AC 2011-1166: AN ONLINE RESOURCE FOR DEVELOPING TECHNOLOGICAL LITERACY COURSES.

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An Online Resource for Developing Technological Literacy Courses

Abstract

This work describes an effort to create an online resource for engineering faculty who would like to teach general education engineering or technological literacy courses for non-engineers. Engineering departments can contribute to a greater understanding of engineering and technology by offering courses on technological topics at a level that is appropriate for non-engineers. However, doing so requires appropriate curriculum and course materials. To facilitate this process, a review was conducted of technological literacy courses already being taught by engineering faculty. It was found that courses can be classified in four categories. These four groups are survey courses, focus courses, design courses, and connections courses. The survey courses aim to cover a wide range of technological products, systems, and issues. The focus courses address a more narrowly defined area, such as energy or nanotechnology. The design courses emphasize developing a familiarity with the engineering design process. Connections courses concentrate on the interconnections between engineering, technology, and other areas of society and culture. These four categories are proposed as templates or models that other faculty can use in developing and planning a course. These four models were found to be consistent with the recommendations made by the National Academy of Engineering and the International Technology Education Association regarding standards for technological literacy. It is intended to develop an online database of course materials organized around the proposed framework. An additional feature to be included is classification of material based on cognitive level of Bloom’s taxonomy. The current status of the development of the online system is described.

Background

The goal of the work reported here is the implementation of an online resource to help faculty develop technological literacy courses for non-engineers. Faculty are more likely to teach these general education engineering courses if appropriate curriculum materials are readily available. This online resource is based on models for general education engineering courses that emerged from a workshop on the technological literacy of undergraduates that was sponsored by the National Science Foundation and held in March 2007 at the National Academy of Engineering1,2.

All Americans need to better understand the wide variety of technology used everyday. The need for technological literacy has never been greater at both an individual and national level. Creating a population with a more empowered relationship with technology will require a significant and widespread initiative in undergraduate education. Courses and materials that are easily adoptable in diverse and varied institutional environments will facilitate this effort. The National Academy of Engineering (NAE), has outlined the characteristics of a technologically literate citizen3-5. The International Technology Education Association (ITEA) and the American Association for the Advancement of Science (AAAS) have also developed standards defining technological literacy6-8. Recognizing the need for standardized and readily adoptable undergraduate courses on this topic, the NSF supported a working group lead by the American
Society for Engineering Education (ASEE) Technological Literacy Constituent Committee. This group met on March 26-27, 2007 and adopted four models to serve as standardized or template courses on technology. In this work, a framework for specific course outlines consistent with the content areas established in Tech Tally of technology and society, design, products and systems, and technology core concepts and the ITEA technology topic areas was created. To balance the need to accommodate the diverse requirements of curriculum committees on varied campuses, the framework offers flexibility to faculty in configuring courses within each proposed model while still accomplishing the intent of the standards. This framework is intended to form the organizational infrastructure for creating a repository of course materials and an online community for course developers and instructors.

The proposed framework will help faculty develop expertise in adapting existing innovative course materials and standards for defining technological literacy and incorporating them efficiently into their own courses.

What Is Technological Literacy?

In 2006 the National Academy of Engineering published Tech Tally. In this document the NAE defined technological literacy as “an understanding of technology at a level that enables effective functioning in a modern technological society”. This reflects E.D. Hirsh’s definition of “literacy” as “information that is taken for granted in public discourse”. Tech Tally was preceded by a 2002 report by the NAE entitled, Technically Speaking: Why All Americans Need to Know More about Technology. Technically Speaking describes the importance of being literate about technology in the 21st century. Both NAE reports emphasize that technology, in a broad sense, is any modification of the natural world made to fulfill human needs and wants. The definition encompasses the products of all of the different disciplines of engineering not just computers and information technology. Technology includes not only tangible products, but also the knowledge and processes necessary to create and operate those products. The infrastructure used for the design, manufacture, operation, and repair of technological artifacts is also considered part of technology.

Other parallel efforts have also developed educational standards and benchmarks to define what K-12 students need to know and be able to do regarding engineering and technology. In 1993, the American Association for the Advancement of Science (AAAS) published Project 2061: Benchmarks for Science Literacy and in 1996 the National Science Education Standards were published by the National Academies Press, both of these documents included sections devoted to technology. In 2000 the International Technology Education Association (ITEA) published Standards for Technological Literacy: Content for the Study of Technology of the goal of which was to encourage educational curricula that would provide technological literacy specifically to students in the K-12 environment.

In Tech Tally, the NAE identified three major components, or cognitive dimensions, related to technological literacy: knowledge, capabilities, and critical thinking and decision-making. As defined in their report, the knowledge dimension of technological literacy includes both factual knowledge and conceptual understanding. The capabilities dimension considers to how well a
person can use technology and carry out a design process to solve a problem. The critical thinking and decision-making dimension concerns a person’s approach to technological issues. This dimension enables the individual to ask questions about risks and benefits when introduced to a new technology, and to participate in discussions and debates about the uses of that technology. In addition to these three cognitive dimensions, four content areas were defined: (1) technology and society, (2) design, (3) products and systems, and (4) characteristics, concepts, and connections. Finally, an assessment matrix was proposed that combined the four content areas (the rows of the matrix) with the three cognitive dimensions (the columns of the matrix), and it is this matrix that spurred the development of the proposed framework.

Simultaneously, the International Technology Education Association (ITEA) also developed a set of standards (ITEA 2000) for technological literacy, which was published in their report entitled, *Standards for Technological Literacy: Content for the Study of Technology*. The ITEA 2000 Standards are divided into five main categories that sub-divide into 20 specific standards:

1. Understanding the Nature of Technology
2. Understanding of Technology and Society
3. Understanding of Design
4. Abilities for a Technological World
5. Understanding of the Designed World.

While the ITEA 2000 standards address K-12 students, it was found that the detail of these standards was helpful in categorizing or classifying content areas that might appear in technological literacy courses for undergraduates. As such, the proposed framework integrates these parallel attempts to define technological literacy and reconciles the overlap between the NAE and ITEA approaches.

**Engineering and Technology Courses for Non-Engineers.**

The engineering education community has begun developing a broader scope and is becoming active beyond its traditional boundaries. Engineers have embraced the need to increase the awareness and understanding of engineering as a career by initiating a number of programs aimed at the K-12 audience. A recent example is the American Society for Engineering Education’s (ASEE) publication, *Engineering Go For It*, and a website aimed at a K-12 students and teachers. Most major engineering societies now have outreach activities for K-12, meanwhile, ITEA is working to develop program and assessment standards, and curriculum materials for the K-12 audience. In the midst of these efforts, Engineering departments offering courses on technological topics for non-engineering students remain relatively uncommon.

Current efforts to address the technological literacy of undergraduates can be traced back to the Alfred P. Sloan Foundation New Liberal Arts Program (NLA) launched in 1982. The objective was to improve the quality of undergraduate education in the areas of technology and quantitative reasoning. The Sloan Foundation sponsored development of a variety of courses on technological topics for non-science majors. The NLA Program broke new ground in establishing technology as the intellectual peer of science at the college level; however, the
results of the NLA program highlighted the difficulty in migration of courses beyond the originating instructor and campus, and sustaining course offerings after the end of the funding period.\textsuperscript{20}

After NLA ended, some engineering educators have worked steadily on aspects of the broad understanding of technology by undergraduates.\textsuperscript{21-23} While the total number of courses reported has been limited,\textsuperscript{24-53,61-63} results have been noteworthy. Many courses have been successful in attracting substantial enrollments of non-engineering students and existing as long-term departmental offerings.\textsuperscript{25-29,35-41,44-46,52,53} Some specific illustrative examples include Technology 21, developed at the University of Denver.\textsuperscript{52} In this course non-engineers study a technological controversy and develop a policy recommendation. The course has been offered by the Electrical Engineering Department for more than 14 years and has been taught by nearly all departmental faculty. The Converging Technologies Initiative at Union College has lead to nearly 30 new or modified courses at Union since 2002 on interdisciplinary technological topics such as pervasive computing and nanotechnology.\textsuperscript{25,35} At California State University Northridge, the Manufacturing Systems Engineering Department has taught Computer-Aided Design to campus-wide constituency for a decade.\textsuperscript{53} Dartmouth College has had a requirement since 1992 that every student take a course in Technology and/or Applied Science. The majority of these courses are taught by engineering faculty, and some have enrolled as many as 150 students.\textsuperscript{54}

In parallel with these efforts by engineering departments to serve non-engineers, some college and university physics departments have reconfigured their courses for non-majors to emphasize technological topics. Representative examples include Dudley and Bold’s, “Top-Down Physics,” Watson’s “The Science Concepts behind High Technology” and “Silicon, Circuits, and the Digital Revolution” courses.\textsuperscript{56} Another example is the course and textbook by Bloomfield entitled How Things Work: The Physics of Everyday Life.\textsuperscript{57,58} This approach of technologically-themed and application-oriented science courses for non-science majors incorporates perspectives more akin to engineering than traditional physical science courses. These recent efforts at motivating the learning of physics by understanding modern technology stand in distinct contrast to earlier classic works such as Physics for the Inquiring Mind and Physics for Poets,\textsuperscript{59,60} which avoided technological applications and emphasized philosophical questions and natural phenomena.

These developments illustrate that demand and interest exist among the non-engineering undergraduate population for courses on technological issues. It also demonstrates that engineering faculty can develop and teach courses on technological topics to non-engineering students. The successful courses taught by engineers span the entire spectrum of institution type and student demographics. They represent diverse campus environments including large state universities,\textsuperscript{45-48,51} small private colleges,\textsuperscript{29,37} technically oriented institutions,\textsuperscript{49,50} highly selective schools,\textsuperscript{26,27,40,43} comprehensive universities,\textsuperscript{28,44} schools serving working adults,\textsuperscript{16} and two year institutions.\textsuperscript{63,64} The background of the instructors represent the major engineering disciplines including chemical,\textsuperscript{48} civil,\textsuperscript{26-28,44} electrical,\textsuperscript{34,36,40} materials,\textsuperscript{45,46,61} and mechanical engineers.\textsuperscript{24,29,31,37} However, a common feature of nearly all successful technology courses is the need to satisfy some component of the college or university general education graduation requirements.
requirement and to be adapted to instructor interests or other aspects of local institutional conditions\textsuperscript{65,66}.

To help define the research issues regarding the broad understanding of technology by all undergraduates, a workshop on the technological literacy of undergraduates was sponsored by the NSF Division of Undergraduate Education and convened at the NAE in April 2005. The 42 participants included individuals who had successfully implemented courses on technological literacy for undergraduates as well as representatives from other engineering and non-engineering disciplines. A primary recommendation from the group at the workshop was: “There is a need for a best practice collection of easily adopted materials\textsuperscript{67,68}”.

Most of the existing technological literacy courses were established before the recent efforts by the NAE and the ITEA to define technological literacy and establish standards for this topic. Individual instructors determined course syllabi based on their expertise and level of comfort with the material. As part of the 2005 NSF/NAE Workshop, participants found that elements of the NAE and ITEA standards had been incorporated into most of the existing courses; however, no single existing course included all of the standards due to their breadth. With this came the realization that no single standard course model could be developed for a course on technological literacy; instead, four standard course models were proposed and slated for development as part of the follow-on NSF/NAE Technological Literacy for Undergraduates Workshop, which was held in March 2007. The four standard course models were: (1) Technology Survey Course, (2) Technology Focus Course, (3) Technology Design Course, and (4) Technology Critique, Assess, Reflect, or Connections Course. The proposed framework was created to serve not only as a guide for developing these standard course models but also as a method for evaluating and benchmarking existing technological literacy courses.

**Description of the Proposed Framework**

The framework takes the form of a matrix that includes content areas – called *cross-cutting concepts* – to different *technology topic* areas. This is illustrated in Figure 1. The technology topic areas – the columns in the matrix – are derived from the “Designed World” categories defined by the ITEA 2000 Standards\textsuperscript{8} and include an additional “Other” category for areas that the faculty felt were missing from ITEA’s Designed World (e.g., space technology, military technology, materials, entertainment systems).

The rows of the matrix in Figure 1 are specific cross-cutting concepts grouped. These are also based loosely on the four content areas defined in *Tech Tally*\textsuperscript{3}: (i) Technology & Society, (ii) Design, (iii) Products & Systems, and (iv) Characteristics, Core Concepts, & Connections.

Each cell in the matrix can be associated with one of four values to indicate the depth of coverage of that cross-cutting concept in each technology topic area:

1. K $\rightarrow$ Knowledge
2. C $\rightarrow$ Capabilities
3. D $\rightarrow$ Decision-making
These three areas (K, C, D) are based on the three Cognitive Dimensions of Technology Literacy that are defined in *Technically Speaking* and *Tech Tally* where “Critical Thinking & Decision-making” has been simplified to “Decision-making”. The levels (K, C, D) are ordered in terms of their depth of understanding, and it is implied that higher levels of coverage (e.g., Decision-making) also include the lower levels of understanding as well (i.e., Knowledge and Capabilities). This is consistent with the scheme used in Bloom’s taxonomy where higher levels of the taxonomy include the ability to demonstrate the lower-level skills as well.

<table>
<thead>
<tr>
<th>Science and Technology</th>
<th>Applications</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical</td>
<td>Agriculture &amp; Biotechnologies</td>
<td>Energy &amp; Power Information &amp; Communication</td>
</tr>
<tr>
<td>Medical</td>
<td>Manufacturing</td>
<td>Construction</td>
</tr>
<tr>
<td>Medical</td>
<td>Natural World</td>
<td></td>
</tr>
</tbody>
</table>

- **Mathematical Underpinnings**
- **Scientific Facts and Principles**
- **Scientific Method**
- **Environmental & Societal Interdependence**
- **History/Evolution of Science & Technology**
- **Disciplines of STEM**
- **Ethics**
- **Design Process**
- **Risk/Safety**
- **Tradeoffs/Cost-Benefit Analysis**
- **Intended/Unintended Consequences**
- **Satisfying Human Wants & Needs**
- **Energy, Materials, & Information Flow**
- **Interdependence/Interactions**
- **Dynamic/Static Systems**
- **Systems Perspective**
- **Control & Feedback**
- **Complexity**

**Figure 1.** Proposed Framework: The Technological Literacy Course Evaluation Matrix.

Using this 2D matrix representation, four generic types of technology literacy courses can be defined. These four types constitute the standard course models that were envisioned as part of the NSF/NAE Technological Literacy Workshop.
(1) Technology Survey Courses  
(2) Technology Focus Courses  
(3) Technology Design Courses  
(4) Technology Critique, Assess, Reflect, or Connections Courses

These are shown in Figure 2. To simplify the figures, the cross-cutting concepts (i.e., the rows) have been condensed into the three higher-level groups (Systems, Design, and Connections). As shown in the figure, it is hypothesized that Survey Courses will span the majority of the matrix with K, C, and D values. Due to time constraints and limited course duration, it is not anticipated that any Survey course will fill the entire matrix, but it would be expected that no row will be entirely blank. Meanwhile, a column could be blank if a technology topic area is not covered due to time limits, but a Survey will likely cover most of these technology areas.

Technological Literacy Focus Courses will go into great depth within one or more technology topic areas with a higher percentage of C and D values in that column(s) when compared to a Survey Course.

\[ 
\begin{array}{cccccccc}
\text{Medical} & \text{Agricultural \& Biotechnologies} & \text{Energy \& Power} & \text{Information \& Communication} & \text{Transportation} & \text{Manufacturing} & \text{Construction} & \text{Other (Space, military, materials, entertainment, etc.)} \\
\text{Systems} & \text{Design} & \text{Connections} & \text{Cross-Cutting Concepts} \\
\text{Technology Topic Area} \\
\text{Technology Topic Area} \\
\text{Technology Topic Area} \\
\text{Technology Topic Area} \\
\end{array} \]

(a) Technology Survey Courses  
(b) Technology Focus Courses  
(c) Technology Design Courses  
(d) Technology Critique/Assess/Reflect/Connect Courses

Figure 2. Using the Framework to Identify Four Types of Technological Literacy Courses.
Technological Literacy Design Courses and Critique, Assess, Reflect, or Connections Courses will cover these respective rows in the matrix for one or more of the technology topic areas as shown in Figures 2c and 2d, respectively. It is expected that these courses will also have a higher percentage of C and D values in the corresponding rows – specifically for the detailed cross-cutting concepts within each group – compared to a Survey Course.

Figure 3 shows two instances of the matrix for two courses that were selected from among the 22 existing technology literacy courses surveyed during the 2007 NAE/NSF Workshop. In this survey, instructors were only asked to what extent their course covered the cross-cutting concepts at the group level (System, Design, and Connections) and which technology topic areas were covered, but not to what extent each cross-cutting concept was covered in each technology topic area.

![Diagram showing matrix of technology topic areas and cross-cutting concepts with instructors' responses indicated]

**Figure 3.** Instances of the Framework Applied to Representative Courses.

**Description of Future Work**

The proposed framework for developing technology literacy courses was developed partly from the results of a survey of technology-focused courses and their instructors conducted before the NSF/NAE workshop. This online survey asked instructors to compare their existing course to the standards prescribed in *Tech Tally*³ and the ITEA Standards for Technological Literacy⁸.
The survey only addressed the topical areas of the standards and did not include questions regarding cognitive level.

The framework illustrated in Figure 1 is expected to serve as an organizational infrastructure for a repository of shared course materials accessible via the internet. This online matrix will include or link to course materials from existing technological literacy courses. The site will allow users to build technological literacy courses by selecting materials as needed. The material can be selected from from cells, rows, or columns as desired. Contributing educators could populate the site by submitting course materials. Posting modules or courses will utilize keywords and course templates familiar to other instructors. By including information about the cognitive level of the material users will be able to select the appropriate depth for the course materials being developed.

The long-range goal of this work is to use the framework as an organizational structure for publicly available materials. These materials will then be accessed on the internet and used by instructors to develop new technological literacy courses. The intent is to simplify the course development task for faculty members at all types of institutions. It is expected that a wiki-like environment of best-practice materials open to the public with controlled editing access will increase faculty participation in this area.

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