

## Introducing Information Technology Fundamentals into the Undergraduate Curriculum

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### Abstract

We have been challenged to introduce our students to “information technology” as part of their undergraduate education. This is not an exercise in training people how to use a word processor, rather it is teaching the undergraduate student, from any discipline, the underlying fundamentals of the technology which pervades our daily lives. The genesis of the course is a result from a survey of senior people at Navy operational commands listing the top ten areas where our graduates could use more emphasis in their education. Of those top ten, we developed a course, which addressed seven of the areas. These areas include Networking, the Internet, Communications Theory, Software, Databases and the World Wide Web. The diversity of the topics and the target audience meant that we were not able to go particularly deep in any one area. One of our main goals was to bring a non-technically oriented student up to a conversational level on the topic areas and to provide them with a foundation and a desire to seek a deeper understanding on their own. The initial target audience for the course is anyone who has had two semesters of Physics. As a result, we had ten different majors in the first offering of the course, varying from History to Economics to Computer Science and Marine Engineering. The course is offered as a lab course in order to allow as much hands-on opportunity as possible. In this paper, we focus on the course topics we covered in hope that others who may face this daunting challenge may gain some insight. We attempt to show how we approached some of the more complex topics without the benefit of higher order math emphasizing the importance of cooperative and collaborative learning in this environment. We also hope to show why a course like this rightly belongs in the Electrical and/or Computer Engineering Department and the challenges that brings.

### I. Background

In 1997 a survey was sent out to the number one employer of our graduates, the operational Navy, known as "the Fleet." The twenty-question survey was sent out to the Commanding Officers and senior enlisted personnel on ships, submarines and aircraft squadrons. The survey was part of a larger curriculum review, the Curriculum 21 study panel, made up of people from both inside and outside of the Naval Academy. The purpose behind the convening of this panel was to review the overall curriculum and to see if our graduates were meeting the needs of our customer. Its other mission was an attempt to envision the future and see if the Academy was properly preparing for the needs of the service as we move into the 21<sup>st</sup> century. In other words, was the core curriculum adequate to meet the needs of both the present and the future Navy?

There were about 455 total responses, a 33% return rate. There were many form-based questions (agree/disagree) and a few questions which were open ended where the respondents were asked to provide their own answers such as “What academic disciplines are necessary for Junior

Officer success in your warfare area? List the three most important.” (The top three were Engineering, English Composition and Mathematics) While there were many areas in this survey, we were particularly interested in the technology areas and so we focused on the question: “List (up to five) those Technologies you feel need increased emphasis in the 21st Century.” The response is summarized in the Table 1 below.

<b>Topic area</b>	<b>Percent Responding</b>
Computer Technology	56%
Communications Technology	39%
Information Technology	31%
Advanced Propulsion & Alternate Energy	13%
Computer Networking	13%
Space Technology and Engineering	11%
Computer Literacy with Applications	11%
Electronic Technology	10%
C4I	10%
Robotics and Artificial Intelligence	9%

**Table 1** Survey Responses: Technologies for the 21st Century

Within the areas of Information Technology and with an emphasis on the present instead of the future, another question of relevance in the survey was: “Do you Expect an Officer, upon graduation, to have a level of preparation/proficiency in Information Technology?” and identify those areas. The responses were similar to the earlier question with the results in Table 2 below.

<b>Information Technology Area</b>	<b>Percent Affirmative</b>
Basic Computer	85.5%
Application Skills	82.4%
LAN Management	29.2%
Communications Technology	68.1%
Net Centric Warfare	26.8%

**Table 2.** Specific areas of emphasis within Information Technology

As with any survey, the results can be interpreted in many ways, however, from the responses to this survey, the Curriculum 21 panel made several recommendations. From the executive summary, two that were relevant to IT were: 1) *Increase emphasis of Digital vice Analog Technologies and Systems* and 2) *Increase emphasis on Information Technology Skills*. Again the ubiquitous term “Information Technology” is used to describe the skills desired. The problem being “IT” is not a commonly defined term.

## **II. Information Technology - What is IT?**

If you ask ten different people what Information Technology is, you will get at least ten different answers. IT has become a nebulous term used to describe anything and everything associated with computers and is often tied to the general area of networking. To educators it can be a great enabler to enhance education, but that definition is IT's use as a tool and not as subject matter.

In a recent US Dept of Commerce report where they attempt to address the shortage of IT professionals in the workforce, they ask and answer the question, “What is an IT worker?” They conclude that it depends on whom you ask and that, in a broad sense, the term “information worker” can be applied to data entry personnel, auto mechanics who use computer diagnostic equipment, medical technicians who operate CAT scan equipment, and loan officers who use computers to assess creditworthiness, as well as computer programmers, systems analysts, and computer scientists and engineers. Information technology is clearly important in our lives today since it is pervasive throughout almost everything we do. We are bombarded with advertisements for courses that teach one how to obtain Certified Network Engineer (CNE), Microsoft Certified Systems Engineer (MCSE) or Certified Network Architect (CNA) qualifications. “These are the tools one needs to get that high paying IT job,” we are told. Clearly, these are not descriptive of what we need, nor do we believe these are the skills requested by the IT response in our survey. We do agree with the Department of Commerce Report that "information workers" are what we are producing, regardless of the student’s major and that our students have a much higher chance of operating and/or being in charge of high technology systems.

One question we had to answer was what part of IT do our graduates need to know in order to be more effective Naval Officers? Apparently, we are not the only ones asking this question. There have been several survey courses showing up at colleges and business schools around the country. It is no longer enough to know how to do some basic word processing or simple spreadsheets, it has become important to understand the fundamental technology that directly affects our way of doing business. For example, the Sloan School of Business at Massachusetts Institute of Technology offers an IT course which “...helps students understand technical concepts underlying current and future developments in information technology. There will be a special emphasis on networks and distributed computing.” Obviously for this school, there were certain areas of IT they felt they needed to stress. We have a similar opinion and have the fleet input to help guide us in our selection. One of our biggest problems is narrowing down the choices to a one-semester course. There is so much material to choose from, this turned out to be a daunting challenge.

The one thing we were certain of is that we did not want to give the appearance of a training course. To train or to educate was not a question although we often walk that line in a survey course such as this one. We did not want to train students to be better users; we wanted to educate them to understand the underlying technologies thus enabling them to train themselves. We already offer incoming freshmen an IT course on how to turn on their computer and the use of some basic application software. In the development of our IT course, we purposefully steered away from anything that may have resembled that introductory course. It was an eye-opening revelation that the “Nintendo generation” does not necessarily have any working knowledge of a computer other than how to turn it on and run some basic software.

### III. Goals and Objectives

The objectives of our experimental course are stated as: “EE485I, Fleet IT Systems is a course in information technology engineering fundamentals. It is intended to give the student a fundamental understanding of networking, the Internet, communications systems, software engineering, databases and fleet applications of information systems. Some labs add emphasis on engineering fundamentals of these systems as well as demonstrate their use and purpose. One week is devoted to DOD/Navy/USMC specific applications. This knowledge is directly applicable to your ultimate effectiveness as an officer and warfighter aboard the most complex, technology-intensive, and expensive machines ever built.” Furthermore, our goals for the course are stated as:

- Computer Literacy
- Understanding of IT Fundamental Building Blocks
- Appreciation for the complexity of the problem

We define Information Technology as the technology which transforms data into information. We further state that Information Technology can be *any* technology that deals with this information, from computers and networks to satellite communications. We differentiate between what we call IT skills, which are acquired through exposure and training and IT fundamentals which are composed of the engineering principles that make it all work.

### IV. Choice of Topics

The topic areas we chose to cover were directly related to the topic areas identified in the Curriculum 21 study and our definition of IT. As stated previously, we wanted to focus on the underlying technology of IT and not the end user’s view. We had some help from the executive summary of the Curriculum 21 report which stated areas of emphasis and specific course topic recommendations as listed in Table 3 below. We settled on seven topical areas which we felt addressed both the fleet input and the panel’s recommendations. We then enlisted the support of the Electrical Engineering faculty in these areas to provide a list of objectives in each area. In the areas of Software Engineering and Databases, we also consulted with the Computer Science Department. The selection of the major focus areas was easy compared to the creation of detailed objectives in each area. Also, at the time we were going through this process, we still had not settled on a format or contact hours for the course. As a result, the initial amount of information to be covered was very ambitious.

Recommended areas of emphasis:	Course Topic Recommendations
Information Warfare	Microcomputer Literacy
Net centric Warfare	Elements of a Network
Use & Security of Electromagnetic Spectrum	Information Access
Integrated/Distributed Systems	Data& Telecommunications
	Security
	Software Engineering
	Using Technology

**Table 3.** Executive Summary Specific Recommendations

The initial version of the course included the seven subject modules listed below to be in the course. These modules were mapped to the survey responses and the executive summary of the panel's findings. They are:

- Module 1: Basics of Computer Networks
- Module 2: The Internet
- Module 3: Communications Connectivity and Topology
- Module 4: DOD/Navy/Marine Corps Applications
- Module 5: Software Engineering Basics
- Module 6: Databases
- Module 7: Basic Web Page Design

The magnitude and variety of subject matter is and will always be a challenge from the teaching aspect. One of the ideas mentioned in the development of the course and a reason the course was formulated as modules is that it could be team-taught by several departments. We elected not to pursue that for the experimental version of the course. Another area where the variety of material can be a challenge is in the selection of a textbook for the course. We were lucky enough to have a publisher who also found this to be a unique challenge and found a text which actually covered much of the material. The problem was the scope and depth at which it was covered. We chose two books, one which was a Java book for the software area and a second, *The Computer Continuum* by Kurt Laukner and Mildred Lintner. Without writing a textbook review, suffice it to say this was the closest book of those examined that covered most of the wide array of topics.

Starting with the list of general objectives for each area, the next step was to create a syllabus and a more detailed list of objectives for each lesson which would fit into the course schedule. It was decided that this would be a 2-2-3 course, which meant two hours of lecture each week and a two hour lab period. The result of this decision allowed us to reinforce classroom material with hands-on activities in the lab but the amount of lecture time was very restrictive for the amount of material we wanted to cover.

## **V. Hands on Learning**

The task of fitting a large amount of material into a short span of time simply meant that we were never going to get into depth in any one area. This was both disappointing and difficult. In addition, the first time this course was taught the students came from ten different majors. As a free elective, it was up to their academic advisers as to whether or not it fit their course matrix. The challenge was then how to describe some rather complex topics in terms which all would understand and develop meaningful laboratories which would re-enforce the material covered in the lecture. There is not enough space in a conference paper to describe all of the methods used in the course so I will highlight those that the students seemed to grasp.

In the first module on Networking, the reality of how much material we were going to cover in a short period of time clearly took some students by surprise. We spent some time on the physical layer while most of the focus was on Local Area Networks, Ethernet and Token Ring, performance and network terminology. Students who had the most difficulty in this module were those who had no knowledge of any of the terminology and while terminology is a large part of

the course, we often defined a term in one breath and used it in the next. For one of the labs in this area we simply installed and configured a Network Interface Card (NIC) in the laboratory computers and ran some diagnostics. This is the first exposure to the student's computer knowledge level and there were a significant number who had never opened the case on a computer, even though they had owned one for at least three years. As a result, we spent some time "touring" the inside of the computer, something that was added to the second iteration of the course.

The second module, the Internet, was less intimidating as much of the Internet terminology was more familiar to the students. Still, the Internet Protocol and the Internet in general was a mystery to most of them. In one of the more successful laboratories, we used *ping* and *tracert* diagnostic tools to "tour the world." The students had to find several sites around the world and map them geographically and then correlate the data on hop counts and Internet Service Provider transitions to the round trip response times of their chosen sites.

The module on Communications was the most challenging technically. Many of the students had some exposure to the terms Amplitude Modulation and Frequency Modulation, though most of those did not understand what they meant. In this area the goal was to expose the students to as much communications theory as possible and relate it to the communications technology that they would see after graduation. We covered both analog and digital communications and even included some satellite communications. The labs in this section received the best feedback from the students. Without doing any higher-level math, we used as much visualization of difficult concepts as possible. We used the Matlab Data Acquisition Toolbox in one of the labs to let the students "see" and hear the effects of sampling and quantization noise. We held a satellite communications lab where we talked to amateur radio operators around the country using a low earth orbiting (LEO) amateur satellite. The students also plotted the Clarke belt using a manually steerable television dish antenna where they recorded azimuth and elevation to several geostationary (GEO) television satellites.

The fourth module on Fleet Systems was an opportunity for the students to see how the technologies discussed up to that point in the course were being used by real Navy and Marine Corps systems. We discussed the Navy's plans for the next century and why we focused on the material we were learning. The concept of "Net-Centric Warfare" was much clearer in light of the topics we had covered. Net-centric warfare is the term being applied to the overall focus on networking and networked communications in the Navy and Marine Corps today.

The next two modules focused on Software Engineering and Databases. The goal of these two modules was to give the students an appreciation for the difficulty and complexity of large-scale software and database development. We did want not this to be a programming course yet we did cover some basic software constructs and design philosophies and used the Java programming language for illustration purposes. We spent an almost equal amount of time talking about the design and development processes including testing. In the database module we focused on the design and construction of databases rather than how to use or build one. However, to re-enforce the database terminology, our lab in this area allowed the students to build a small address database using Microsoft Access.

The final module allowed the students to get some insight into the protocols behind a web page and gave them an opportunity to build a personal web page. We felt this was a topic the students would have some experience with already if not having created a web page, at least as a user of the web. It turned out that about half of the students had done some HTML work prior to taking this class and this was a popular area with the students.

## **VI. First Iteration Feedback**

One of our goals from the beginning of this course was to develop an assessment process that would enable us to evaluate the value of teaching this course to all students. The Curriculum 21 study panel was clear that their recommendations applied to all of our graduates, regardless of their major. As a result, we instituted several plans for evaluation of the course. The first method involved a short-term evaluation; we tested the students with a generic technology quiz on the first day of class. We gave the same quiz on the last day, unannounced, to see if their basic knowledge had improved. The results were quite good with only a few areas that did not appear to take hold. We also implemented a web based feedback form that would allow the students to give their opinion on each module as we completed it and while it was still fresh in their minds. This form was anonymous with the option to provide their name for further discussion/clarification of their viewpoint. The responses, while sporadic, provided valuable input for the second iteration of the course. In addition, we have our standard department evaluation forms, which the students are familiar with, and can be useful in a course to course comparison. The most difficult task for a course evaluation is to prove some long term benefit. Obviously, this will not happen for a while but we have plans to track the first group of students and request feedback from them after they have been in the fleet for a couple of years.

The initial offering of the course was well received by the students. Also, a common response by many on the faculty who have reviewed the syllabus is that they would like to take "a course like this." By its broad nature, it usually covers some aspect of IT that people are not familiar with. One thing which was clear in the student feedback was that the hands-on laboratories were invaluable in driving home the concepts and terminology introduced in lecture. We did not teach anything that the students thought was a waste of time. We may have covered some subjects too quickly as we tried to insure that certain concepts were covered. This is where some minor restructuring of the course will help. Upon completion of the first attempt at teaching this course, many lessons have been learned. One thing we feel confident about is that the original objectives were very closely met. The students' comments reflect that the course was successful in educating them in critical IT areas.

## **VII. Second Time Around Changes**

This course is being taught for the second time in the spring semester. The original modules have been modified and there were minor changes to the original syllabus and objectives. The objectives were re-written with more realistic expectations of the students' capabilities and knowledge. Some objectives were dropped, some were added and some were clarified with the appropriate wording reflecting our lessons learned. One of the experiences from teaching this course is that some topics can be covered survey style while others are simply too difficult. The hardest topics to cover turn out to be those where the laboratory does not provide a good environment for re-enforcement or there is simply not enough time in either class or lab.

Because the course already contained a lot of material, some modules had to be reduced in scope to make room for areas which were not well covered. A module on basic computer architecture was added in the beginning of the course covering the internals of a computer. Another topic that was added is the unique military requirements placed on IT systems. Military systems have to survive sea spray, salt fog, severe temperature ranges and other unfriendly environments. A module on maintainability, sustainability, reparability and fault tolerant, real time systems has been added. While these topics continue to be woven throughout the rest of the course, basic terminology and definitions needed to be introduced. Finally, the networking section needed to be lengthened to be able to address some timely and relevant topics which were not covered, such as Asynchronous Transfer Mode (ATM) and Digital Subscriber Lines (xDSL). The biggest problem with adding any material to this course is that something has to give way. The reason that this is so difficult is that we have to stay within our three-credit hour limit. We can't add any more contact hours, the laboratories are too important to lose and the course is already too full. Given this, we had to make a trade-off with some of the other areas. To accommodate the additions, we scoped down the database section and the Software Engineering area. The new modules, shown below, reflect the second iteration of the course.

- Module 0: Basics of Computer Architecture
- Module 1: Basics of Computer Networks
- Module 2: The Internet
- Module 3: Communications Connectivity and Topology
- Module 4: DOD/Navy/Marine Corps Applications
- Module 5: Software Engineering and Database Basics
- Module 6: Basic Web Page Design

The two weeks we had initially devoted to databases was absorbed into one week of Computer Architecture basics where we cover the internal components and interfaces of a personal computer and rudimentary microprocessor architecture. The other week we had devoted to databases was split between an extra lesson in networking and the military requirements area. The database lab remained in the syllabus as a practical method to explain database composition.

### **VIII. Why EE or ECE and not CS?**

Since much of IT is closely related to computers, initially it would appear to be a good match for a Computer Science course. However, on closer examination of what we wanted the students to learn, much of the underlying technology is not software. Interestingly enough, the Commerce Department study stated that the National Science Foundation does not consider computer programming as a science or engineering occupation. We consider computer science to be a great deal more than computer programming, however, it is often further away from the hardware and thus the underlying technology. Most of networking and communications is Electrical and/or Computer Engineering. One of the traits of being an engineer is that we often have to be inventive and practical in figuring out a solution to a difficult problem. From that perspective, this type of IT course is a perfect match for an engineering course, it is a difficult problem for which there is no obvious solution on how to teach it. In addition, modules on communications theory and satellite communications are clearly outside the scope of a typical



computer science department, yet fundamental to data communications. We have considered changing the name of the course to "Data and Computer Communications" to alleviate the confusion surrounding the term IT, yet it does not address all of the material covered in the course.

## IX. Future Directions

Aside from continuing to offer the course and assess its effectiveness on the student, we have plans to go back to some of the operational commands that participated in the original survey and show them what we have done. We also plan to get back to some of the key members of the Curriculum 21 panel and give them an opportunity to comment. In addition, we feel that even after the second time teaching the course, the content will not be entirely stable. In this area it is usually not a question of what to teach in the course but rather, what do you leave out? One of the great challenges in teaching a course about technology is not getting out of date. In order for this course to work, it has to stay current. However, we believe that as long as we stay focused on teaching the fundamentals of the technology, whose lifespan is much greater than an instantiation of the technology, we will be successful. Part of the plan is to work on a methodology to accomplish this goal.

The final challenge of this course is to continue to evolve the teaching techniques and pedagogy to make the material take root. To accomplish this task, we need to insure that the labs are complementary and reinforcing of the classroom material. We also need to continually evaluate the material and the flow of the content such that the bigger picture, of which each of these components is a part, can become clear to the student by the end of the course. It is important from the pedagogical perspective that this course not be taught piece-meal or threaded into existing courses. The thread for an engineering fundamentals course is too easily lost when this occurs, yet this is often mentioned where there is a misunderstanding of IT as we teach it. Information Technology is composed of many facets, yet we need to convey to the student that while the successful transmission of data is important, in Information Technology, the conversion of that data into information is also important. In order to do that, we need to present a complete picture.

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