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**Expanding Frontiers -  
Challenges and Opportunities in Maritime Education and Training**

**Internet-based, multi-media education  
for classroom and distance learning at MMA**

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**Abstract:** The internet is by far the most important development for our last generation of students in the twentieth century. Twenty-First century maritime professionals rely increasingly on electronic hardware (i.e., computers and the network), and more importantly, on the resulting information technology and communication tools (IT-Tech). These tools are an essential part of maritime engineering education. This paper looks specifically at internet-based, multi-media education for both traditional classroom, and long distance learning programs at the Massachusetts Maritime Academy (MMA). The author currently teaches traditional engineering classes at MMA in electronics and computer control. These physical classes, and associated laboratories, increasingly utilize internet-based materials in a variety of constantly changing formats. The paper examines specific internet, multi-media, and engineering software applications in the form of interactive email assignments, internet labs (iLabs), and electronic course-notes. These digital elements expand the universe of traditional classes by adding more current material such as Matlab/Simulink design iLabs, PLC design iLabs, and applied engineering Case Studies. At the same time, engineering classes must continue to teach fundamentals by incorporating non-electronic, but still essential, analog forms of education such as textbooks, written assignments, and interactive lectures. In addition to his “brick and mortar” classes, the author has also developed a non-traditional, internet-based, certificate class at MMA in “Marine Pollution and Vessel Engineering Systems”. This BlackBoard-based, distance learning class was taught to 18 maritime professionals located worldwide. There was no physical classroom, no analog communication, and no one in the class was ever in physical contact. Weekly lessons, assignments, and quizzes were in the form of off-line videos and electronic course-notes. As a result, the author has developed a unique perspective on these trends in “modern” marine education. This paper compares these emerging digital information tools to the resulting analog student outcomes, and examines the lessons learned.

**Keywords:** Multimedia Case Studies, Education, Matlab, Simulink, Electronics, Control Systems, Marine Engineering, Distance Learning.

## 1. Introduction

Before reading further, it is helpful to have a brief understanding of the author's personal background. The author began his career as a marine engineer (SUNY-Maritime College), and served four years in the Merchant Marine on U.S. Great Lakes bulk carriers. He then spent seven years in graduate school doing active research and teaching in the area of automation and computer control while earning a master's and Ph.D. in mechanical engineering (MIT). After leaving MIT, Dr. Bausch spent a number of years teaching at several engineering schools, and doing applied R&D with companies in the area of design and control for automation. As a result, his career has spanned the diverse ends of the engineering spectrum, from hands-on to hi-tech, during the evolution of "the computer-age".

Most recently, Dr. Bausch teaches two key classes at Massachusetts Maritime Academy (MMA) in the rapidly changing area of *Electronics, Instrumentation, and Control (EI&C)*. These classes were specifically developed, based on experience in graduate school and industry, to target the many job opportunities for today's MMA engineering graduates [1]. The career paths for MMA graduates can range from engineering officer positions in the U.S. Merchant Service, to shore jobs in the power plant and facilities industry, to entry level engineering positions in manufacturing and related industries, and even to post-graduate engineering school at some of America's top universities.

### 1.1 ECI-Electronics & INC-Controls: two core classes at MMA

The speed of development in the area of electronics, and specifically computers, can make the teaching of the engineering subject particularly challenging: the tools and standards used for EI&C hardware and software are improving almost daily. Unlike some traditional marine engineering classes (e.g., boilers, turbines & diesels), the EI&C subject matter is in a rapid state of change. As a result, the two core classes at MMA, *Electronics (EN-3212)*, and *Instrumentation & Control (EN-4223)*, make extensive use of electronic media and software. The media itself is designed for just-in-time delivery to students. These two, upper-level classes are divided along the lines of hardware and software, electronic circuits and system dynamics, and, either PLCs (programmable logic controllers) or PIDs (proportional, integral & derivative control) for real-time applications.

ECI-Electronics covers the broad area of electronics and includes sensor, actuator and controller hardware relevant to marine and power systems. Case studies and problems examine the electronic circuits used for process monitoring and control. ECI provides the foundation for the more advanced INC-Controls class. INC addresses advanced concepts in dynamic systems, and the computer control software used for modern, closed-loop PID design. Case studies focus on single and multi-variable closed-loop systems, and on PID controller design (where the underlying application of electronic hardware and software is understood by the student through their ECI experience).

From the administrative point of view; ECI and INC are standard engineering classes taught three days a week, to a maximum class of 24 students (currently 3 sections in Electronics, and 1 in Controls). ECI and INC are particularly blessed to have a dedicated space specifically designed for use with those classes [1]. The new Electronics and Control Systems (ECS) class/lab was designed and implemented in 2009-10, and includes a lecture area with multi-media projection and sound, eight

lab benches with digital instrumentation, and a demonstration space for PLC and PID controllers.

**Table 1: Tradition Engineering Educational Tools**

- Instructors and Textbooks.
- Lecture-based Course-Notes, and a slate Blackboard or Whiteboard.
- Homework (textbook Problem Sets with required reading), Quizzes and Exams.
- Engineering Example Problems and Application Case Studies.

Table 1 is a non-comprehensive look at the educational tools used every day in a traditional, college level engineering class. These tools are not battery operated; they don't require electricity; they are analog and physical. We've all seen them. They are employed daily by the author, and were a fixture in his own college classes. One might think that listing the instructor is too obvious, but given the emergence of online degree programs and learning software (e.g., the University of Phoenix), distance learning is starting to look like automated teaching. This new technology is changing all aspects of education, and is rapidly evolving along with all the developmental pros and cons.

While MMA still has its share of chalk-based, slate blackboards, all newly renovated classrooms have whiteboards and markers (which, while more expensive, are commonly preferred by most faculty). Textbooks are hugely expensive for engineers with new editions issued sometimes yearly. Huge amounts of time can be spent editing and fine-tuning lecture course-notes as handouts for the class. The author spent a great deal of time this year converting PowerPoint lectures into Apple Keynote, and there is always the danger of "death by PowerPoint". And while in-class, multiple-choice exams can be graded in real-time using the "iclicker" device, there are deeper, critical thinking skills required when students are asked to complete paper & pencil Problem Sets (PSets), short in-class Quizzes, and 50 minute Exams. These, of course, require a lot more faculty time to develop and grade.

## **1.2 Engineering Educational Trends: ABET & Distance Learning**

During the writing of this paper, two recent developments were announced that are worth including. First, a new engineering degree program was approved at MMA. Energy Systems Engineering (ESE), the third engineering degree program at MMA, is an ABET accredited degree [2]. ABET, the Accreditation Board for Engineering and Technology, accredits post-secondary programs in "applied science, computing, engineering, and engineering technology". The class of 2016, entering this fall, will be the first ESE class to graduate. As required by ABET, the ESE program will include an emphasis on engineering design within the classes and laboratories. The ESE degree also requires the completion of a major Capstone Design; an open-ended engineering application project.

On a larger scale, MIT and Harvard recently contributed \$30 million dollars each (for a combined total of \$60 mega-dollars), to setup the joint "edX" program for distance learning [3]. This latest program has evolved from the MIT Open Courseware initiative; formally introduced in 2002 [4]. MIT Open Courseware now

has materials from over 3,000 courses available online - all for free. This trend, the Open Source philosophy, can be traced back to the GNU free-software movement [5]; a project initiated by Richard Stallman and Project Athena back in 1983.

The first MIT online class, MITx 6.002x (Circuits and Electronics) is a core undergraduate class in electrical engineering. Over 120,000 students are currently taking it online in the initial offering [6]. Students are required to take exams and do weekly assignments in this certificate class. The MITx exams are very likely not being graded by hand. As planned, the edX program will run independent of the university operating budgets. Based on a hypothetical calculation, if each student were charged a nominal \$10 registration fee, 6.002x becomes a \$1.2 million dollar class. Not a bad return on the university bottom line; as with baseball, modern education is now big business.

### 1.3 Distance Learning at MMA: The Seafarer's Program

In the Fall of 2008, the author signed up to teach a distance learning trial-program at MMA, the Seafarer's certificate program, specifically to develop the online class: Sources of Marine Pollution I: Engineering Systems. This class was rapidly rechristened, Marine Engineering & Pollution, or MEP for short. The first offering of MEP ran for 8 weeks from January to March in 2009.

Week 1 was a learning experience for the whole class, especially the instructor. There were 18 students in the class, all with a computer, access to the internet, a high-school degree or GED, and an interest in the maritime world. The program was affiliated with the Seaman's Church, and most of the class had career experience related to the Maritime industry.

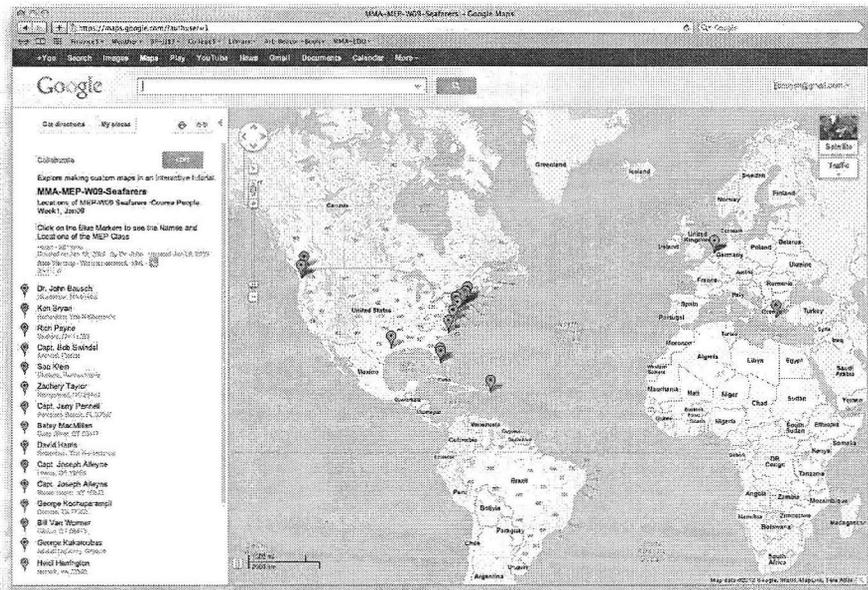


Figure 1: Distribution of MEP students in the MMA Seafarer's Program (Google Maps).

As is a challenge in many MMA classes, the 18 students in MEP had a very wide range of experience and ability (especially with regard to computer and internet skills). MEP was the second of five course modules in the one-year Seafarer's program; so students were already familiar with getting online, and using BlackBoard to participate in the class (see next section). The first week involved a number of warm-up exercises. These were designed to introduce MEP, the class and the instructor, and to gauge the internet response times for file size, video transfer rates and image resolutions; to flex the internet muscles. It took the first few days to learn that Quicktime (videos.mov) was the only format that could be viewed by all students on BlackBoard. Then more time was needed to provide instructions to download and install Quicktime on the predominantly Windows computers.

One of the first MEP assignments was to use Google Maps (see Figure 1) to identify the names and locations of all 18 students on an electronic map of the Earth. Additionally, as it was a bad winter in Worcester, students needed to report their daily temperatures. As you can see from the figure, the class was completely spread out over the northern hemisphere, with students on the East and West coasts, on the Gulf and in the Caribbean, and in the Netherlands and Greece. There proved to be a wide range of computer literacy with little technical support available at MMA. One student was even working on a cruise liner at sea, and had internet access only every second or third day.

## **2. MEP-Marine Engineering & Pollution: MMA Distance Learning**

A key element in the MMA Seafarer's program is the use of BlackBoard Software [7]. BlackBoard became a publicly traded company in 2004 in order to "work with our clients to develop technology that improves every aspect of education". Students log-in to their own account on a dedicated BlackBoard server, and then have access to the course materials posted by the instructor. BlackBoard includes its own messaging system, a bulletin board for student posts, and a grading system (primarily for multiple choice exams). The instructor edits the course web page (primarily text-based) using a hierarchical menu system.

In the MEP class, BlackBoard was setup using a main page with links to the weekly pages, and a very similar layout of posts for each of the 8 weeks. The pages for each week were activated on Sunday night (Eastern Standard Time) with assignments due by the following Sunday. The BlackBoard page for Week1 (see Figure 2) is shown here in the Edit Mode. As MEP developed, the instructor tinkered with a number of electronic tools with varying degrees of success (as listed in Table 2).

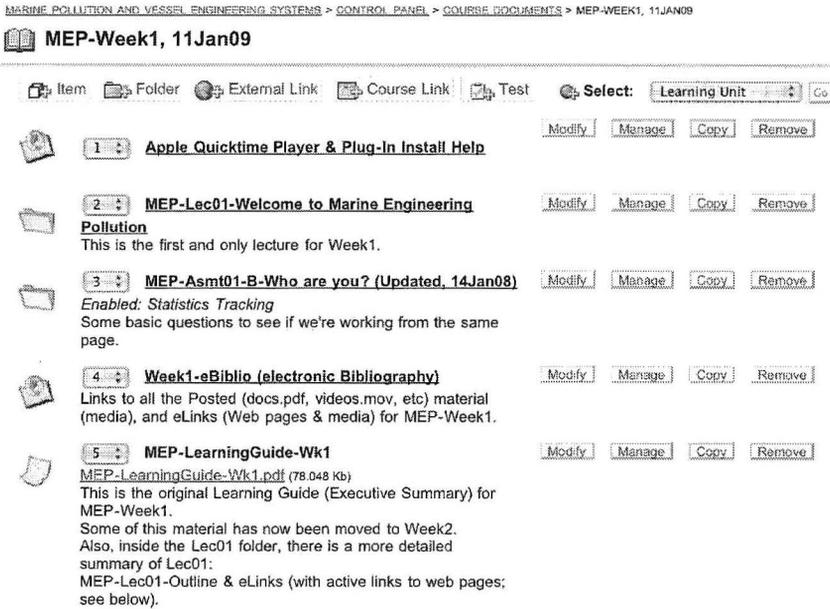


Figure 2: BlackBoard Course page for Week1 of the MEP Class.

Once on the MEP BlackBoard page, the student would view any current announcements before being directed to the Weekly page. The main feature each week was the Video Lecture. These lectures were a series of PowerPoint slides with an accompanying narration by the instructor. The Video Lecture was typically broken down into 6 or more 10 to 12 minute segments to keep the file size manageable. Lectures were followed by weekly assignments. These would include reading a class research paper, posting responses to topical questions on the class bulletin board, searching the internet for new information, and taking a short multiple choice quiz on BlackBoard.

Some of the early assignments introduced the class to the Wikipedia and the Google websites. It is interesting to note that even three years ago, these were new tools for many MEP students. In addition to the weekly video lecture, an “Outline & eBiblio.pdf” file was posted each week. These files can easily be created using a simple email editor (e.g., MacOS Mail) using only basic formatting (the KISS principle [8]), and keeping the non-multimedia content to a relatively small file size.

**Table 2: MEP-Distance Learning Educational Tools**

- The Internet (the online library of the information world)
- BlackBoard (the digital software not the analog device)
- Video Lectures (narrated PowerPoint presentations saved as Quicktime movies)
- Snap-Z video capture and Quicktime Pro editing software
- Wikipedia & Google (as primary search sources on the internet)
- eBiblio.pdf Posts (detailed electronic bibliography files with live links)
- eNote.pdf Posts (detailed course files with live links as weekly outlines)
- Email & the email editor software (Apple MacOS Mail program)

- Electronic Case Studies on Marine Engineering Systems
- Online MEP Team Research Project (a group PowerPoint or Electronic Paper)

Electronic links (eLinks) were embedded in the file as live or active urls (uniform resource locators; i.e., internet addresses) which, when clicked-on by the mouse, point the student to the article or website. Since all MEP resources needed to be available on the internet, the instructor could easily embed the url address, the webpage location, within the email while creating the lesson plan. The email could then be saved as a more universally read “.pdf” file (portable document format, Adobe).

It was discovered that when copied to BlackBoard, the webpage links (eLinks, the live url addresses) remained active for the students inside and outside of BlackBoard. Internet search results could be saved as an electronic bibliography (an eBiblio.pdf). When in BlackBoard, the students could click on the eLinks (displayed as standard, underlined blue text in BlackBoard, email and other text software) to direct their internet browser to another webpage, and view the material being referenced. More importantly, when saved as a stand-alone .pdf file, the eLinks still remain active outside of BlackBoard. Figure 3 shows one section of the MEP Week4 Outline Notes on Steam Turbines.

**2. Week4 Review Paper: Ultra Steam Turbine - Is the Age of (Merchant) Steam Over?**

Are the days of mighty Steam Ships (commercial ships, not the nuclear-navy) over? Is this Early 21st Century Age we live in strikingly similar to the Early 19th Century Age of Sail, when Sailing Ships were at their peak. (Again, for commercial sailing ships; the Square Riggers and Clipper Ships of the 19th century. I sail a 25 foot sloop on Narragansett Bay. Modern, non-merchant sailing, for those of us that are wind-energy sailors, is very high performance. Maybe a possible topic for MEP Alternative Energy?).

In any event, 19th Century Steam Ship development clearly ended that Age of Sail.  
So right now in 2009, Is the Age of Steam Over?

Read/Skim the Lec04 Review Paper on the "Ultra Steam Turbine".  
Use this paper for basic Turbine/ Boiler engineering review (as you go through lecture materials).  
Then re-read when completing Asmt04 to reinforce understanding of MEP enviro/pollution issues.

Post: Wk4 Paper- Ultra Steam Turbine (5pg).pdf (you may want to print a hard copy for your notes).  
[Technical Review i Technology i Mitsubishi Heavy Industries, Ltd.](#)

Some background material from the Lecture Slides on Great Lakes Shipping (SS Harry Coulby):  
<http://www.boatnerd.com/>  
<http://www.boatnerd.com/pictures/fleet/kenterprise.htm>

For those of you who are unfamiliar with Steam Plants, if you ever have a chance (before, and if, they are a thing of the past), take a tour of a Steam Turbine Plant with one of the engineers. Have the engineer trace the main Steam Cycle with you. You will be fascinated by the both the complexity, and the simplicity of the Steam Plant; an engineering work of art. I imagine, you would have been similarly impressed a century and a half ago, on taking a tour of a Square Rigger with the Sailing Master.

Last fall, sadly, I finished reading the last book in the Aubrey/Maturin series (Master & Commander) by Patrick O'Brian. Sadly, because no more will follow (Mr. O'Brian died in 2000). I highly recommend these books to anyone who is interested in great historical fiction (but very accurate fiction), and in the "engineering" of the Age of Sail:

[Amazon.com: Patrick O'Brian: Aubrey/Maturin Books](#)  
[Aubrey/Maturin Prints by Geoff Hunt \(Patrick O'Brian novel covers\)](#)  
[Patrick O'Brian - Wikipedia, the free encyclopedia](#)  
[http://www.amazon.com/exec/obidos/search-handle-url/ref=nt\\_athr\\_dp\\_sr\\_1?%5Fencoding=UTF8&search-type=ss&index=books&field=author=Patrick%20O%27Brian](http://www.amazon.com/exec/obidos/search-handle-url/ref=nt_athr_dp_sr_1?%5Fencoding=UTF8&search-type=ss&index=books&field=author=Patrick%20O%27Brian)

**Figure 3:** Sample from MEP Week4 Outline Notes (as an eNote.pdf email file).

As a final project for MEP, students were given an online assignment to create a research document as a team (see Figure 4). A list of 14 project topics was posted, and each of the 18 MEP students picked their top 3 topics (as a Quiz assignment in BlackBoard). Each student was then assigned to the best match of team and topic (with 3 to 4 students per team). Each team had four weeks to organize the project, compile the material, and put together their final result; either a PowerPoint presentation, or an eLink.pdf paper using live links to reference web pages (to be posted in BlackBoard).

Keep in mind that these teams were geographically dispersed across the planet. Communication was done either online through BlackBoard or through direct peer-to-peer email (the preferred method). This was only three years ago. Today they could easily meet and video conference using Skype. Even so, the project results were impressive. It is interesting to note that one of the predominantly older teams (two of three members were retired sea captains) chose to do a PowerPoint presentation, but put it together as a primarily text-based document with bullet points, and long sentences; more like a paper. They, in particular, learned a lot from the project. Generally, all the MEP students felt the project gave them something active and creative to do for the class. After submission, the projects were posted on BlackBoard; then evaluated by the instructor, and the students through a peer review.

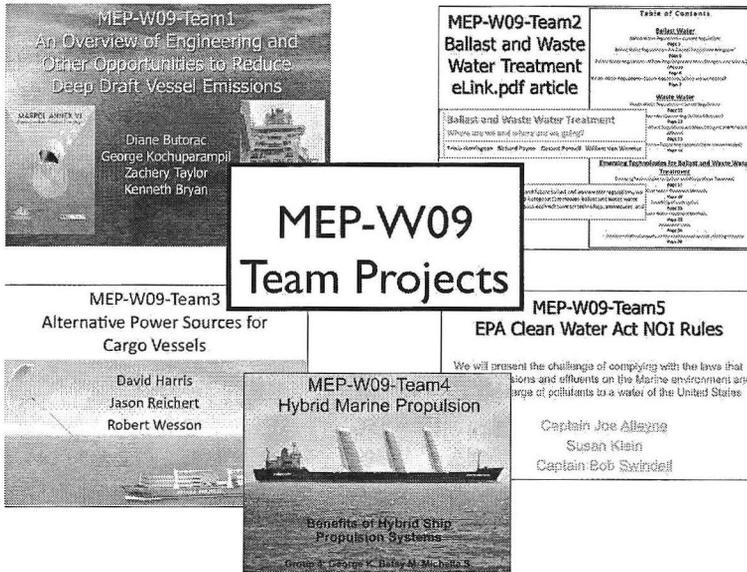


Figure 4: MEP Distance Learning Team Research Projects (using internet tools only)

### 2.1 MEP-Case Study: The HMS Titanic

Case Studies are frequently used in engineering classes to provide a link to “real” applications with real numbers; especially in scenarios involving decision-making and design. In MEP, the assigned research paper readings accomplished much of this. However, as the instructor frequently noted, MEP was not a “real” engineering class. The student backgrounds were too diverse; some not at the college level, and many not engineers by training. MEP case studies also needed to be more diverse.

One MEP Case Study, the good ship HMS Titanic, was useful to tie in many aspects of marine power, the steam cycle, boilers and thermal efficiency, in a more general way. The story of the Titanic is well known, and there are a number of websites and articles available online. The “encyclopedia titanica” site in particular was useful to introduce the steam cycle and boilers (see Figure 5), to show the developmental history of steam propulsion and engine design, and also to illustrate information technology basics [9]. We even came back to it when discussing Coal as a fuel source. And, the movie version didn’t hurt either. To illustrate a Google

Search, the class was asked to type only three key words: “Titanic”, “30-seconds”, and “bunnies”. The result is unique and memorable. Try it!

## 2.2 Lessons learned through Distance Learning

As the saying goes, “the first time a class is taught, the instructor learns a lot, the second time, the students learn a lot, and the third time, no one learns anything.” For MEP, this was somewhat true as the author taught the class only once during its two year trial. As it was a winter class, he was able to devote a large amount of time. It was a huge amount of work; to setup, to teach, and to manage.

Much of the work load involved making the course material compatible with BlackBoard, and then posting into the BlackBoard modules. As these modules came online Sunday night, the routine caused some disruption at home. Yes, that may have been better the second year, but the following year saw the instructor on cruise with the cadets for Sea Term training. But speaking as an electronics instructor, the MEP experience was adventurous and enlightening, and I did indeed, learn a lot.

I became adept at producing the video lectures. This involved evaluating and learning many software programs, and developing a uniform production process. As the MEP class developed, the production quality improved enormously as well as the amount and value of the multimedia content. Apple Quicktime proved both easy to implement and relatively powerful, and was used to polish both the video lectures and a number of movie clips (many re-used in the ECI & INC classes). The use of the email editor for outlining and publication was also valuable, and led to the use of eLinks in email and eNotes saved as .pdf files. One note of caution, however, it is understood that information posted on the web is dynamic; it changes rapidly. Web-based information I have cited here may likely be changed or even gone when this paper is read. This places an additional burden on the instructor.

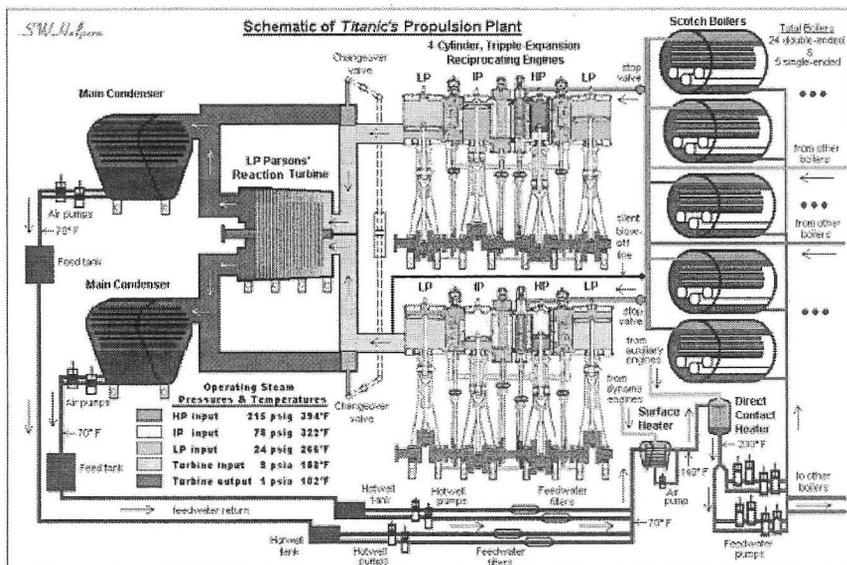


Figure 5: Steam Plant schematic for the HMS Titanic (electronic media using an eLink)

### 3. ECI-Electronics (EN-3212) and Computer Integration

A significant number of MEP internet and multimedia tools have found a home in the brick-and-mortar ECI class. Surprisingly, however, BlackBoard software was the first thing to be discarded. MMA engineering students live on campus, own or borrow textbooks, have access to the MMA library, computers, and the internet, and, hopefully, attend a physical classroom with a living instructor three times a week. In this case, BlackBoard adds a layer of complexity to internet communication without much benefit.

ECI is all about analog and digital electronic hardware, signal processing, and the integration of electronic systems with computers and PLCs (programmable logic controllers). The class includes a one-credit practical laboratory or ELab. The multimedia content of the class and lab, which is substantial, is presented in three ways; either within the real-time lecture with accompanying course-notes, through email-based reading and assignments, or as posted on a simple archival website.

As a result, email, which is easily written and can be read on your iPhone, is used as the main non-verbal communication tool between instructor and student. This is useful for career training as well, as email is the primary information tool in most companies. Many MMA instructors, though, prefer BlackBoard for one stop shopping. Textbooks now include BlackBoard modules with tools for assignment logging, test creation and grading (using multiple choice), and on-line grade posting.

In ECI, however, most quiz and exam questions are open-ended, solved problems, and the primary form of non-electronic feedback to students is in the form of red ink on physical papers that are individually graded by the instructor. The ECI textbook, "Process Control Instrumentation Technology" by Curtis Johnson [10] is the eighth edition; copyright 2006, and not currently in production. This is actually a good thing, as the current text includes a large number of correctly solved problems, and is on-target for non-electrical engineers. This provides a relatively stable foundation for the development of the remainder of the ECI class. Additionally, the sale and re-sale of the same edition of the ECI text in the MMA used-book market, keeps the average textbook price much more affordable for the average student.

Using the textbook as the base, the more dynamic ECI material (i.e., news articles and emerging technology) is developed through electronic media. These include daily lecture course-notes (presented by the instructor), email-based reading and Problem Set assignments (PSets), and scanned solutions for PSets, Quizzes and Exams. These multimedia electronic materials are sent as email, along with eBiblio and eNote attachments. They provide live links to more up-to-date supplemental material. Many of the video tools and techniques developed in MEP, are incorporated into the daily lectures as short video clips and software demonstrations. Digital music demos, for example, are used in a unit on signal processing to actually listen to the effects of gain and filters on sound (music).

**Table 3: ECI-Multimedia Tools (in addition to MEP developed tools)**

- ELabs-Electronics Laboratories (a 1-credit companion laboratory to ECI)
- Digital Projector (high resolution & large screen) with a quality Stereo Sound system
- Email & the email editor software (Apple MacOS application)
- Webposts (simple to maintain, text-based website @mac.com; see note below)
- iCalendar real-time Syllabus (Apple MacOS application)

Table 3 expands the educational tool list developed for the MEP class to include some additional tools used in ECI-Electronics. As an engineering class, the Electronics Labs (ELabs) add a level of hands-on experience impossible to recreate in a virtual, digital world. The ELabs, however, benefit greatly from training materials and software that are delivered over the internet. The instructor is currently evaluating the use of electronic lab notebooks and data logging for ELabs at MMA.

At this point, for the author, it would be extremely difficult to teach without the use of a high quality digital projector and sound system. All of the ECI lecture media, other than calculations on the whiteboard and equipment demos, are delivered from a computer through a digital projector. One technique that works quite well is to project figure images directly onto the whiteboard. Then colored markers are used to draw circuits and calculations on top of the projection as part of class discussion. This is essentially a low-tech version of smart board technology, but very effective in encouraging the students to take notes, to fill-in the blanks, when providing course-note handouts to the class.

In addition to email, a web-page is used to archive digital information. Originally, the author used his personal mac.com account to setup a text-based webpage to support the ECI course. This provided a simple way to post material without requiring BlackBoard. In addition, mac.com supported the use of web-based iCalendars (based on MacOS built-in calendar software). This allowed calendar events for the ECI class (lecture times and titles, Exam dates, PSet due dates) to be listed on a public website. In this way, the instructor created a real-time, electronic Syllabus for ECI. Apple is now phasing out the mac.com service and replacing it with a cloud-based service more in-line with iPhone and iPad usage. At the same time, however, MMA switched over the campus email and information system over to Google (but managed by MMA). As Google provides the same web and calendar services as mac.com, the author is planning to port these services from Apple to Google for next semester.

### **3.1 ECI-Case Study: Dr. Smith's Mouse Machine**

Figure 6 shows an example of one application Case Study used in the ECI class. This case, Dr. Smith's Mouse Machine, is part of the unit on ladder-logic circuits and PLCs (both the operation and the programming). Dr. Smith is a bio-chemist involved in medical research on sleep apnea. The author worked with him to design, build, and program a PLC-based "machine" to simulate sleep apnea in mice in order to develop treatment therapy for humans.

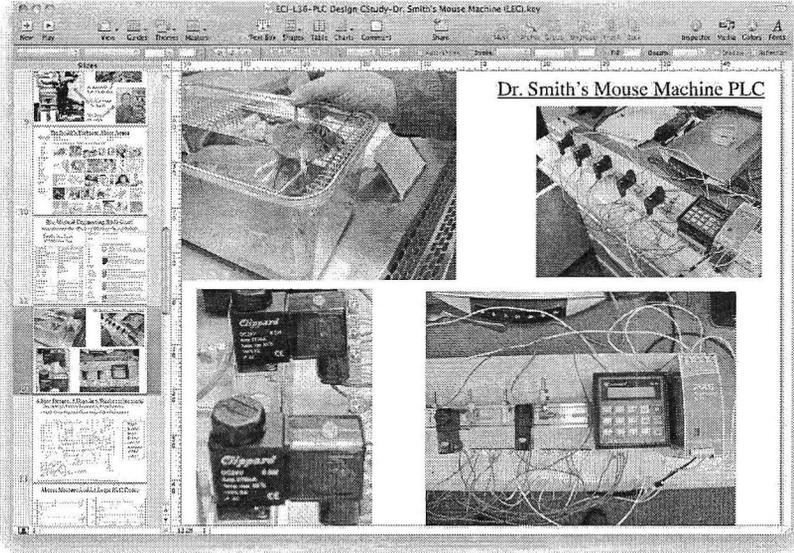


Figure 6: A PLC-based Control System developed for sleep apnea studies on mice.

The Mouse Machine, provides a very accessible case study for ECI students that touches many aspects of the class. It is presented as an open-ended design study of the electronics and the machine interface, but also on the use of PLCs and the subsequent logic programming. A follow-up package is sent as an eBiblio.pdf email communication to the class, with live eLinks to relevant on-line material (to broaden the student experience). Figure 7 shows the actual PLC code as implemented. Students are encouraged to try their own “solutions” in an optional LQR assignment (low quiz replacement).

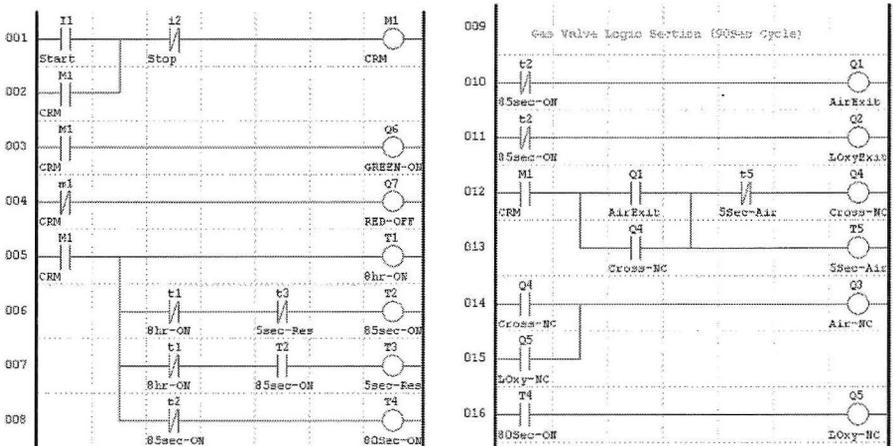


Figure 7: The resulting PLC Ladder-logic program generated using TECO-SG2 client software. The PLC uses only 2 inputs, 7 outputs, 1 momentary relay, and 5 timer relays to regulate the process.

#### 4. INC-Instrumentation & Control (EN-4223) using Matlab/Simulink

While the focus of ECI is at the machine level of electronics, the INC class deals with dynamic systems (i.e., differential equations and calculus) and closed-loop PID control (proportional plus integral plus derivative). As a result, the biggest change is the use of Matlab technical software for dynamic system modeling and closed-loop controller design. Whereas the PLC software in ECI is fairly common, and used in a variety of low-end units from many different companies, Matlab is a unique, high-end, developmental “environment”. Matlab is one of the most universally applied engineering programs; or, as the marketing people say, “the language of technical computing”. Matlab is a standard development environment in both education and industry, and gives MMA students experience in systems programming at the hi-tech end of the engineering spectrum.

As in ECI, the INC class uses a comprehensive textbook to establish the foundation material in the Controls class; “Modeling and Analysis of Dynamic Systems”, [11]. As the MMA engineering curriculum does not include a dynamics class prior to INC, the MADS text includes complete sections on dynamic modeling. In addition to a broad treatment of controls, it also includes sections on Matlab and Simulink, with detailed examples using both for PID control applications.

While on appointment at the US Coast Guard Academy, the author developed a similar class for USCG engineering students with similar curriculum constraints. The INC-Controls class is divided into three parts: 1) dynamic system modeling based on LODE equations, 2) control system analysis using Laplace Transforms and Block Diagram Models, and 3) closed-loop PID controller design with Matlab and Simulink. While INC includes many of the electronic tools discussed previously, INC also uses some new ones.

**Table 4: INC-Multi-Media Tools (in addition to MEP & ECI developed tools)**

- Matlab & Simulink case studies and software demonstrations.
- Email example programs using Matlab.m files (executable command files).
- iLabs (assignments to teach Matlab, and develop dynamic models and parameters).
- Take-Home Final Exam (Matlab PID Closed-loop Design Final)

At present, INC does not include a scheduled laboratory. As a result, the instructor needs to use class time to introduce and demonstrate Matlab. This is done more efficiently by running example programs and models that are developed off-line (outside of class); these programs are known as M-files (filename.m). After demonstration, these M-files can be sent as email attachments along with eNotes and eBiblios as part of instructional email to the class.

Another tool that has been useful and popular with students are team-based iLab assignments. iLabs are interactive, take-home laboratories also known as the “Coke-can Labs”. In these labs, students use physical models (rubber bands and coke cans filled with water) to develop actual parameters for physical models, and then to work together in teams to learn and develop their Matlab skills. These assignments are submitted as email and processed electronically.

INC benefits from a number of PID design case studies found on the internet, and also tutorials within Matlab. While including two paper and pencil exams on Control fundamentals, the INC class needed an evaluation tool that would allow students to demonstrate their command of larger concepts and the use of Matlab for design. As a result, the INC final exam is a PID-

design take-home exam where students are given a week to do an open-ended control system design. While challenging (especially for the instructor to grade), the take-home final provides a valuable learning experience as well.

#### 4.1 INC-Case Study: Segway Scooter Human Transporter

Figure 8 looks at one popular case study for INC-Controls: the Segway Scooter. In addition to being a terrific example of a modern, non-military application of a stability compensator, the system is easily grasped by the student. There is also a wealth of online information for eBiblio background: video clips (on youtube), Wikipedia articles, and even dynamic models for the classic “broom balancing problem”. The Segway case is used in the first week of INC to introduce the class to dynamic models and MIMO (multi-input, multi-output) closed-loop controllers. Then, later, the controller feedback system is analyzed using the block diagrams included within the Segway patent. The author also has a personal connection to the case. He worked directly with one of the engineers who designed the original control system on the original patent.

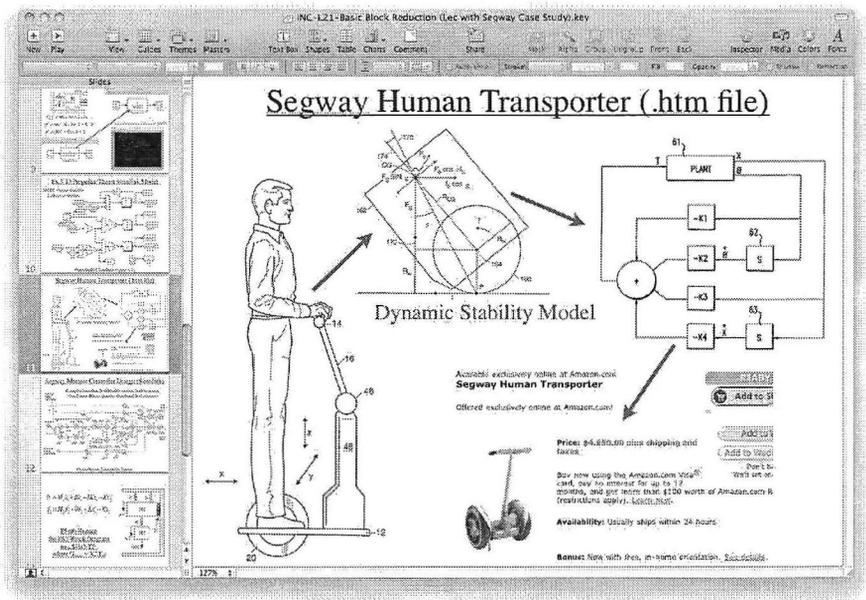


Figure 8: A sample of multimedia Lecture course-notes for the Segway Case Study.

Cc: "Dr. John" <jjbausch@mac.com>  
 3 Attachments, 828 KB

Dear INC,

The Segway Human Transporter (i.e. Scooter) is a great example of mechatronic design using current control system technology (and Matlab!).

FYI-I'm attaching the links and articles I developed for class.

There's some great background information here if you're interested in next generation automation design.

cheers, Dr.B.

**Segway Articles-**

[http://en.wikipedia.org/wiki/Segway\\_PT](http://en.wikipedia.org/wiki/Segway_PT)

<http://www.time.com/time/specials/packages/completelist/0,29569,1991915,00.html>

<http://www.dailymail.co.uk/news/article-1315518/Segway-tycoon-Jimi-Heselden-dies-cliff-plunge-scooters.html>

**Dean Kamen & the US First Competition-**

[http://en.wikipedia.org/wiki/Dean\\_Kamen](http://en.wikipedia.org/wiki/Dean_Kamen)

[http://en.wikipedia.org/wiki/Woodie\\_Flowers](http://en.wikipedia.org/wiki/Woodie_Flowers)

<http://en.wikipedia.org/wiki/FIRST>

**Segway Patent-**

<http://www.google.com/patents/US6661766>

[http://www.patentsform.us/inventors/Dean\\_L\\_Kamen/701867.html](http://www.patentsform.us/inventors/Dean_L_Kamen/701867.html)

**Figure 9:** *A sample of an eBiblio.pdf file sent as email for additional reading in the Segway Case. The file includes eLinks to more detailed background, images & movies, and the original patent.*

## 5. Conclusion

Hopefully, this paper will speak for itself through the brief examples of multi-media and internet as applied to engineering education. In conclusion, the author feels the need to revert to the first person (i.e., I need to get personal). As I tell my students, I left my service in the merchant marine to go on to graduate school because I wanted to study the emerging world of robotics and computers. I wanted to be a part of the computer generation. That expression is now passé. My students have all grown up with computers and the internet. They are the first wave of the information generation; surpassing even Guttenberg, and the age of the printing press; information on demand.

My children have always known the internet, from our first phone-line modem, the family computer located centrally in the living-room (does anyone remember aol?), to wireless internet, to cell phones, to texting, and now the iPad. They even have their own texting language [12, 13]. This is a very rapid transition, in what, a dozen or so years. This is the information generation. More, and more of my students are responding to my email directly from their smart phones, and while they can at least read the text, they still need to sit down at a desk to work with the software on a computer. They still need to read and absorb the articles and dynamic media, and actually take out a pencil and paper to try out some of the calculations and models for themselves. At least their phones keep them up to date on the assignments and due dates (and at some point they will need wicked smart phones).

The subject area of EI&C is also very dynamic; 10 years ago I was using floppy disks, and just starting to use USB and portable hard drives. This summer, in addition to backups to a hard drive, I will transition to Carbonite; an internet-based backup service. I need to. So much of my life is stored in the digital world. But despite advances in technology and in Distance Learning, I believe firmly in the need for face-to-face teaching in small class sizes. The interactivity of classroom instruction (in real-time), the retention inherent in physical note taking

and pencil-based calculations, and the use of hands-on laboratories make a major difference in engineering education. The best students come prepared for class, and participate fully for a challenging 45-minute, interactive experience. The worst students treat the class as a 45-minute T.V. show (and long for a remote channel changer).

Multimedia tools and the internet do provide a much needed supplement to traditional engineering classes, but are unlikely to completely replace key brick-and-mortar resources. This is already seen in the job market with regard to the wider variety of college degrees available. Employers are much more savvy about student credentials. Here is a direct quote heard while providing a job referral, “was that Master’s degree from a thesis program or a non-thesis program”? In the long run, the relative quality of degrees, Distance Learning or Brick-and-Mortar will be decided in the competitive marketplace, or in the words of W. Edwards Deming, “the customer will decide”.

In my experience, distance learning, while an interesting technical challenge, and a potential source of income (certainly from the administrative point of view), simply removes too much humanity from teaching. It’s part of the joy of teaching. I am also convinced that we would do our students a disservice in the long run. I have only a few hard and fast rules for my own teaching. One is to get all quizzes and exams graded and returned by the following class. Another is to learn and use every one of my student’s names, in class, in real-time. That way I can call them by name as they start dozing, and before their heads hit the desk.

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