2006-620: TEACHING TECHNOLOGICAL LITERACY: AN OPPORTUNITY FOR DESIGN FACULTY

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Teaching Technological Literacy:
An Opportunity for Design Faculty ?

Abstract

The National Academy of Engineering, the National Science Foundation, and various prominent engineering faculty and administrators have pleaded over the last decade that technological literacy is a topic which engineering faculty ought to provide for non-technical majors. We explore here the notion that design faculty are well qualified, perhaps uniquely so, to teach such courses for non-technical majors, i.e., to represent engineering and technology to the non-technical campus population.

Engineering design instruction is universally present on the more than 300 campuses hosting an engineering school. Since each engineering department has at least one design instructor, in excess of 1,000 faculty are identified from which to recruit future technology literacy instructors. We propose this novel activity as a logical component of design instruction. Further, such novel participation will accomplish a second goal, long sought by design instructors, namely that their profession will have an increased, and more public, visibility and appreciation. In sum, involvement of design instructors as teachers of technology literacy will both assist a national need and simultaneously satisfy a professional goal.

Our presentation is structured as follows. We first consider the definition of technological literacy, noting its many dimensions and its need to represent technology through a variety of lenses including historical context, technical content, and device dissection and assembly. We then cite the similarity of activities undertaken by both design instructors and teachers of technological literacy, in particular the broad range of issues (historical, economic, technical, social) inherent in design instruction and problem solving. In consequence, we propose instruction in technological literacy as a new opportunity for design faculty. Through this activity, these faculty will be among the first to be viewed by non-engineering students, not just the last instructors to be encountered by undergraduate engineers. This situation could provide design instructors with a new and professionally rewarding territory for representation of both the design process and designers themselves.

Introduction

More than ten years ago, Edward W. Ernst [1] discussed the technological literacy of students in non-technical majors:

> "Within the past decade (approx. 1985-1995), those at NSF concerned with science, engineering and mathematics education have suggested that technical education of non-specialists should concern those in higher education as much as the education of technical specialists."

He noted also that non-technical curricula often require a technical contribution, presenting a potential opportunity for students to choose engineering and technology courses. This opportunity routinely goes unrealized because engineering schools fail to provide "service courses" for non-engineering students. In consequence, such students "… nearly always [select] science and mathematics courses" instead. This circumstance is unreasonable, Ernst argued, because "Technology literacy for the 21st century requires not only an understanding of mathematics and science, but also an increasing understanding of engineering, which has shaped, if not created, our man-made world. "

Within a national context, for K-12, colleges, and universities, and the general population, the present situation is not substantially different. A two year technological literacy study performed by NAE , funded jointly by NSF and Batelle Memorial Institute, was completed in 2002, and published as *Technically Speaking, Why All Americans Need to Know More About Technology* [2] The report concluded that "The idea that all Americans should be better prepared to navigate our highly technological world has been advocated by many individuals and groups for years Nevertheless, the issue of technology literacy is virtually invisible on the national agenda [1]."

As a following activity, NSF last year sponsored an expert workshop[3] to assemble current technological literacy faculty, with NSF and NAE observers, to identify and discuss academic issues arising if increased undergraduate instruction in technological literacy is to be achieved on US campuses. The dozen or so practitioners of technical literacy instruction were drawn from electrical engineering, chemical engineering, mechanical engineering, and physics. Such broadspread and apparently arbitrary prior background suggests strongly that there is not yet an inherently unified instructional group which could lead a charge towards increased technological literacy instruction. <u>If instruction in this topic is to increase, from whence will come the US instructional manpower pool ?</u>

We advance the notion that engineering design faculty are particularly qualified to teach such courses for non-technical majors, i.e., to represent engineering and technology to the non-technical campus population. Recently we reviewed the attributes of the various groups promoting technological literacy[4]. We noted that engineering, with its balance between theory and practice, has a distinct and highly effective perspective on technology, making engineers especially qualified to explain technology to the non-engineer. Here we focus on engineering design faculty as those engineers most qualified to carryout this effort.

Themes of Design and Their Relation to Technological Literacy Instruction

The multiple dimensions of technological literacy instruction (historical, economic, technical, and social) relate clearly to the central themes of engineering design.

Theme: Design is multidimensional Technology literacy instruction may contain lectures on history and technical content, laboratory work involving device dissection, assembly, or even de novo construction, and complete case studies (technical, economic, social and cultural aspects). As students with different learning styles may receivesome of these approaches more easily than others, the multi-dimensionality of technology literacy instruction opens a broad door to exploring the psychology of how students learn information presented in different contexts

Theme: Design as inquiry and learning Design is an activity driven by societal , governmental, and corporate needs. The history of artifact and system design tells us about how we have responded to characteristic institutional needs, for example: communication, transportation, and mechanical power. Thus design may present a “user friendly” entryway for general undergraduates to understand technology and the impact it has had on their lives.

Theme: Learning how to design. Technological literacy frequently involves the physical exploration of current artifacts, through dissection and assembly of existing devices, and thereby provides a deep contact with designed objects. Such device manipulation, and the step-by-step consideration of their operation, reveals much about how engineers design, and the processes involved in the activity of design.

Need for Technological Literacy

The NAE report *Technical Speaking* urges that citizens must understand our technical environment. Such knowledge, according to viewpoint, may include knowing the object and its functions (how stuff works), knowing as well the process by which it arose as a designed object, and even knowing the historical and social context from whence it arose. All three dimensions are included in case examples, such as biographies of scientists and engineers, and histories of particular technical developments. Among undergraduate technical subjects, design is pre-eminent in its content of these dimensions. Hence, design faculty may be those instructors particularly well suited to develop an instructional community in technology literacy.

To be sure, other instructional pools suggest themselves. Technology literacy requires the cognizance of multiple dimensions of technical endeavor. Other faculty with such broad background include those who teach the first year introduction to engineering courses (i.e., those who teach across the majors, as students have not yet chosen a major) and engineering faculty who lead “device dissection” labs of one type or another. Easily the most populous of these three categories is the cadre of design instructors, as “capstone design” is virtually universal among engineering schools, whereas first year instruction is highly variable in coverage and level of effort, and even device dissection labs are not present in the majority of engineering departments.

The materials needed for instruction in technological literacy courses (TLCs) are substantial and varied. Materials available to address this need include an increasing number of books by engineering and science authors such as Billington [5], Bloomfield [6], Florman [7] , Lienhard [8] , and Petroski [9]. Radio programs featuring engineers are written and narrated by John Lienhard on National Public Radio in the United States [10], and Bill

Hammack on Illinois Public Radio [11]. National Public Radio commentator, Ira Flatow addresses technological issues [12]. Engineering topics are the subject of recent video documentaries such as the widespread use of electricity [13] the development of radio and television [14], the technical drama of work done by the Wright Brothers [15], the development of the transistor [16], the engineering details of the world trade center collapse [17] and the design process in the aerospace industry [18]. A number of popular books aim to explain the workings of modern technology to the general public, such as Macaulay [19], Fountain [20] and Brian [21]. This latter book is derived from the extensive and popular website [22]. These examples illustrate the richness of resources already at hand; this area of instruction does not require de novo invention of instructional materials.

On the undergraduate campuses across the US, silence reigns in technology literacy instruction, despite this abundance of materials potentially useful for such instruction. The 2005 NAE workshop on technological literacy struggled to locate 20 faculty involved in teaching some version of this topic, these 20 constituting scarcity considering the existence of more that 300 US schools of engineering which could teach "Engineering for Everyman" and the more than 1,000 departments of physics to explain "The Physics of Everyday Life". Why the lack of engineering instructors in particular, how to increase their number, and why are engineering design faculty a promising source for mounting a new academic crusade for increased instruction in technological literacy?

Defining Technological Literacy

"Technological Literacy" is remarkable for the range of definitions found even among the present scarce offerings. We begin with the most general, that for an informed citizenry, including K-12, college, and the larger US population.

Definition: What is Technological Literacy ?

The NAE report proposes that "Technological literacy encompasses three interdependent dimensions-knowledge, ways of thinking and acting, and capabilities. " "Like literacy in reading, mathematics, science, or history, the goal of technological literacy is to provide people with the tools to participate intelligently and thoughtfully in the world around them." While "The kinds of things a technologically literate person must know can vary from society to society and from era to era," the characteristics of such literacy for our times are clearly identifiable (Table I) [2].

Table I Characteristics of a Technologically Literate Citizen[2]

<u>Knowledge</u>

Recognizes the pervasiveness of technology in everyday life.

Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.

Is familiar with the nature and limitations of the engineering design process.

Knows some of the ways technology shapes human history and people shape technology.

Knows that all technologies entail risk, some that can be anticipated and some that cannot.

Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits

Understands that technology reflects the values and culture of society

Ways of Thinking and Acting

Asks pertinent questions, of self and others, regarding the benefits and risks of technologies

Seeks information about new technologies

Participates, when appropriate, in decisions about the development and use of technology

Capabilities

Has a range of hands-on skills, such as using a computer for word processing and surfing the Internet and operating a variety of home and office appliances

Can identify and fix simple mechanical or technological problems at home or work

Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits."

Undergraduate student education

Within the context of undergraduate education, Prof. Nan Byars of University of North Carolina-Charlotte proposed specific, measurable criteria in her admirable 1998 review "Technology Literacy: The State of the Art."[23]

Table II Technology Literacy: A Working Definition

"The ability to understand, intelligently discuss and appropriately use concepts, procedures and terminology fundamental to the work of (and typically taken for granted by) professional engineers, scientists, and technicians; and being able to apply this ability to:

(1) critically analyze how technology, culture and environment interact and influence one another.

(2) accurately explain (in non-technical terms) scientific and mathematical principles which form the bases of important technologies

(3) describe and, when appropriate, use the design and research methods of engineers and technologists

(4) continue learning about technologies, and meaningfully participate in the evaluation and improvement of existing technologies and the creation of new technologies."[23]

Example student learning objectives for lecture-laboratory format

Many of the technology literacy courses presented in the NSF 2005 workshop contain a device demonstration and dissection laboratory in addition to lectures. Here the course definition would logically include aspects related to laboratory evaluation and assessment, as the following NCSU student learning objectives illustrates [21].

Table III Technology Literacy: Student Learning Objectives

"Students in this course will:

(1) develop a basic vocabulary and conceptual framework for describing the technical and historical origins of modern technological devices

(2) explain the conceptual operating bases of current and prior technologies which address similar societal needs

(3) use and dissect devices to develop understanding of the relationships between technical subsystems of a device (e.g., the optical, electrical, and mechanical subsystems of a facsimile (FAX) machine), and their influence on device design and operation.

(4) develop an understanding of the impacts (technical, economic) of a device in a given context, through lecture and individual analytic written papers.

Matching Design to Technological Literacy

Design instruction for engineering students usually includes many more dimensions than the typical engineering science offering. Economics, ideation, product development, customer needs, manufacturability, ease of assembly and if needed, repair and service, reliability, and teamwork are among the plethora of topics present in design but otherwise absent from broad visibility in engineering curricula.

A convenient approach for connecting prospective technology literacy instruction to present design instruction is to consider successful strategies for technological literacy courses outlined by practitioners in area [23,25]. We have re-ordered these suggestions to show (Table IV) that the first six are also common to engineering design courses, and the remaining recommendations are simply guidelines appropriate to teaching to a non-technical audience. Thus, with only a slight stretch, we may claim that Technological Literacy is merely "Engineering Design Literacy" for the general university audience !

Table IV Successful Strategies for Technological Literacy Courses (Re-ordered)[23,25]

Synonymous with Design:

1. Teach design and the engineering design process. Have students design and construct projects themselves, hands-on"
2. Build on your strengths as an engineer and use what you know to demonstrate principles of engineering and technology.
3. Focus on what engineers actually do
4. Duplicate the manufacturing process, from design through production
5. Use team teaching
6. Encourage open discussion and thoughtful analysis of technology and its impacts on culture and the environment. Exploration of topics such as product design, safety and testing, cost-benefit analysis and engineering ethics can help develop technological literacy and critical thinking skills.

Audience specific items for non-technical majors

7. Make the course fun through activities, videos and projects
8. Remember that the first few weeks are crucial, especially for students belong to groups under-represented in engineering such as women and minorities, and those who have a poor preparation in math.
9. Focus on four or five key concepts
10. Choose topics relevant and familiar to students. Focus on "real world" applications and technologies that make a difference in daily life (computers, transportation , heating and cooling, xerography, aviation, communications …)
11. Draw on introductory engineering textbooks in your field as a source of simple problems for the class to tackle.
12. Use computers for more than word processing. Introduce students to programming, CAD/CAM and computer modeling. Have students use email and explore the Internet.
13. Arrange visits to places where technology can be seen in action, such as labs and such taken-for-granted places as the college heating and air conditioning facilities.
14. Involve engineering and/or engineering technology students in teaching liberal arts students

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Example Syllabus for Technological Literacy

The 2005 NSF-sponsored faculty workshop demonstrated the largely individual structures of the twelve technological literacy courses featured in presentations. A common characteristic, however, was the very broad exploration of issues and devices discussed in each course. An example illustrating these characteristics is our NCSU course which is comprised of four elements: *context, content, contraption and case*. Two lectures per week set the background (*context*) and current technology (*content*) for a given societal need (power, communication, music, etc), followed by a laboratory period (*contraption*) for dissection, assembly, and use of the modern device. In addition, students read three "*cases*" per semester, involving a technology device, company, and individual. The first two cases are reported in the form of short papers; the last is a Power point presentation to the class. This multidimensional method of contacting students with information is characteristic of many "tech lit" courses presented at the 2005 workshop.

A current topic syllabus for this course appears in Table V.

Table V Lecture topics for NCSU Technology Literacy course: "How Stuff Works"

Week	Evolutionary context (lect #1)	Technical content (lect #2)
1	Introduction to technology	Engineering: 'Design under constraints"
2	Fuels to work: fire to engines	Internal combustion engine
3	Electricity to work: Franklin to electric power	Electric motors & drills
4	Electrons to information: telegraph & telephone	Cell phone networks
5	Catching the light: Archimedes to lasers	Optical fiber communications
6	Tracking commerce: barter to bar codes	Bar code scanners
7	Recording images: Niepce to film	Digital cameras
8	Producing sound: Galileo to grunge	Acoustic & electric guitars
9	Making new materials: ceramics to semiconductors	The chip
10	Computers: Eniac to Apple	Personal computer
11	Codes: Obelisks to Java	Computer security
12	Flight: Ancient gods to Wright brothers	Modern jets/rockets

"Representation" is the Road

How is engineering to be represented through technological literacy ? To answer, consider that old dichotomy of scientists vs. engineers. Recall two familiar definitions:

"Scientists explore the laws of nature; engineers create that which never was"

"Scientists play with ideas; engineers build devices"

The kernel of each claim is that engineers are connected inextricably to their devices. Such being the case, then we engineers ought represent ourselves and our profession through the devices we design and build, a vantage point which would clearly distinguish us from our science colleagues. This approach applies not only to our own engineering students, but also to our non-engineering students, i. e, those whom we (are about to) instruct in technological literacy. Such an educational approach could also provide a professional and social representation of the engineer to the rest of society.

Representation is a word with great resonance within the community of design professionals and instructors. For example, in *Engineering Design: A Synthesis of Views*, C. Dym [26] writes "The principal thesis of this book is that the key element of design is representation. If we were to consult a standard dictionary, we would find representation defined as 'the likeness, or image, or account of, or performance of, or production of an artifact.' He continues that representation may have "aspects of a verb because it defines the design process in terms of a performance or a production" , raising the possibility that "representation in design incorporates both representation of the artifact, being design, as well as representation of the process by which the design is completed"[26]. Thus, the technical representation of design has great parallelism to the social representation of engineering.

The similarity continues. Dym notes that "a multiplicity or diversity of representation is needed for design, a collection of representation schemes that would enable description of: those issues for which analytical physics-based models are appropriate; those that require geometric or visual analysis to reason about shape and fit; those that require economic or other quantitative analysis, and those requiring verbal statement not easily expressed in formulas or algorithms. The teaching strategies for technological literacy listed in Table VI similarly argue for a "multiplicity or diversity of representations" for teaching technological literacy. Thus, design faculty are professionally aligned with such teaching strategies, and as such, are a natural manpower pool from which to draw future instructors for this national need.

Laboratories for Technological Literacy Instruction

Laboratories for technological literacy explorations may contain many devices, most of which are suitable for table top use and assembly with ordinary tools such as screwdrivers, small wrenches, and simple gauges.

As an example, our NCSU laboratory for our technological literacy course, "How Stuff Works", currently houses the devices and apparatuses of Table VI.

Table VI Devices in NCSU Technology Literacy Lab

Bar code scanner and PC
Compact disc (CD) players and burner
Facsimile (FAX) machines
Satellite TV (portable)
Bicycle and cycle exercise machines (floor)
Electric and acoustic guitar
Electric motors (drill, mixers, hair dryer)
Photocopier and scanner

Optical fiber communications and devices (lamps, endoscopes)
Videocameras, VCRs, digital cameras
Water purification system
Internal combustion engine
(Model) airplanes (battery powered flyers)
Laptop and PC versions of computers.

Yet other versions of such laboratories focus upon information technology and include both hardware and software aspects, and others are centered around mechanical devices appropriate to the discipline of mechanical engineering. Some devices straddle these areas, e.g., digital photography combines device (camera) and software (image manipulation and processing)_ to bridge both device and information technology (IT) domains, as does laptop and PC dissection.

Finding Facilities

Most, but not all, current examples of technological literacy courses [24,25] include use of a device laboratory, wherein everyday devices may be used, dissected, assembled, or where simple equivalents (e. g. of radio, telephone, etc) may be created by students. From whence is such instructional space to spring on campuses often strained for such resources? We identify common candidate spaces for device laboratories below, and suggest processes for their (periodic) conversion to technology literacy labs.

Mechanical dissection laboratories. Device dissection as an activity to introduce new engineering students to their discipline via use of engineering products has a history reaching back in time to the early 1990s. One design pioneer, Prof. Sherri Sheppard of Stanford initiated such a course and corresponding website for instructional materials (bicycle, internal combustion engine, etc). She has surveyed adoption and adaptation of such labs, finding in excess of forty [27]. In all likelihood, these lab spaces are used once per year, and their devices may offer dual use for "tech lit" instruction, or be sufficiently portable to allow periodic displacement for set-up of technology literacy lab devices such as those above in Table VI.

Laptop instructional classrooms: Many campuses offer laptop computer instructional space, with auditorium style curved desks which could provide adequate set-up space for a portable technology literacy class. These rooms contain Internet wiring or are "wireless", allowing real-time access to technological literacy related websites such as "HowStuffWorks.com."

Office carrels: Our NCSU Technology Literacy laboratory lab is set-up on metal office desks in a conventional space requiring no fume hoods, no floor drains, and no unusual power supplies. Such desks (most without drawers) allow teams of two students to easily sit at a single device station to use, dissect, and assemble the common devices of Table VI.

Design Studio: Colleges of Design feature the studio approach, which provides permanent, semester-long assignment to design teams of a given exploration space, suitable for table-top devices and for providing floor space for yet larger devices such as full auto engines and furniture.

Conclusion

The National Academy of Engineering, the National Science foundation, and American industry and academic leaders have argued and pleaded for a greater level of technology literacy among students (all levels) and the general population. The question which naturally arises on the undergraduate campuses is: "Who will bell the cat? Who will create and teach these technology literacy courses, and why?" By framing technology literacy as a series of design related topics: design history of a device, design of modern device, dissection of modern device, and case history of a creator (person), manufacturer (company) or artifact (device), a new role appears for design instructors as purveyors of technology literacy.

The broadened subject consideration engendered through teaching "tech lit" may also prove rewarding to individual instructors who seek design considerations broader that those of their disciplines. Also, the multiplicity of subject approaches nicely encourages future cross-college collaborations, e.g., with a "history of science/technology" instructor taking the first approach, an engineering faculty member the second and third, and an instructor in English or technology management taking the case exercises. Thus, enlarging the community of technological literacy faculty through collaborative modes of instruction is encouraged naturally, potentially leading to cost-effective initiatives and reforms.

In sum, the national challenge of creating and improving the technology literacy of undergraduates could be approached through the recruitment and reward of design faculty, inter alia. This instructional group is widely present on every engineering campus. Further, as S. Sheppard has documented, the present of device dissection labs in US engineering schools is also appreciable[28]. The combined availability of both instructors and device lab space suggests a natural doorway for widespread enhancement of technology literacy instruction at the undergraduate level.

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