Session 1661

Technology 21 – A Course on Technology for Non-Technologists

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Abstract

There is a need to prepare non-technologists to assume senior management, political and other leadership roles in a highly technological world. Many non-technical college students have a fear and distrust of learning things mathematical, scientific or technical. At the University of Denver we have created a successful three-quarter long course called Technology 21 that has been offered for fourteen years to non-engineering and non-science students as a means to meet their science general education requirement. The course covers the three basic resources of technology – Energy, Materials and Information – during the first two quarters. At the start of the first quarter a discussion of numbers to include orders of magnitude, charting of data and proper presentation of data using numbers is presented for a better understanding of the numerical content of the course. The material in these first two quarters remains relatively constant and includes numeric and laboratory components. The course culminates with a capstone quarter wherein students working in groups of ten are required to solve a current national or global technological issue for either the current US president or Congress. Issues change every year and address such topics as “What should US policy be towards: Electricity”, “Petroleum”, “Automobiles”, “Global Warming”, “Mass Transit”, “The Internet”, or “Nuclear Energy”. Each group is required to produce a learned, 20-page, single-space, coherent policy paper that considers the scientific, technological, social, political, economic, legal, safety, environmental and ethical aspects of the issue. Each group must orally defend their position vis-à-vis other positions arrived at by other groups in a press conference type setting. Invited lectures by local and national experts, as well as, other experts from across the faculty add realism to the course since they often express contradictory views. Enrollment is usually capped at about 90 students and the course has always had a long waiting list.

I. Introduction.

A persistent, if unsung, challenge for institutions of higher learning is to graduate technologically literate graduates in non-technical fields. Students of the Liberal Arts, Business, Law, and others non-technical disciplines are usually required to take a common, general or Core curriculum for the specific purpose of expanding their horizon and turning what would otherwise be a narrowly educated practitioner into a broadly educated professional. As our society becomes increasingly dependent on technology, it becomes essential that we provide all our students with
knowledge that opens their awareness to various technologies around them and their possible societal impacts. This increases a student’s ability to meaningfully participate in technological arguments and to make smart decisions as to the adaptation of particular technologies. A few recent examples of technological decisions with far-reaching implications range from the overhaul of our national power grid, the adaptation of HDTV (See Appendix II for acronyms), electronic fingerprinting and whether or not we should return to the moon and go on to Mars.

Over the last decade there have been calls by some noted individuals such as Nannerl O. Keohane\textsuperscript{1} when she was president of Wellesley College, William A. Wulf\textsuperscript{2} current president of the National Academy of Engineering and others\textsuperscript{3} who have recommended adding the knowledge of technology to liberal education. In 1991 Dr. Keohane speaking about educating women wrote:

\begin{quote}
Teaching the leaders of tomorrow will also require the ability to turn their sophistication with TV and computers and video to good advantage. And this means an education in technology. Burgeoning stores of instructional software are now available in almost every field -- in classics, history, art and anthropology, as well as math and science. Such software allows students to create exemplary graphics in math and science, to perfect their understanding of a foreign language by electronic immersion in another culture, to explore ancient buildings and great museums of art at their own desks, to find a word in Homer's Iliad at the touch of a fingertip. It will be particularly important for our future women leaders to become familiar with such technology, since women have traditionally shied away from math and science and too often have been afraid or ignorant about technology. If they are to be confident leaders of tomorrow's world, they must understand the power of such techniques and be comfortable with using them.
\end{quote}

More recently Dr. Wulf in his keynote address to the 2002 Annual ASEE Conference made a most compelling statement about the need for including technology in liberal education:

\begin{quote}
In "real life" I have been a professor at the University of Virginia, which was founded by Thomas Jefferson. He founded the university based on the conviction that we could not have a democracy without an educated citizenry.

I think he would consider the current state of his democracy to be dangerous. Technology is one of the strongest forces shaping our nation, and our representatives in Congress are called upon regularly to vote on issues that will profoundly affect the nation -- and whose roots are technological. Yet both those representatives and the people who elect them are, for the most part, technologically illiterate.

Every person with a "liberal education" needs to be technologically literate!

I am consciously saying "technologically literate" and not just "scientifically literate" because it’s not enough to understand something of nature, what is. An understanding of the larger "innovation engine", the process by which an understanding of nature is converted into what can be -- into a better, richer life -- is critical.

Engineering schools have not traditionally provided courses for liberal arts majors -- but in my view they must. These courses will not be of the kind we are accustomed to teaching, since they need to relate technology and the process of creating it – that is engineering, to larger
societal issues. But the urban myth of engineers, whether faculty or practitioners, is in my experience just that -- a myth.

In a Bridge article in the Summer of 1996, analyzed some popular modern American history texts and discovered that most of them ignore the impact of technology on society -- yet nothing, absolutely nothing has had a more profound impact in the 20th century.

Teaching non-engineers about technology has long been a charge of professional societies. For example, the Institute of Electrical and Electronic Engineers (IEEE) fifth tenet in its Code of Conduct states the obligation of all of its members
to improve the understanding of technology, its appropriate application, and potential consequences

Universities often tout their general education or Core requirements in their catalogs and web pages, yet few have a required course in understanding the implications of technology. The University of Denver, for example, has developed a unique award-winning Core curriculum. In their web-catalog they state,

“One of the goals of a liberal arts education is that students become well-rounded individuals. That means wide exposure to a variety of academic disciplines across the arts and sciences, as well as a foreign language. We take pride in the fact that all DU graduates, no matter their major, leave here having completed University Undergraduate Requirements courses designed to provide a broad education.”

The course described herein is part of that Core curriculum. But even at DU the course is considered part of the Natural Sciences requirement not a separate area of study.

No matter how well intentioned and designed most Core curricula fall short of providing a true liberal education by limiting the exposure of non-engineering students to technology – not so much in using technology as understanding its impact on society and the role of the graduate in making smart decisions concerning it. In this paper we present a different way of looking at liberal education – a new paradigm. Subsequently we outline a successful yearlong course offered for fourteen years at the University of Denver that helps fulfill the need for courses designed to provide technological literacy and numeracy.

II. A Truly Liberal Education

In selling the significance of including technology in a liberal education it is important to envelop a logical construct that places technology on a par with the other generally accepted liberal divisions of knowledge: the Arts and Humanities (AHUM), the Social Sciences (SOCS) and the Natural Sciences (NATS). To develop this construct, we begin by assuming that we can encompass all known knowledge within a boundary – a circle for simplicity. In this approach we assume that there is no known knowledge outside the circle – all that is known about the universe, about our behavior, about the laws of physics, of biology, of everything lies within the boundary of the circle – excluding theology. Knowledge or truths still needing to be "discovered" or created lie outside the circle.

We can begin to create our taxonomy by partitioning the circle into two halves as shown in Figure 1. The left half holds all the truths that have been found that are natural, basic or
fundamental – that is truths, the existence of which men and women had nothing to do with, other than their discovery. The right half are applied truths -- those natural truths that have been modified or adapted by men and women for their use. As additional "truths" are uncovered or natural truths modified into applied truths the circle grows in size.

We can partition the same truths into another way as shown in Figure 2. We can call all the truths that are best explained and understood using words, language or non-mathematical symbols literate truths. The remaining truths represent those that are best-described and understood using numbers or formulae. We call these facts numerate truths.

If we superimpose both of these divisions on a single circle we produce four quadrants as shown in Figure 3 that can be viewed as the basis of a Core curriculum. Three of the four quadrants represent the traditional areas of a Liberal Education, the remaining quadrant -- the one involving numerate, applied truths -- we will call TECH -- short for Technology. This fourth quadrant, we believe, is as important as the other three and more often than not in a modern society is the source of issues and problems that must be resolved vis-à-vis the knowledge and understanding gained from the other three quadrants. It is our thesis that learned individuals, that is, liberally educated college graduates, should possess appropriate knowledge from each of the four quadrants. The role of the Core, then, is to ensure all individuals that graduate possess this knowledge regardless of what discipline they pursue. It should be noted that individual disciplines do not always lie neatly in these four quadrants but often spill over across these boundaries.

Universities have had many decades of practice in determining what set of knowledge best helps fulfill the needs of the traditional areas, and although there is always innovation in what to cover and how to present it, there is general agreement on the broad types of knowledge that one expects from a college graduate in the areas of Arts and Humanities, Social Sciences and the Natural Sciences. That experience (and legitimacy) is not immediately available regarding the area of Technology.

Believing strongly in the need to help produce a technologically literate citizenry, in 1988 the Department of Engineering at DU set out to create a course designed to fit into this new quadrant. We will describe that course next.

III. Technology 21 – A Course for Leadership in the New Millennium

With the above background in mind several engineering faculty met and created the pedagogy for a new Core course that would fit in the technology quadrant. We set up several challenges so that when students had completed the course they would have gained some of the knowledge and
experience to help them in making smart choices about technology – for their career and for themselves. We wanted students to know what questions to ask about such things as costs, power, safety, reliability, ethics, usefulness and consequences of the technology they recommended or purchased. The course had to be seen as clearly useful to each student. In sum, we desired to create a course that met two overarching goals:

- To expose students to the key basic resources that humankind has available to create technology and to provide some insight to the scale, limitations, and possibilities of each resource.
- And to subsequently have students bring this new knowledge and that of their individual disciplines to bear on a recommended solution to a challenging current, national, technological problem.

In determining how to organize such a course we settled on developing three modules one on each of the fundamental resources needed by humankind to develop its technology: Energy, Materials and Information. The first resource provides the effort needed for things to work. The second represents the “stuff” that things are made out of. And the third is what has revolutionized our society, namely the availability, processing and transferring of information. Although our intent was to keep the use of mathematics to the minimum necessary to understanding the topic at hand there had to be some numeracy to understanding technology. We recognized that non-technical students needed a better insight into numbers – especially very large and very small numbers, exponentials, and the ability to interpret charts and graphs. We begin the course with some coverage of numbers and numeracy as part of the Energy module.

Throughout the yearly offerings we kept the purpose of these three modules constant. The reason was to make them generic enough so that the course would not become too dependent on any one instructor. Over the years most of the department faculty members have taught in the course. In spite of different instructors their efforts have been to improve the course by modernizing the topics and by improving teaching techniques and tools, but have kept the basic purpose of each module intact. Students meet our first goal by completing the first three modules.

We knew from the very beginning in designing our course that meeting the second goal was to be our most challenging task. We wanted to have the students work in teams in order to combine their varied disciplinary and often divergent backgrounds and to understand a major technological issue sufficiently well that they could make a serious recommendation for its solution. We decided on a module that would focus on a current technological issue that was receiving a lot of national press and viability. The issue was to be broad enough that they all knew of it and may even have a preconceived opinion for a solution. However, the issue would be complex enough that once its subtleties were exposed, its solution became very complex and obscure. Each team was required to consider the solution from a scientific, technological, social, legal, ethical, economical and global perspective. To further complicate the finding of a solution, students would be provided with in-depth views from “experts” that were often biased. The intent was to have students tussle with the realities of making a team decision on a very complex issue. Then once they made their decision they had to “sell” their solution to others who might have arrived at a very different solution. The issue is changed yearly to reflect a current national technological concern and to help avoid the “borrowing” of data from previous offerings. The course description and outlines of each module are appended.
IV. Course Mechanics

The course extends over three-quarters for four credit hours per quarter. It carries a Natural Science tag (NATS 1204) and has been offered for fourteen years to about 100 students per year. It is organized in four modules offered over three academic quarters (10 weeks per quarter). The course meets three times a week for fifty minutes and there is a two-hour laboratory period (first two quarters) or a two-hour seminar period (last quarter) per week.

The Energy module is delivered during the first five weeks of the first quarter and the Materials module during the second five weeks. The Information module is divided into two parts of five weeks each. The first part is on Information Processing (Computers) while the second is on Information Transfer (Communications). The last module on the Issue is taken during the third quarter and lasts ten weeks.

Six usually different faculty members are assigned to the course. The Energy module is taught by a physicist; the Materials module by a mechanical engineer; the first part of the Information module (Computers) is taught by a computer engineer, while the second part (Communications) by an electrical engineer. The Issue module is co-taught by two faculty members that are selected as most knowledgeable of the issue to be covered. The Issue module also asks faculty from other parts of the campus that are experts on various aspects of the issue such as from the departments of Social Science, International Studies, Law, Economics, Biology, Geography, Chemistry, Physics, Political Science, or from local, state or federal agencies, local companies and non-profits advocates to provide key lectures. Who we invite depends on the Issue. One person we always invited was the Head of freshmen English who reminded students the mechanics of how to write good policy papers. There are two teaching assistants assigned per quarter to help with the various duties especially setting up the laboratories and observing in the seminars.

V. Course Content

The following section outlines the content and syllabus for each module. Since the content of the first three modules remains mostly constant the following represents what has been delivered throughout the various yearly offerings. The Issue module varies greatly and what is described represents a general philosophy of what is typically covered.

A. Energy Module. The Energy module is delivered through traditional lectures three times a week with a supporting two-hour lab that meets weekly. It will cover the concepts and physical definition of energy and how it is used in practice. To show the importance and diversity of energy in each student’s life, a project concerning a current energy problem will be required.

The syllabus for the Energy module is as follows:
1. Measurements, units and data analysis
2. Introduction to the study of energy
3. Energy mechanics
4. Conservation of energy
5. Home energy conservation
6. Solar energy
7. Fossil fuels
8. Air pollution and global warming
9. Generation and transmission of electricity
10. Renewable energy sources
11. Nuclear energy
12. Energy module review
13. Energy module examination

B. **Materials Module.** The Materials module is delivered through traditional lectures three times a week with a supporting two-hour lab that meets weekly. The materials segment of the course will examine basic material properties with relevant examples that show how the basic properties of materials affect their applications. We will also discuss new materials created to meet special needs. Materials are fundamental in practically every phase of human life. Recognition of their fundamental nature and an understanding of their properties are essential for success in our technology-oriented society.

The syllabus for the Materials module is as follows:
1. Introduction; “Weight” of materials
2. Strength of materials
3. Stiffness of materials
4. Directional properties of materials
5. Movement of moisture, heat, and air through materials
6. Material properties versus design properties
7. Wear and environmental degradation of materials
8. The effects of repeated loading on materials
9. Cushioning applications of materials
10. Dissipation of impact energy by materials
11. Reliability, flaws and product liability
12. A review of the materials block
13. Materials module examination
14. Student evaluation; project questions; return of examination
15. Materials reports due

C. **Information Module.** The Information Module is divided into two parts – Information Processing and Information Transfer (Communications).
   - The **Information Processing** module is delivered through traditional lectures three times a week with a supporting two-hour lab that meets weekly. Students learn how computers transfer, process, and use information. To this end, an introduction to the organization, the internal components, of a personal computer is presented; followed by a study of how computers process information and the many ways in which the processing power of the computer is used (the internet, software applications, music, language, speech, graphics, etc.).

The syllabus for the Information Processing section is as follows:
1. Computing Issues – E-voting, identity theft, computer viruses
2. Computer Organization
3. Encoding Data – Binary numbering system
4. Music and Pictures (Sound and Graphics)
5. Internet and Multi-Media
6. Information Processing section examination

- **Information Module (Communications).** The Information Transfer section is delivered through traditional lectures three times a week with a supporting two-hour lab that meets weekly. In this module students examine the informational aspect of a computer or telecommunication signal. This will be tied to every day appliances/applications such as: the TV set, radio, household phone, cell phone, computer, Internet, etc. Issues such as the data encoding/decoding, information measurement and cryptography will be discussed with the aid of applications.

The syllabus for the Information Transfer section is as follows:
1. Introduction to Information
2. Encoding/decoding for error correction/compression
3. Measure of Information
4. Information Security
5. Review
6. Information Transfer section examination

**D. The Issues Module.** The Issues module is delivered through traditional lectures three times a week and a weekly two-hour seminar wherein each team meets alone and organizes itself into a task force with a leader to solve the problem at hand. A teaching assistant acts as an observer in the seminars and keeps track of each team member’s contribution to the team. Grades in this module consist of 50% individual grade (block exams on in-class lectures), 40% team grade (Policy Paper and its oral defense), and 10% peer evaluation (individual’s contribution to the team).

In broad terms the earlier three earlier modules were designed to give students a technical background to prepare them for this exercise. This module represents the “practical” or “doing” part of Technology 21. In this module students will be given a real world technological issue to attempt to solve. The problem is never a trivial one, the answer may be quite difficult to find and in fact, asking the right questions may prove to be just as challenging as finding the answers to the problem itself. Fortunately students will not tackle the problem alone. Each student will be a member of a team of 8 to 10 students that must all work together to arrive at the best answer possible. Students are asked to imagine themselves as members of a *Think-tank*, which has been given a technological issue to solve. Their team is to produce a coherent 20-page single-spaced “Policy Paper” that puts forth a concise policy statement that could be adopted as viable, practical US policy.

For the group to solve this problem they need to gather lots of information. From the information each team will have to sift the truth from fiction, facts from emotions, and major issues from minor ones. To help teams with exposing the facts, we ask several experts from both on and off campus to talk to the students in the course on areas in which they have expertise. These experts (a few of the many organizations that
participated are shown in parenthesis) are members of government (local (RTD), state (CIT) or federal (USAF, NOAA, WAPA, NREL, DOE, LANL)), industry (Toyota, GM, Excel Energies, Qwest), quasi-political organizations (NCSL), environmental groups (Greenpeace, EDF), academicians (DU, CU, CSM, UC-D), etc. that are known to espouse a particular viewpoint on the issue at hand. Although these individuals are all noted authorities they come, as all individuals do, with strong opinions about the topic they are discussing. They will be essentially providing information that each team must deal with. In addition to expert testimonies presented as lectures in class each team must search for other material from the Library and the web that would provide credible justification for their ultimate position. They must “brief” their findings to the guest faculty who evaluate the positions and their presentation and to the other student teams who likely will have arrived at different solutions and are eager (for team points) to challenge the presenting team on their position.

Issues that have been studied thus far varied considerably and tended to follow a current hot topic. All of the Issues begin with “What should US Policy be Towards _____” and specific topics were Nuclear Energy, Space, Petroleum, The Ozone Hole, Space Station Freedom, Renewable Energy, Global Warming, Mass Transit, Automobiles and Light Trucks, Electricity, and the Internet. Since there is considerable variability on speakers and topics depending on the issue there is no consistent syllabus. Rather the course generally has several lectures on the science of the issue, several on the engineering, several on social and political concerns, always several lectures on economic issues and possibly a lecture on legal issues, a lecture or two on background and history, and possibly a lecture or two on possible scenarios if the issue is not solved. At the end of the course the group papers are graded and returned to the group. A copy is kept on file to share with interested individuals.

VI. Conclusion

We have shown that a popular, credible, yearlong course can be developed that helps to educate non-technologists to make smart decisions regarding technology in their lives and careers. The overall course has been extremely successful in meeting its overarching goals. It has been offered continually for thirteen years and is scheduled for a fourteenth. It has survived two major top to bottom revisions of the university’s Core curriculum and it is still viewed as instilling essential integrative, decision-making value to students. Because the Issues topic is always current it is very popular among students and always generates positive critiques. That is borne out by a waiting list of students every year who want to take the course.

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1 Interestingly students often come to the course with preconceived views and opinions on these topics that are current and usually carried widely in the mass media. Nevertheless, after studying the course and hearing talks by authorities in the field many will change their prejudices. For example, at the start of the Issues block out of ten groups working the nuclear issue problem most individuals, including a vocal group of students from Sweden, when asked their opinions wanted nuclear plants removed. By the end of the course after studying all practical alternatives, and in spite of anti-nuclear advocacy by several external speakers, seven of the groups decided that nuclear energy has a strong place in the US energy mix and should be continued or increased, two groups said that the plants should be allowed to operate until they need replacement and then be replaced with renewable or fossil-fuel plants. Only one group said that all nuclear plants should be discontinued as soon as possible.
Numerous individuals (including Dr. Wulf of the National Academy of Engineering), deans and department chairs have enquired and received information about this course over the years. While some schools offer courses on the history of technology or the impact of technology we are not aware of any institution that offers a similar year-long, hands-on exercise on learning how to make smart choices about technology.

VII. Acknowledgements

This course owes its success to the many dedicated engineering faculty that helped develop and evolve the course and to the many speakers from other parts of the campus and from external agencies, universities, companies or organizations. Ownership of the course rests with the entire department for its support and its continued success. The following specific individuals have made extraordinary contributions to the course: Ronald R. DeLyser (EE), Irvin R. Jones (CpE), J. Chuck Wilson (ME), Daniel Armentrout (PHYS), Marvin A. Hamstad (ME), Gerald P. Edelstein (PHYS), Roger E. Salters (EE), Margaret Whitt (ENGL), Don Stedman (CHEM) and Richard Caldwell (IPPS).

Bibliography


Biographies

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GEORGE EDWARDS received the BS, MS, and Ph.D. degrees in electrical engineering from the University of South Florida. For five years he worked at Precision Systems (PSi) in St. Petersburg Florida, on research and development of real-time DSP algorithms. His research interests include cellular communication, personal communication systems, modeling and performance analysis of communication systems and networks, signal processing, image processing, and the application of fuzzy logic and neural network in communication.
Appendix I. Catalog Course Description

NATS 1204 (1,2,3) Technology 21
Technology 21 is a course for leadership in the new millennium. The course prepares you to make wise technological decisions. Today technology is pervasive in every fiber of the fabric of the human effort. Decisions on technology that affect all of us are rarely made by scientists or engineers—but rather by business people and politicians who often are swayed by emotion, popular opinion, misconceptions and/or mistrust of technology. This course will provide you with sufficient background to help you make smart technological decisions. The first two quarters help you understand the basic resources available to humankind to develop technology: energy, materials and information. These resources comprise the fundamental building blocks of a modern technological society. The first quarter begins with a review of numeracy—since all technology is in a major part numbers-based. Then the course demonstrates our dependency on energy. The amount of energy used is staggering, especially when most of our energy comes from non-renewable fossil fuels. This dependency is a major political issue. The final topic discussed in the first quarter is a look at materials. Almost everything technological is made of some tangible “stuff.” This block looks at the stuff used today, including modern materials like composites and ceramics. The second quarter looks at information. Today information drives much of the technological world. The second quarter looks at both the processing of information, i.e. computers, and the transmission of information, i.e. communications. This quarter you will obtain an understanding of the technical language of computers and communications. You will look at limitations and goals of information—like the third and fourth generation personal communication devices that will combine functions like personal day planners, with the Internet and cell phones. The last quarter allows you to practice making smart technological decisions on a national or global issue. The issue will be approached in a team effort of about 10 students. The team looks at the issue from a scientific, technological, social, legal, ethical, economical and global perspective. The team, made up of students from different disciplines, will bring different, often divergent, views to the group. During lectures the team hears from experts who may also offer similar contradictory positions that often reflect the real world. In spite of these positions the team must develop the best compromise position on what United States policy on the issue should be. The team’s policy will be presented in a position paper and articulated in a “press conference” to the other teams, who might have arrived at quite different conclusions.

Appendix II. Acronyms

ACLU – American Civil Liberties Union
CIT – Colorado Institute of Technology
CSM – Colorado School of Mines
CU – University of Colorado – Boulder
DOE – Department of Energy
EDF – Environmental Defense Fund
HDTV – High Definition Television
LANL – Los Alamos National Laboratories
NCSL – National Council of State Legislators
NOAA – National Oceanographic and Atmospheric Administration
NREL – National Renewable Energy Laboratory (DOE)
RTD – Regional Transportation of Denver
UC-D – University of Colorado – Denver
USAF – United States Air Force
WAPA – Western Area Power Administration (DOE)