Abstract
A person who has achieved technological literacy has an understanding of technology. It is tempting to assume that people with degrees in engineering and engineering technology are either technologically literate by nature or become literate by osmosis through study and practice. However, the breadth of knowledge and understanding necessary for technological literacy is such that, for our students, this needs to be addressed directly in the program of study. Technological literacy goes well beyond developing specific abilities in the use, analysis, design, and application of specific elements of technology to issues of the relationship between technology and society, such as recognizing the importance of technology in our lives and our collective ability to direct or restrict technological change, and recognition of the importance of economic, social, legal, and public policy considerations.

The need for engineering and engineering technology degree programs to address issues of technological literacy directly in the curriculum is inherent in the EAC of ABET and TAC of ABET program accreditation criteria. While the lists of program outcomes (criterion 3) are different for engineering (EAC) and engineering technology (TAC), both lists include topics that directly relate to developing technological literacy in students. Issues such as design within constraints, social and ethical issues, and globalization are included on both lists and relate to technological literacy.

This paper will examine both the TAC of ABET and EAC of ABET lists and will highlight areas related directly to technological literacy. The paper will explore the concept of technological literacy as a framework for addressing these topics throughout the curriculum and in a specific school’s or department’s lists of program learning outcomes. This framework has the potential to be very useful as faculty members work to relate material in different courses to meeting common curricular goals. Also, recognition by faculty members that they are already teaching elements of technological literacy to their majors may also encourage them to attempt to teach these concepts to non-majors as well, either through revamping existing major courses for majors and non-majors or by creating new courses for non-majors by drawing on elements of existing courses for majors.

Introduction
Degree programs in engineering and in engineering technology are expected to prepare graduates to play leading roles in the development and management of technology. Graduates should have the foundation of knowledge necessary both for initial employment in their specific field and for them to continue to learn throughout their careers. With experience, graduates should grow professionally from the level of a junior team member to that of a leader with responsibility for the broad scope of a technological project. Their job duties should progress from dealing with
specific problems as part of a broader project to managing the entire project where the person must deal with social and economic as well as purely technical issues.

While the initial job function may have the graduate performing basic tasks such as calculations and analyses where someone else makes critical judgments based on these calculations, or the graduate does detailed design work where someone else makes the design decisions, in time this person should grow in the profession to where they are required to make decisions at progressively higher levels. They must be able to work with, understand the needs of, and be understood by people with a wider range of backgrounds. To do this successfully, they need a broader understanding of technology and of how technology affects society. They need to have developed sufficient technological literacy to understand the broader scope of their work and to be able to help others understand the issues related to their work.

Technological Literacy
In the National Academy of Engineering publication “Technically Speaking,” technological literacy is discussed as the knowledge necessary for citizens to understand, make informed decisions, and think critically about technology. This is described as having three major components: knowledge, ways of thinking and acting, and capabilities¹. These are described in more detail as follows.

Characteristics of a Technologically Literate Person
A technologically literate person has knowledge of technology and is capable of using it effectively to accomplish various tasks. He or she can think critically about technological issues and acts accordingly. Technological literacy can be visualized in three dimensions.

Knowledge
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.

The concept of technological literacy has received significant attention in recent years (3-16). Much of this attention has been focused on efforts to develop greater technological literacy in the general population. Significant efforts have been made at all levels of education, including the efforts by the International Technological Education Association (ITEA) to develop standards and materials for teaching this subject at the K-12 level. From the perspective of faculty in colleges and universities, discussion of this topic has focused on courses aimed primarily at people who are not majoring in engineering or engineering technology.

The attributes given for each dimension describe a technologically literate member of the general population. This same list could be used to describe the desired outcomes for people earning degrees in engineering or engineering technology, although specific expectations for majors will often exceed expectations for non-majors. A graduate of an engineering technology or engineering degree program would have knowledge and capabilities required for practice in their field that would go far beyond expectations for a non-major. These aspects are directly related to the curriculum in any degree program. Aspects related to broader questions and concerns, such as the impact of technology on society, are not closely linked to the traditional elements of the curriculum. These aspects of technological literacy are, however, at least as important to our graduates as they mature and move into positions of leadership as they are to non-majors.

Accreditation Criteria – Program Outcomes
The need to prepare students both with the material needed for practice in their specific field and to understand and address broader issues in technology is reflected in current criteria for engineering and engineering technology degree program accreditation. Since 2000, the Accreditation Board for Engineering and Technology (ABET) standards have been based on outcomes assessment. As part of the criteria, both the engineering accreditation committee (EAC of ABET) and the technology accreditation committee (TAC of ABET) include lists of expected outcomes. Programs are required to develop lists of program outcomes for graduates which incorporate these common elements. All elements of the curriculum in accredited programs in engineering and engineering technology are mapped to these outcomes. The common lists of outcomes for engineering and for engineering technology are listed below.
Engineering Degree Programs: EAC of ABET Accreditation Criteria

**Criterion 3. Program Outcomes**

Engineering programs must demonstrate that their students attain the following outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Engineering Technology Degree Programs: TAC of ABET Accreditation Criteria

**Criterion 3. Program Outcomes**

Each program must demonstrate that graduates have:

a. an appropriate mastery of the knowledge, techniques, skills, and modern tools of their disciplines
b. an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology
c. an ability to conduct, analyze and interpret experiments, and apply experimental results to improve processes
d. an ability to apply creativity in the design of systems, components, or processes appropriate to program educational objectives
e. an ability to function effectively on teams
f. an ability to identify, analyze and solve technical problems
g. an ability to communicate effectively
h. a recognition of the need for, and an ability to engage in lifelong learning
i. an ability to understand professional, ethical and social responsibilities
j. a respect for diversity and a knowledge of contemporary professional, societal and global issues
k. a commitment to quality, timeliness, and continuous improvement

When these lists are considered in light of the dimensions for technological literacy, it is apparent that these common outcomes may be mapped to the dimensions of technological literacy. Gorham et al have done this with the engineering accreditation standards and the standards developed by the International Technical Education Association (ITEA) for technological literacy developed in 2000, and their paper includes a map which shows links...
between the two sets of criteria. It is useful to consider the dimensions of technological literacy when designing program outcomes. Also, consideration of the concept of technological literacy and the attributes of each dimension may be helpful in designing both outcomes and program learning objectives related to broad issues in technology.

Mapping Program Outcomes to the Three Dimensions – Knowledge, Ways of Thinking and Acting, and Capabilities - of Technological Literacy

To use the concepts of technological literacy in the development of curriculum and program outcomes, it is useful to relate the outcomes to the dimensions of technological literacy.

As a start, one can place all of the program outcomes in the category of capabilities. This is appropriate and useful up to a point. While some of the outcomes are related to specific areas of knowledge, the emphasis is on the graduate’s capability to use this knowledge. Hence, categorization under capabilities is appropriate.

Dimension of Technological Literacy - Capabilities

Has a range of ... skills ....
Can identify and fix ... technological problems
Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.19

Many of these outcomes focus on the critical capabilities needed for employment in the specific field. These may be separated into discipline-specific and general capabilities. While the accreditation criteria as given in general terms, it is assumed that unique, discipline-specific capabilities are included in any program’s list of outcomes.

Discipline-Specific Capabilities

EAC of ABET Accreditation Criteria Items

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints ....
(e) an ability to identify, formulate, and solve engineering problems
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.20

TAC of ABET Accreditation Criteria Items a), b), c), d) and f)

a. an appropriate mastery of the knowledge, techniques, skills, and modern tools of their disciplines
b. an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology
c. an ability to conduct, analyze and interpret experiments, and apply experimental results to improve processes
d. an ability to apply creativity in the design of systems, components, or processes ....
This dimension is likely to receive the most thorough coverage in any program’s curriculum. A major thrust in any curriculum is the analysis, design, and application of specific elements of technology. For example, a mechanical engineering student studies subjects related to the creation of machines – the mechanics of forces and torques, the resulting stresses and strains and their effects on materials, and the relationship between heat and mechanical energy. They are required to build from basic courses in mathematics and science through more focused engineering science courses to courses where they learn the application of these tools in the design of components and systems. The new mechanical engineering graduate should be prepared to start the next stage of their life (and of the life-long process of learning) in a job where they are expected to either already know or be able to easily learn to use specific tools, such as solid modeling software, and to follow standard design procedures for specific components and systems.

In addition to discipline-specific capabilities, these outcomes also fit aspects of the dimension of knowledge.

Knowledge

- Understands basic engineering concepts and terms …
- Is familiar with the nature and limitations of the engineering design process.\(^2\)

As with other areas of knowledge, the graduate is expected to know how to use this directly in discipline-specific applications.

General Capabilities

EAC of ABET Accreditation Criteria Items

- (d) an ability to function on multidisciplinary teams
- (f) an understanding of professional and ethical responsibility
- (g) an ability to communicate effectively
- (i) a recognition of the need for, and an ability to engage in life-long learning\(^3\)

TAC of ABET Accreditation Criteria Items

- e. an ability to function effectively on teams
- g. an ability to communicate effectively
- h. a recognition of the need for, and an ability to engage in lifelong learning
- i. an ability to understand professional, ethical and social responsibilities
- j. a respect for diversity ….
- k. a commitment to quality, timeliness, and continuous improvement\(^4\)

Some of the outcomes focus on critical skills that are not discipline-specific. All graduates must be prepared with the necessary communication and people skills to function as part of a technological project team. Up to a point, students are expected to develop some of these capabilities in general core courses. However, it is likely that most programs require some work of this type in the major courses as well.
The items discussed to this point are those that prepare the graduate for initial employment. At this level, it is assumed that the person will be working as a junior member of the team and that their work will be defined by other, more experienced members of the team. The new graduate is unlikely to be dealing with broader questions of trade-offs or of social and political issues of an engineering project. With experience, that graduate should reach a level where they must consider societal issues and constraints in making decisions. It is this area where thinking in terms of technological literacy is most likely to be useful in curriculum development for engineering and engineering technology programs. For this, the categories of knowledge and ways of thinking and acting are most important.

**Dimension of Technological Literacy - Knowledge**
- Recognizes the pervasiveness of technology in everyday life.
- 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.

**Dimension of Technological Literacy - 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.\(^{25}\)

In engineering or engineering technology curricula focused on teaching specific capabilities needed for employment, these issues would have received at best only limited attention. A student could be exposed to these topics in greater depth in a course on technology and society or on the history of technology.

While these issues may not fit well into traditional curricula, they are important issues. In promoting technological literacy among the general population, these aspects are listed because of the need for people to recognize the importance of technology in their lives, the benefits and risks that come with new technological innovations. A major goal in this effort is to prepare people to make informed, and hence better, decisions in the management by society of technological change. People are required to make decisions about technology in their homes, in the workplace, and as citizens in a democracy.

As people being trained to have expertise in technology, it is critical for engineering and engineering technology majors to be prepared to understand and to help others understand and find good answers to questions about technology. They will be making decisions in the
development and use of technology that will affect society. Giving proper consideration to social needs in the development process will reduce the risks of problems later. Likewise, failure to consider societal issues can have catastrophic consequences. Not only do our graduates need to be prepared to make good decisions, but they also need to be prepared to help society make good decisions. They need to be active participants in the public debate over technological questions. Compared to the general population, they should be better informed about technology and better able to understand the trade-offs and risks. Our graduates should be taking leading roles in public debates on technological issues. Incorporating these aspects of technological literacy in the curriculum would help to prepare graduates for this role.

Both lists of accreditation criteria include elements that are related to these aspects of technological literacy.

EAC of ABET Accreditation Criteria Items
   (c) an ability to design ... within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
   (f) an understanding of professional and ethical responsibility
   (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
   (j) a knowledge of contemporary issues

TAC of ABET Accreditation Criteria Items
   b. an ability to ... adapt to emerging applications of ... technology
   i. an ability to understand professional, ethical and social responsibilities
   j. a respect for diversity and a knowledge of contemporary professional, societal and global issues

It is likely that these items are among the most difficult areas for programs to cover adequately in traditional engineering or engineering technology courses. Approaching these issues from the perspective of teaching technological literacy may be useful in efforts to strengthen the curriculum in these areas.

Criteria related to engineering ethics have been included here even though they were also listed as general capabilities and are likely to have received attention in the curriculum. They are listed here because facets of technological literacy relating to technology and society can give students a better perspective on ethical issues.

Integrating the Teaching of Technological Literacy in the Curriculum
Recently, a significant body of literature has developed on the teaching of technological literacy. This has been encouraged through efforts by the National Science Foundation (NSF) and the National Academy of Engineering (NAE), including an NSF conference report and NAE publications and website. Efforts to teach technological literacy include K-12 and university level instruction as well as activities by museums and other entities. A technological literacy community has developed within the American Society for Engineering Education.
ASEE. This group has sponsored workshops on developing technological literacy courses and has presented a series of sessions at ASEE conferences where papers have been presented that document a variety of approaches to teaching technological literacy. While the course structures vary, including approaches ranging from lecture courses on technology and society or on the history of technology through to courses where the central activity is technology dissection, all address the different aspects of technological literacy. While the emphasis here has been on bringing technological literacy to the general populace, engineering and engineering technology majors have taken and benefited from these courses. As discussed in earlier sections, courses designed to teach technological literacy cover topics that are highly relevant to engineering and engineering technology majors as reflected by accreditation criteria.

One approach to formally incorporating the teaching of technological literacy in an engineering or engineering technology degree program would be to add a required course in the subject to the curriculum. Given the pressures on universities to limit the number of credit hours required for degrees, addition of a new course is likely to be difficult. An existing course may need to be deleted from the list of requirements to make room for the new course. Even if a course can be identified for deletion, there is likely to be competition to fill this slot with other proposed new courses that would meet other critical needs in the curriculum. Finally, even if a program decides to add a required technological literacy course, either a current faculty member must be available and willing to take on this assignment or a suitable new faculty member must be hired.

There are advantages to this approach. A technological literacy course can serve both majors and non-majors. This can be a service course that attracts added enrollment from outside of the engineering or engineering technology program offering the course. With success in attracting non-majors, this course would help to improve the technological literacy of a broader population. This has been identified as a significant societal need. It would also serve the program offering the course by increasing number of students served by the department or school. This increase in productivity would be reflected in metrics used to judge the performance of programs and should justify more faculty lines and funding for the department. It is difficult to attract students and establish such a service course. Using this course for majors as well as non-majors would ensure enrollment as the course is being established.

Another option for consideration is to incorporate elements of technological literacy in courses throughout the curriculum. With this approach, it would not be necessary to make room for and staff a new course. Instead of finding a faculty member who is prepared and willing to take on an entire course on technological literacy, many faculty members must be willing to allot time in existing course for technological literacy issues. It is likely that these issues are already being addressed, albeit without formally thinking of this as teaching technological literacy, to meet accreditation requirements. The framework of technological literacy and techniques from existing courses in this area could be incorporated into existing courses to enhance the treatment of these elements.
The best approach may be a hybrid where there is a designated technological literacy course (or course sequence) serving both majors and non-majors reinforced with technological literacy issues related to specific accreditation criteria distributed in other courses throughout the curriculum. Whatever approach is used, the framework of teaching technological literacy should be very useful in efforts to meet accreditation criteria related to social, political, and other issues that do not fit traditional course based on specific capabilities.

Conclusions
There are strong correlations between the dimensions of technological literacy and accreditation criteria for degree programs in engineering (EAC-ABET) and engineering technology (TAC-ABET). The perspective of teaching technological literacy may be very helpful to those who are working to develop or enhance their curriculum to meet outcomes linked to specific accreditation criteria. The literature on teaching technological literacy offers useful examples to this end. Finally, this approach can serve both to help satisfy accreditation criteria for majors and to serve non-majors.

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