students are able to pause, skip forward and back, etc. These classes are only 30 minutes instead of the 50 minutes used for the same on-campus classes. The content is exactly the same, but the presentation has been organized and "packaged" in a way that makes it more concise and allows it to be presented more briefly. In a normal classroom a large part of the time is taken up by the instructor writing on the board, and the students copying this material. In most cases the instructor writes the material precisely because it is important, and the twin actions of writing it and copying it emphasize this importance. Also the students are doing something physical, rather than being purely passive. But in a (well organized) Distance Learning class the students already have a hard copy of the material, and the more important material (should) always have a special prominence in the graphical presentation, using various graphical techniques. In a live class it is also possible to "add" a few extra words or simple sketches, so that the students can copy it and thereby be more active. But all the important words, figures and equations should already be in the student's hard copy material, and so the time devoted to copying is a tiny fraction of what it typically is in a classroom.

The course is hosted through a Blackboard website where students can

- Read announcements.
- Download course documents, such as Problem Sets and worked solutions to homework.
- Download copies of all of the Powerpoint pages from all classes – both "live" and "pre-recorded". These are available before class so that students can print them and have them during class.
- Upload their homework files. Students are required to do all homework calculations using MathCad.
- Take quizzes and exams.

3.1.3 Assessment of students

Homework	20%
3 50 min. quizzes @ 10%	30
1 2 hour midterm exam	20
1 2 hour final exam	30

Homework is assigned in every class. It is due by 10 am 3-5 days later according to the following schedule:

Class day	*Homework due*
Mon	Thurs
Wed	Mon
Thurs	Mon

Table 1: Assignment schedule for AOE 5074/5374.

This gives students at least 3 evenings to complete each assignment. For the homework students must use Mathcad, and send the resulting file to the Blackboard "Assignments/Homework Submissions" page. This requirement forces students to become familiar with a mathematical software package and allows for consistency in online submission and grading of assignments rather than having students send assignments in a variety of different formats.

The homework deadline is rigid, operating on the tenets that:

- Students perform better, and learn more, if they do it promptly
- Students keep up with the topics, and that is necessary because each topic builds on previous topics
- It allows the instructor to give prompt feedback. Worked solutions are posted on the website on the same day that the homework is due.

It is recognized that students with full-time employment may be required to travel. Therefore, while students are given three evenings to do homework and send it, missed homeworks will not be counted. The homework grade will be based on the homeworks that each student submits on time. Because there are three assignments per week, there is enough homework for this to be feasible. The topics, book pages, problem sets and homework assignments are all posted on the Blackboard website, so students can also move ahead and do the homework early. Graded homeworks are returned by the instructor via Blackboard. Students who cannot avoid missing a homework are encouraged to do it anyway, for their own benefit, because the quizzes and exams will be on the same material as the homework.

The dates of the quizzes are shown in the course schedule, on the website. Employed students are urged from day one to discuss these dates with their Supervisor to avoid foreseeable problems. On those days the quizzes are available on the course website for a pre-announced period (e.g. 5-12 pm). They are all open book and timed (typically 50 minutes). Make-up quizzes are not permitted, however an early quiz is possible. Students who foresee that they will miss a quiz because of travel and no internet access are required to send the instructor, by email, an earlier time period within which they could access the quiz. If a student cannot avoid missing a quiz, the other two quizzes count for 15% each.

In this course, as in most technical courses, it is vital that the student be able to solve realistic technical problems. These cannot be true/false or multiple choice. They usually require multiple steps and at least some mathematics. This can be done in the Blackboard Quiz feature by breaking up each problem into its principal steps and making each step an "essay" question. The student solves each step by hand and enters the answer in the textbox for the "essay". This "reveals" what are the principal steps, but most students would know that anyway.

The dates of the Mid-term and Final exams are pre-announced in the course syllabus. Both exams are open book, and are conducted during 2-hour live sessions in the evening. The exams must be faxed to the instructor by 10 am the next day. Again, students are advised to discuss these dates with their Supervisor to avoid foreseeable problems. The exams are longer than quizzes and the problems are usually more challenging. Thus, to avoid the requirement of revealing the principal steps, as done on quizzes, the students do the entire exam by hand and fax the pages to the instructor. A special live class is scheduled prior to the final exam as a concluding interactive review and question/answer session for students.

All quizzes and exams are open book. In a Distance Learning environment, even with a University-wide honor code, open book appear the most realistic approach. This also more closely emulates the real world engineering environment graduate students operate within. As professionals and researchers, the students will be given problems to solve and they will be expected to gather whatever information is needed to solve them. Therefore the problems that are given in Distance Learning exams need to be realistic problems that are not answered by quoting some words from the textbook or plugging into a single equation from the textbook. Formulating such problems requires more work by the instructor yet serves the student greater in their career.

3.2 AOE 5314 and AOE 5994 – Naval Ship Systems Engineering and Ship Design

3.2.1 Course philosophy

These two courses, taken together in the final two semesters of our Distance Learning MS, are intended as a capstone engineering project in Naval Ship Engineering. Projects are initiated with a mission need statement for a naval ship or submarine. Students perform concept exploration for a design to satisfy this need in the first semester's work (AOE 5314), and develop selected design concepts in the second semester (AOE 5994). Working in teams of 2-6, the students communicate entirely online including sharing of design computer software, concurrent engineering, review, critique, and presentations. Teams travel to Blacksburg at the end of the project for their final project presentation which also serves as their final MS examination.

The scope of the project includes the following Naval Ship Engineering disciplines, processes and steps:

- Mission requirements, required capabilities and measures of performance
- Review of surface ship hydrostatics and submarine hydrostatics and trim
- Systems engineering and multi-objective optimization using cost and overall measures of mission effectiveness and risk. Two to three day optimizations are performed to search design space using on-campus computers remotely online.
- Ship synthesis models (surface and submarine) are developed including combat systems, propulsion and power, electrical, hullform, weight, space and feasibility, and the resulting modules are run in a design integration computer environment (ModelCenter) remotely, using on-campus computers online.
- Manning and automation
- Ship production and design for production
- Standards and specifications
- Subdivision
- Machinery arrangements
- General arrangements
- Structural design and analysis
- Seakeeping, maneuvering and control

The goals of the project are to review and apply the material from most of their MS coursework which for many students may go back as much as five years, to learn the basics of naval ships systems and their integration in a ship design, to provide a teaming experience, to learn a systems engineering approach to ship design with quantitative objectives and optimization methods, and to appreciate the possibilities and effectiveness of design and engineering when not collocated, a very common situation in large multi-disciplinary projects today.

Collaboration with the American Society of Naval Engineers (ASNE) and the Society of Naval Architects and Marine Engineers (SNAME) is ongoing to provide mentors to further support and motivate the students in completing the project, and to sponsor an annual graduate-level international ship design competition to provide a real-life competitive environment and assessment.

3.2.2 Course presentation

Online classes meet once a week for one and one half hours and often consist of student Powerpoint presentations at various stages of their projects. These presentations are ultimately pieced together as an outline for their project reports. Templates and examples are provided as a starting point for these presentations and required content is very specific.

Most of the basic course material is presented in asynchronous online presentations using Breeze (more than 35 online lectures in the two courses), and reinforced in online discussion using CentraOne software and in the project. The Breeze lectures are each followed by a short multiple choice / true or false quiz. Students are able to log-in online to on-campus computers with necessary ship design software, and to run their own sessions online using CentraOne for concurrent engineering sharing of these applications. A typical shared-application session is shown in Figure 1. Note that a student's name appears with the instructor's name as a session leader. In this course, each team leader is given the same Centra privileges as the instructor.

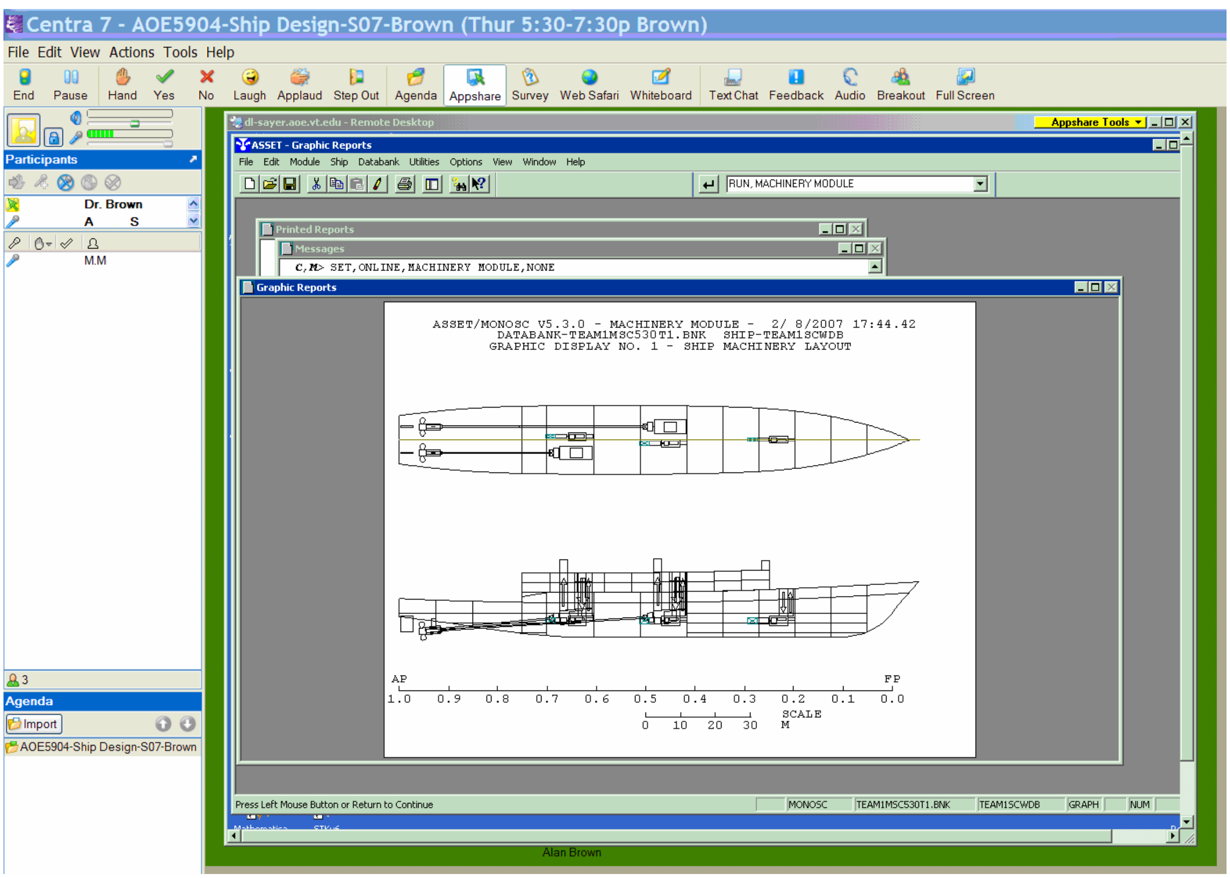

Figure 1: Shared Application on Distance-Accessed Computer in Centra (Student names removed digitally to preserve confidentiality.)

Student deliverables include Powerpoint presentations, software data files, a mid-course and final technical report, various calculations often in MathCad, and a full set of ship drawings developed in Rhino or AutoCad and submitted as .pdf files. All work is submitted and graded electronically.

3.2.3 Assessment of students
Online lectures (individual quiz grades) – 20%
Team presentations (team grades) - 20%
Interim products (team reports and drawings) – 10%
Final presentations (team) – 10%
Final products (team reports and drawings) and design – 40%

Team grades are broken-out to individuals based on student peer reviews done by team. Preliminary and final design reviews are provided by US Naval Sea Systems Command in on-line presentations.

3.3 AOE 5334[11]–Advanced Ship Dynamics

3.3.1 Course philosophy
The distance learning teaching philosophy for the online Advanced Ship Dynamics (AOE5334) course is based upon the following principles:

(a) On-campus students are given the choice to attend class in person.
(b) Off-campus students are to be served as effectively as on-campus students.
(c) Both student groups stand only to benefit from a joint educational experience.
(d) Embrace new technologies to create a live interactive teaching and learning environment for on- and off- campus students.
(e) Work to create an environment that will complement the on-campus experience for traditional students.
(f) Provide a forum for students with work experience to share their knowledge/ expertise.
(g) Ensure the broad availability of the course; that is, use technology that does not require students to be at any specific physical location.

Students learn best when they can actively participate in a classroom environment. Every instructor has their own mechanisms of engaging students in the material at hand, often through some combination of active learning exercises, demonstrations, personal interaction, etc…. For this class, instruction is conducted in a manner to allow on-campus students to attend in person while off-campus students have the option of attending the course live online or asynchronously. That is, all lectures are taught using the Centra software using a tablet pc with on-campus students physically in attendance and off-campus students virtually present. The combination of on- and off-campus along with being appropriately motivated to introduce a high tech classroom allows for engagement of students in a new a different variety of ways. Ready links to external sources, convenient file sharing, classroom coding and simulation, the introduction of the tablet PC where students can be asked to freehand sketches and solutions and can see the sequential free-form thought process of the instructor are all innovations which greatly improve the enjoyment and interactivity of the classroom.

3.3.2 Course presentation

Operating on the assumption that (a) and (b) above can be accomplished with available technology, these principles are not mutually exclusive. Thus the structure of the class involves meeting live three times weekly for 50 minutes scheduled in the evening to accommodate the work schedules of employed students. On-campus students are encouraged to physically attend the real-time lectures. Off-campus students log onto the lecture via Centra to participate in a live broadcast. Every lecture is recorded and posted on the course's Blackboard website for later review for those who either miss the lecture or who simply wish to revisit material covered.

Qualitative impressions indicate both student groups benefited from the physical presence of a group of students. Specifically, the ability of the instructor to read body language of on-campus students allowed for readily adjusting the pace and activity level of the class to meet on and off campus students needs. Additionally, the audible activity in the physical classroom prompted activity with the off-campus students. A routine exercise would divide the class into sections "classroom to the left," "classroom right," "classroom back," and "online." Hearing the bustle within the room would prompt a flurry of messaging dialogue in the Centra "text" window amongst the online students. In this format all students know they are accountable for their participation in a classroom exercise.

Prior to each class, partially complete lecture notes in PowerPoint are distributed on the course website. The instructor then lectures in much the same manner as a typical classroom environment and 'fills-in' the partial notes. To emulate the format of writing on a board, the instructor in this course instead chooses to write on the slides with the aid of a tablet PC. Students see each writing stroke of the instructor and from that learn the material in the same sequential manner as they would by formulating a problem on a traditional blackboard. On and off-campus students alike are both able to ask questions out-loud, with off-campus students using the microphone option in Centra. For the most part, off-campus students appeared to prefer the text-chat option for posing their questions during class, therefore the Centra text-chat window was referred to regularly. Primarily utilized Centra functionalities in the course include the ability of-students to ask questions, either speaking or by text message, 'raise' their electronic hand, indicate problems or understanding with a check mark or 'X', even electronically smile or applaud. Additionally, applications can be 'shared'; for example, the instructor can show and run a Matlab script as an in-class example. Sample snapshots of the Blackboard website and Centra environment are presented in Figure 2. In this figure, note the student checkmarks acknowledging comprehension of material in the upper right image, the 'X' in the lower left image used in this case to answer a posed 'yes/no' question in the negative, and the ability to conduct demonstrations in other software programs, specifically Mathematica shown in the lower right image.

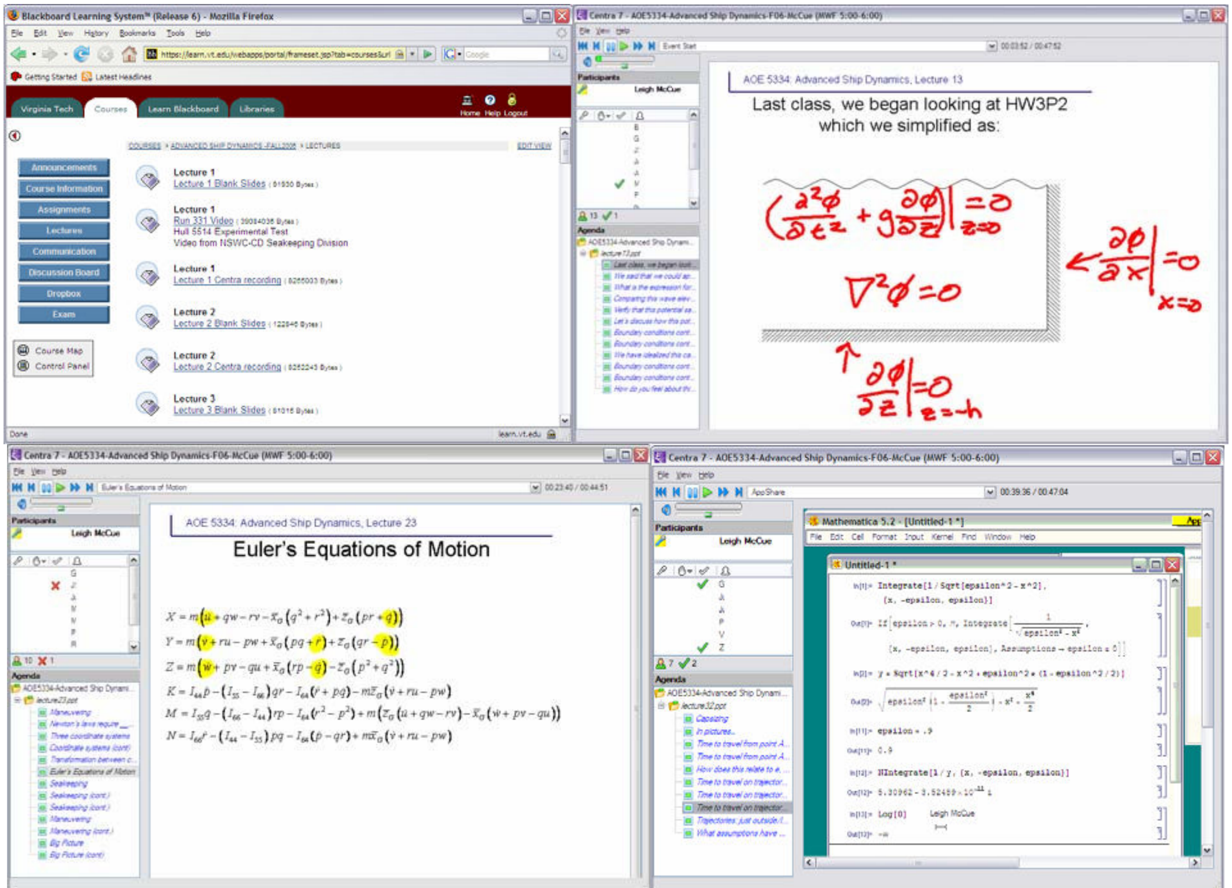

Figure 2: Snapshots of Blackboard website and Centra slides during live class session[11]. (Student names removed digitally to preserve confidentiality.)

Because a lecture-type style is used in the classroom, that is, the instructor is not sitting at a desk using a wired headset, a bit of technological creativity must be employed for voice recording of the course. Since students are present in the room, initially a desktop microphone was tested, however this resulted in uniformly poor sound transmission quality of the students and instructor's voices. The instructor for this class instead prefers a wireless Bluetooth enabled microphone/headset combination. While this does not allow for strong recording of student dialogue in the classroom, it does enable a higher quality recording of the instructor's voice. To overcome the lack of student voice recording, the instructor simply must be consistent about repeating questions posed.

3.3.3 Assessment of students

The nature of this course lends itself to homework and project-style evaluation. Students are given a midterm exam, worth 20-25% of their final grade with the remainder of the course grade determined by performance on 7 homework assignments, four of which contain a large simulation component[12], and a final project. To accommodate the schedules of working students, the open-book midterm exam was allowed to be taken during any two-hour period within a one week window. In addition, to stress the importance of the final project, one third of the midterm was devoted to forcing each student to describe their planned project and formulate a realistic time-line for completion. In future offerings, the instructor is likely to remove the midterm exam altogether and instead focus entirely on the homework assignments and project.

The assignments and project for the course focus largely on training students to conduct research and apply graduate-level knowledge to realistic problems. As such, the homework assignments are demanding, yet students typically have two weeks to complete each assignment. With a lesser emphasis on examination, this approach avoids the encumbrances associated with administering an online test. Additionally, the project is formulated so as to be largely open-ended. Students are tasked simply to apply the material they are learning in the course to their research or a work-related project. As such, projects have included everything from preparing a training tutorial for in-house use that teaches high-level concepts to new hires, to fundamental literature surveys, from application of simulations developed in homework to problems of specific interest to the student, to flushing out an otherwise neglected dynamics component of a research project. The diversity of projects poses an interesting challenge for the instructor in assessing the quality of students work. However, the result is a prompt student appreciation of the material at hand and a rather entertaining set of projects to read. Additionally, it allows students to incorporate course work into an application with direct and immediate benefit to their research and/or employment.

4.0 Student and Employer Feedback

The popularity of online courses is growing rapidly, rather than leveling off as some had anticipated previously[13]. A recent study by Eduventures Inc. summarized in the *Chronicle of Higher Education* indicated that of 731 companies surveyed, a greater percentage of employers "would be likely or very likely to purchase, endorse, or support" internet-only or hybrid internet/traditional classroom programs to purely traditional classroom programs[14]. Specific to Virginia Tech, a 2005 survey of current Virginia Tech distance learning students asked respondents to indicate their preferred way of receiving instruction for distance learning courses. As a departure from the results of a 2001 survey, the students surveyed in 2005 responded that their preferred delivery method is online as shown in Table 2, and when asked what things students liked best about distance learning, the most frequently mentioned response was convenience[15].

Method of Instruction	*Percent*
Via the internet-learning at the same time with instructor and students	36
Via the internet-(online) self paced	24
Interactive video teleconferencing in a room	20
Via the internet-some instruction self-paced and required face to face instruction with professor	16
No response	3

Table 2: Preferred way of receiving instruction for distance learning courses (from Scales, *et al.*[15]).

Results of students' self assessment of their learning and their satisfaction with the technologies in the online courses as measured by the end-of-course Student Perceptions of eLearning surveys are in Table 3. The online survey is administered by Virginia Tech's Institute for Distance and

Distributed Learning (IDDL) to students in all eLearning courses at the end of each term. The survey has a Likert Scale that ranges from 1 to 4, where 1=(Strongly Disagree), 2= (Disagree), 3= (Agree) and 4= (Strongly Agree). Note that students largely expressed that they were only able to take the course because it was available online and they found VT AOE's distance learning program offered them knowledgeable instructors. Students consistently agreed or strongly agreed that they were satisfied with their eLearning experience. Note, students are asked to anonymously complete this form for each class, so it is indeed possible that some responses in Table 3 represent feedback from the same student on more than one course.

Question	*Aggregate Mean*	*Number of Responses*
Category: Instructor Performance		
Apparent knowledge of the subject matter	3.86	21
Overall rating of the instructor	3.68	22
Encouragement and management of class interaction	3.36	22
Category: Course Design and Communication Information		
Course activities enabled my regular interaction within the class	3.50	18
Overall course design enabled my learning	3.33	21
Category: Technology Information		
The quality of technology and connectivity supported my learning	3.18	22
The technologies used in the course enabled my access to others	3.42	19
eLearning did not make me feel isolated	2.95	22
After completing this eLearning course I am more confident that I can reach my academic goals	3.33	21
My plans are to take additional eLearning courses	3.05	20
My learning in this eLearning environment was as effective as in other courses	2.71	21
I am satisfied with this eLearning experience	3.05	22
Category: Access and Support Services		
I could only take the course because it was available online	3.09	22

Table 3: Aggregate student survey results for 3 recent course offerings—AOE 5074 (Spring 2005), AOE 5314 (Fall 2005), and AOE 5334 (Fall 2006)

5.0 Conclusions

This paper describes current, successful distance learning tools and techniques employed by Virginia Tech's Aerospace and Ocean Engineering Department. Through detailed descriptions of three similar, but unique teaching approaches, it is hoped that others embracing distance learning in their curricula will benefit from the experiences and strengths of the AOE online MS program. Through regular assessment and continual technological improvements, it is becoming increasingly more feasible to create connected, effective, and enjoyable experiences for students studying off-campus and around the world.

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