Engineering Courses for Non-Engineers: Identifying and Developing Course Models

Abstract

The National Academy of Engineering advocates that all Americans should know more about engineering and technology. Some engineering departments are beginning to offer courses specifically for non-engineering students. Although common practice among many STEM departments, teaching service courses is a new development for engineering programs. To create a population with a more empowered relationship with technology, a significant and extensive initiative by engineers will be needed. Curricula and course materials that can be adopted in diverse and varied institutional environments will be essential to this effort. The National Academy of Engineering in two reports: *Technically Speaking: Why All Americans Need to Know More about Technology* (2002), and *Tech Tally: Approaches to Assessing Technological Literacy* (2006), describe and define characteristics of a technologically literate citizen. Technological literacy implies understanding of all of the diverse technological products produced by engineering, not just computers and information technology. The National Science Foundation (NSF) sponsored a working group led by the American Society for Engineering Education (ASEE) Technological Literacy Constituent Committee to develop standardized and readily adoptable undergraduate engineering courses for non-engineers. This group reviewed courses already being offered for non-engineers and developed four models to serve as potential templates or standard course models. A framework was established for specific course outlines consistent with the content areas established by the NAE in *Tech Tally* of: technology and society, design, products and systems, and technology core concepts and the ITEA technology topic areas. To satisfy the diverse requirements of curriculum committees on varied campuses, the framework offers faculty flexibility in planning courses within each proposed model while still accomplishing the goals of the standards.

Introduction

In *Technically Speaking*[1] and *Tech Tally* [2], The National Academy of Engineering emphasized the need for all Americans to understand and appreciate our technological infrastructure. The National Science Foundation's "*Shaping the Future"* suggested that science and engineering faculty must insure that: "All students have access to supportive, excellent undergraduate education in science, mathematics, engineering and technology [3]."

While these calls for technological literacy have resulted in some progress, most efforts are thus far directed largely toward the K-12 population. The International Technological Education Association (ITEA) with support from the NSF and NASA produced a set of standards that help define the concept of technological literacy[4] and are intended for K-12 students. The ITEA is also working to develop program and assessment standards and curriculum materials for the K-12 audience [5]. The engineering community has responded enthusiastically to the need to increase the career awareness and understanding of engineering among K-12 students. However efforts directed at the undergraduate non-engineering student population have been limited.

To achieve widespread impact, classes must be taught at many institutions around the country. To accomplish this, standard models of technological literacy courses must be developed. Standard course models will reduce the effort needed by instructors who desire to offer courses for non-engineers. As a beginning to this process, a workshop was convened at the National Academy of Engineering of representative individuals with experience relevant to improving the technological literacy of undergraduates [6,7]. Participants included individuals who successfully implemented courses on technological literacy for undergraduates, representatives of other disciplines such as Science Technology and Society (STS), History of Technology, Education, and the humanities, and representatives of the National Science Foundation and the National Academy of Engineering. The participants are listed in Tables 1 and 2.

Table 1: Developing Standard Models Workshop: Participants from Academic Institutions.

Vince Bertsch, Santa Rosa Junior College
Cathy Brawner, Research Triangle Edu. Consultants
Taft Broome, Howard University
Bernie Carlson, University of Virginia
Stephen Cutcliffe, Lehigh University
Marie Dahleh, Harvard University
Kurt DeGoede, Elizabethtown College
Richard F. Devon, Penn State University
Katy Disney, Mission College
Elsa Garmire, Dartmouth
Camille George, Univ. of St. Thomas
Mary T. Huber, Carnegie Foundation for Adv. Teaching
Mary Kasarda, Virginia Tech
J. Doug Klein, Union College
John Krupczak, Hope College
Renee Lerche, University of Michigan
Deborah Mechtel, United States Naval Academy
Ron Miller, Colorado School of Mines
Kay Neeley, University of Virginia
Jean Nocito-Gobel, University of New Haven
M. Grant Norton, Washington State University
Barbara Oakley, Oakland University
David Ollis, North Carolina State University
Greg Pearson, National Academy of Engineering
Sarah Pfatteicher, University of Wisconsin
Mary Annette Rose, Ball State University
Mark Sanders, Virginia Tech
Bruce Seely, Michigan Technological Univ.
Tarek Shraibati, Cal State, Northridge
Tim Simpson, Penn State University
Larry Whitman, Wichita State University
William Wulf, President, NAE
James F. Young, Rice University

Table 2: Developing Standard Models Workshop: NSF Participants.

Barbara N. Anderegg, Division of Undergraduate Education
Diana Burley, Division of Undergraduate Education
Dan Litynski, Division of Undergraduate Education
Daniel P. Maki, Division of Undergraduate Education
Nancy J. Pelaez, Division of Undergraduate Education
Russ Pimmel, Division of Undergraduate Education
Sheryl A. Sorby, Division of Undergraduate Education
Keith A. Sverdrup, Division of Undergraduate Education
Elizabeteh J. Teles, Division of Undergraduate Education
Wanda Ward, Division of Undergraduate Education
Bevelee A. Watford, Division of Undergraduate Education

At the workshop, groups reviewed descriptions of engineering courses for non-engineers in an effort to identify templates or standard models of technological literacy courses that could serve as the basis for future course development. The ultimate goal is to create materials for both students and instructors with the intention of easy adoption and widespread use.

Candidate Models for Standardized Technological Literacy Courses.

Based on a review of courses already developed and comparisons to other disciplines, four candidate standard models were identified:

1. The Technology Survey Course.
2. The Technology Focus or Topics Course.
3. The Technology Creation Course (Design Course).
4. The Technology Critique, Assess, Reflect, or Connect Course.

The technology survey courses offer a broad overview of a number of areas of engineering and technology. The technology or topics or focus course is narrower in scope and develops one well-defined area. The engineering design course, or technology creation, places an emphasis on the engineering design process to develop technological solutions to problems. The last model to emerge is concerned with assessing technological impacts, connecting technological developments to other areas of society, history and culture, or reflecting on engineering in a broader context.

1 Technology Survey Courses.

Technology survey courses are those found to address a wide range of technologies. Many include aspects of the social and historical dimensions of technology. The course formats were found to be diverse but typically include lectures, demonstrations, and laboratories. Explanation of scientific principles utilized in technological devices is usually a major component. This category includes courses that classify themselves as “How Things Work” courses and includes physics courses that emphasize everyday technology. In some cases broadly based introduction to engineering courses may be considered in this category.

Survey Course Examples:

- Billington ....Engineering and the Modern World [11]
- Bloomfield. ....How Things Work: Physics of Everyday Life [12,13]
- DeGoode ....How Things Work [17]
- Disney ....Science at Work: Technology in the Modern World [18,19]
- Hammack ....The Hidden World of Engineering [22]
- Kim ....Introduction to Electro-Technology [24]
- Krupczak ....Science and Technology of Everyday Life [27-29]
- Lienhard ....Engines of our Ingenuity [32-34]
- Oakley ....Everyday Engineering [41]
- Ollis.......................................How Things Work [42-45]

2 <u>Technology Focus or Topics Courses</u>

These courses tend to address a single technological topic or issue. The subject matter is intentionally focused and selective rather than intentionally broad. These courses may have a substantial quantitative component. The focus courses may include laboratories or projects. In some cases, social and historical aspects of the topic are included.

In developing and teaching these courses, instructors are often working from their area of research expertise. The instructors can then rely on their extensive often life-long experience in the focus area to craft a course accessible to non-engineers. Topical courses focused on one area of technology were characteristic of many of the courses developed under the Sloan Foundation New Liberal Arts Program[8].

Focus Course Examples:

- Klein and Balmer: ....Converging Technologies at Union [10,15, 25]
- Billington, Littman et. al ....Civil Infrastructure. [11]
- George ....Fuel Cells [20,21]
- Mechtel ,Korzeniowksi et al. ....Electrical Engineering for Non-Engineers [26]
- Kuc: ....Information Technology [30,31]
- Norton and Bahr ....Materials [39,40]
- Orr, Cyganski, and Vaz: ....Information Technology [46,47]
- Pisupati, Mathews, and Scaroni ....Energy Conservation [48]
- Walsh, Demmons, and Gibbs.............Materials [51]
- Shraibati ....Intro to Computer Graphics Tools.[50]

<u>3. Engineering Design for Everyone (Technology Creation or Application Courses)</u>

A third type of course emerged from the review that emphasized the engineering design process. These courses focus on the creation of artifacts of various types using engineering design methods. In some instances these courses may include engineering majors along with non-engineering majors and would also apply to courses on engineering design for K-12 teachers.

Although not included in the set of courses reviewed, it is apparent that many introduction to engineering courses for first-year students could be considered in this category .

Design For Non-Engineers Course Examples:

Baish ....Designing People, Form and Function [9]
DeGoode ....How Things Work [17]
Mahajan. and McDonald...................Exploring Technology [35]
Mikic and Voss ....Engineering for Everyone [36]
Nocito-Gobel.....................................Project-based Introduction to Engineering [16,38]
Whitman..Engineering for Non-Engineers [53]
Weiss...Hands-on Projects for Non-Engineers [52].
J. Young ....Introduction to Engineering [23]

4. Technological Impacts, Assessment, and History Courses.
(Critique, Assess, Reflect, and Connect Courses)

A fourth category of courses that have been taught for non-engineers address issues such as the impacts of technology, technology assessment, and history of technology. These courses emphasize the relation between technology and culture, society, history and also include technological policy assessment or analysis. The particular group of courses reviewed were primarily developed and taught by engineering faculty so the number of courses was not large. This type of course is well represented in Science Technology and Society (STS) programs which were not included in the scope of the present study. A few examples exist of courses in this category that are jointly taught by engineering and non-engineering faculty.

Technological Impacts, Assessment, and History Courses Examples

Carlson and Gorman, UVa: ....Invention and Innovation [14]
Cutcliffe, Lehigh ....Technology and Human Values
Klein and Balmer ....Converging Technologies Courses at Union [15]
Neeley UVa.....................................Engineering in Context [37]
Rosa...Technology 21 [49]

A Framework to Facilitate Course Development

To promote future course development, it is desirable to have a framework that includes the elements of technological literacy as identified by the National Academy of Engineering [1,2] and the International Technology Education Association [4,5]. Toward this end, the workshop participants developed a 2D matrix that maps content areas called *cross-cutting concepts* to different *technology topic* areas. This matrix is shown in Figure 1.

The matrix is intended to merge the slightly different definitions of technological literacy developed by the NAE and ITEA. The columns in the matrix are derived from the "Designed World" categories defined by the ITEA 2000 Standards [4]. The rows are specific cross-cutting concepts grouped under the broader headings of Systems, Design, and Connections, which are also based on the four content areas defined in the NAE's *Tech Tally* [2]. Each cell in the matrix can be populated with one of four values to indicate the depth of coverage of that cross-cutting concept in each technology topic area based on the three Cognitive Dimensions of Technology Literacy that are defined in *Technically Speaking* [1] and *Tech Tally* [2]:

- K → Knowledge, i.e., the course will provide knowledge about this concept.
- C → Capabilities, i.e., the course will develop capabilities in this cross-cutting concept that can be applied within the context of this technology topic area.
- D → Decision-making, i.e., the course will enable decision-making within the context of this cross-cutting
- Blank→Indicates no coverage of this concept.

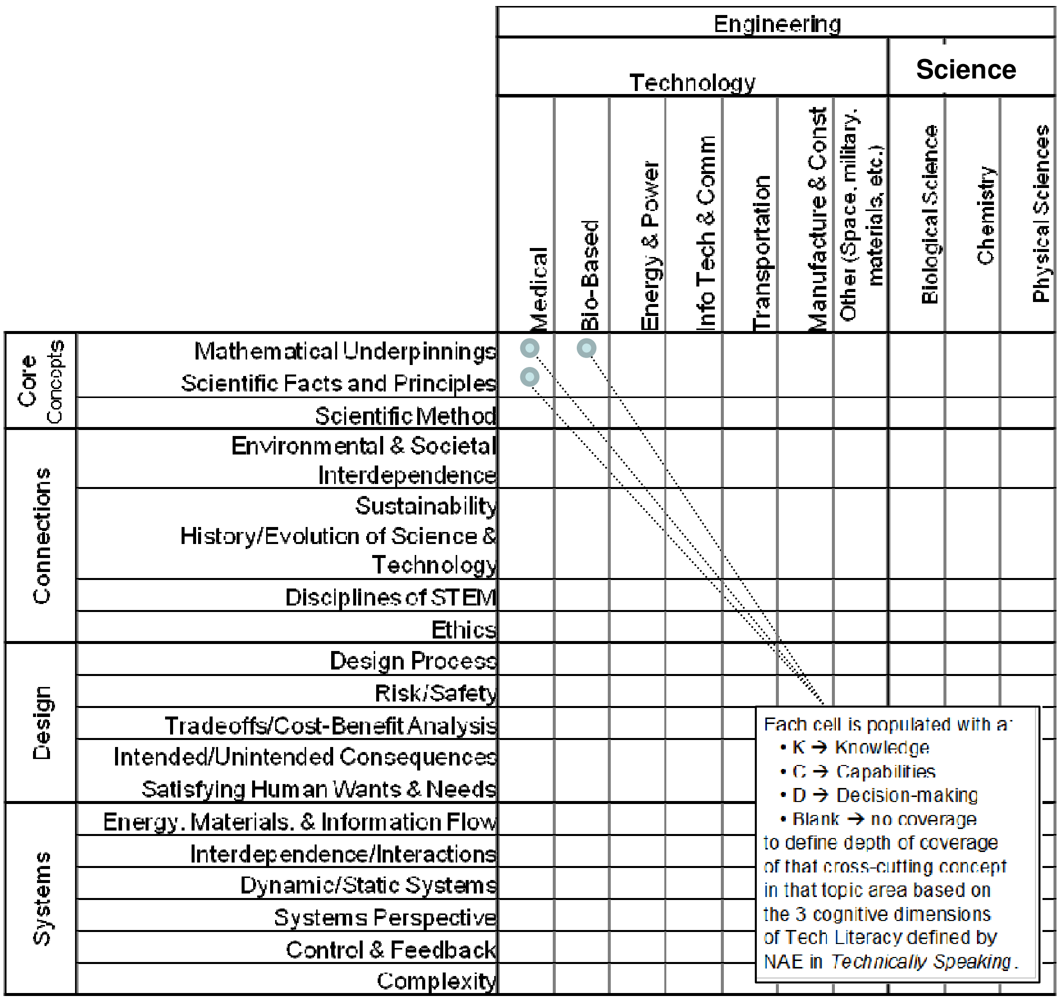

Figure 1. Framework for Engineering Courses for Non-Engineers.

Using this 2D matrix representation, four generic types of technology literacy courses can be defined based on coverage of material in the matrix. This is illustrated in Figure 2.

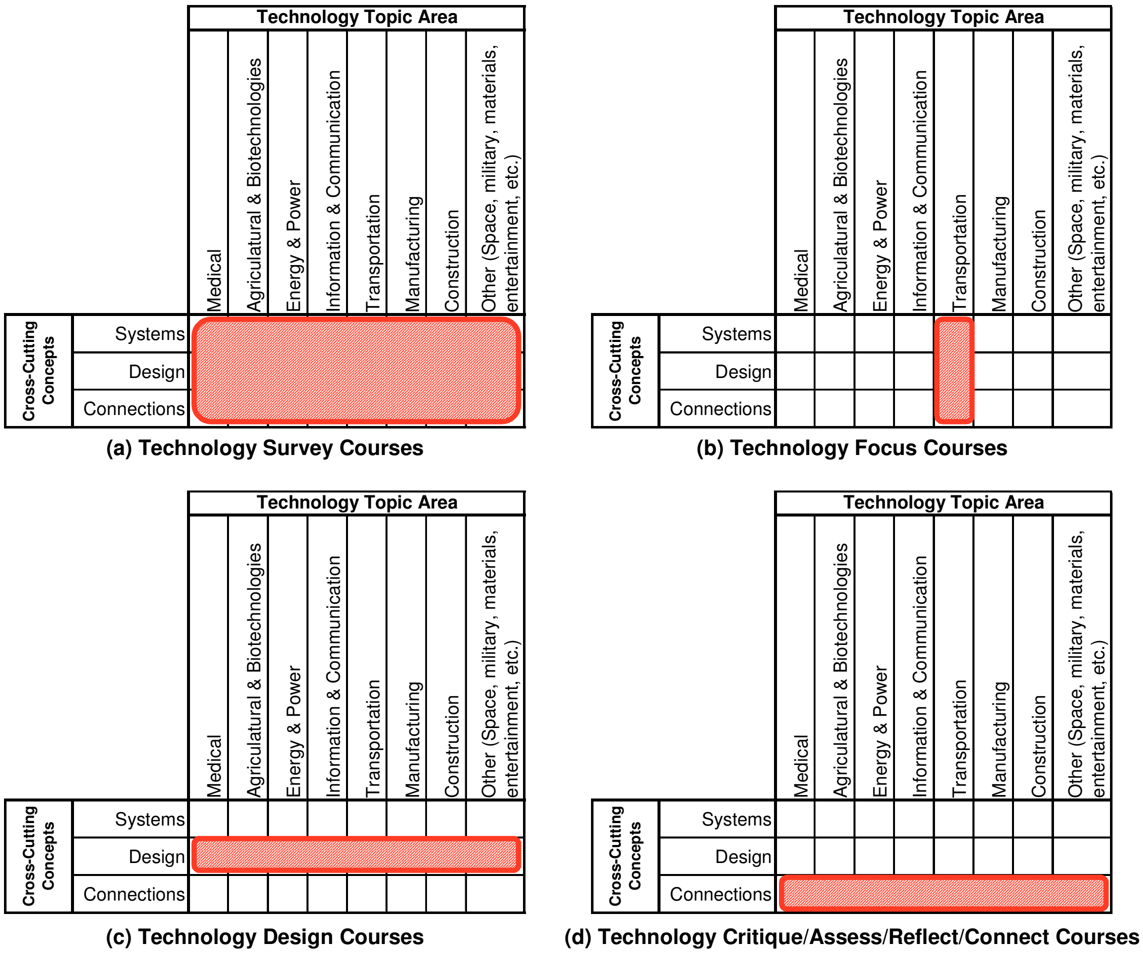

Figure 2. Using the Matrix to Define Four Types of Courses for Non-Engineers.

These are shown in Figure 2. As shown in the figure, it is expected that survey courses will span the majority of the matrix with K, C, and D values (see Figure 2a). Due to time constraints and limited course duration, it is not anticipated that any survey course will completely fill the entire matrix, but it would also be expected that no row will be entirely blank – if it is, then it will not likely qualify as a true survey course. Meanwhile, a column could be blank if a technology topic area is not covered due to time limits, but a good survey course will likely cover a majority of these technology areas.

Technological literacy focus courses will go into great depth within one or more technology topic areas (see Figure 2b) with a higher fraction of C and D values in that column(s) when compared to a survey course.

Technological Literacy Design Courses and Critique, Assess, Reflect, or Connect (CARC) 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.

To satisfy the diverse requirements of curriculum committees on varied campuses, the framework offers faculty flexibility in planning courses within each proposed model while still accomplishing the goals of the national standards.

Current Work

The framework shown in Figures 1 and 2 could serve as an organizational infrastructure for a web-based repository of shared course materials. The long-range goal of this work is to populate all cells of this framework with publicly available materials[54]. These materials will then be accessed from the web and used by instructors to develop curriculum for new courses in technological literacy. The goal is to simplify the course development task for faculty members at all institutions.

Conclusions

A framework to evaluate technology literacy courses was proposed as part of a recent NSF/NAE Workshop. This work attempts to forge links between recently established definitions of technological literacy, course structures and student learning at the undergraduate level, and the needs of faculty in proposing and developing new technology literacy courses. The framework also provides a benchmark to institutions for evaluating and establishing new technology courses. This was accomplished through a review and survey of existing courses on technology recently developed and being taught. The proposed framework intends to form the facilitating infrastructure for an online repository of course materials to help expand and enrich the growing community devoted to a broader understanding of technology by all Americans.

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