AC 2012-5100: DEFINING ENGINEERING AND TECHNOLOGICAL LITERACY

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Defining Engineering and Technological Literacy

Many Americans lack even a rudimentary understanding of the principles underlying the technology essential for daily life. Engineering concepts are pervasive in decision making within industry, government, education, and health care, yet most people complete formal education with little exposure to the central ideas and principles underlying our technological society. The terms engineering literacy and technological literacy have been used to describe aspects of this understanding of human-developed process and products. This work addresses some of the differences and similarities between the concepts of engineering literacy and technological literacy. A clear well-defined understanding of each of these areas is an essential first step in developing a means to promote these understandings in the undergraduate general education program. Engineering literacy is viewed as having a focus directed more toward the process of creating or designing technological artifacts or systems. It is argued that technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society. Each literacy is seen as having a time-independent and a constantly evolving or changing component. The engineering processes can be viewed as independent of the specific nature of technology which changes over time as technology evolves. The specific artifacts, processes, and systems that define any technological era are transient. The hardware aspects of technological literacy will be an ever-changing subject. The interactions and relationships of society to technology are viewed as constant and little-changed as different artifacts and systems move into and out of importance to daily life. This work will use the process of a comparison of engineering and technological literacy to help define and describe each area of knowledge.

The Need for Understanding Technology and Engineering

Technology affects nearly every aspect of our lives, and informed citizens need an understanding of what technology is, how it works, how it is created, how it shapes society, and how society influences technological development. The critical role of technology in creating and maintaining our modern standard of living has been emphasized by the National Academy of Engineering in *Technically Speaking: Why All Americans Need to Know More about Technology*[1]. The NAE promotes technological literacy as means by which individuals can function more effectively in modern technological society. This is consistent with E.D. Hirsh's general definition of "literacy" as "information that is taken for granted in public discourse.[2]"

The importance of understanding engineering has also been advocated. The National Academy of Engineering (NAE) has published *Changing the Conversation: Messages for Improving the Public Understanding of Engineering*[3]. The NAE document outlines the importance of clarifying the nature of engineering and the role engineers play in improving the quality of life. It has also been argued that a person who has no perception of the contribution that engineering can make to our understandings of behavior and society is not liberally educated[4].

The American Society for Engineering Education (ASEE) has an established Technological Literacy Division. A goal of the division is to advance "broad technological understanding" by all individuals. Based on topics addressed by papers in the divisional sessions at ASEE national

conferences it is apparent that the subject matter of technological literacy encompasses a wide range of issues related to helping all types of students to understand engineering and technology.

Recently the authors, who are also members of the ASEE Technological Literacy Division, have noticed that the terms technological literacy and engineering literacy appear in discussions in similar contexts with differing meanings. In some discussions technological literacy and engineering literacy are treated as synonyms. In others the two are treated as separate concepts. There appears to be a need to clarify the ideas of engineering and technological literacy. This paper intends to begin a discussion about the differences and similarities that might exist between engineering and technological literacy.

There are a number of possible types of literacy relevant to engineering and technological literacy. These include such concepts as computer literacy, mathematics literacy, and financial literacy. A more thorough and wide-range review of literacies should include the similarities, differences, and nuanced distinctions between these concepts and technological literacy. The present analysis will be confined to engineering and technological literacy as a first step.

Definitions of Technological Literacy

Technology is all of the many products of the engineering disciplines not just personal computers and information technology. Technology, in a broad sense, is any modification of the natural world made to fulfill human needs and wants. This includes not only its 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.

At the start, it is essential to distinguish technology and engineering from science.[1,3] Science is the development of an understanding of the natural world, while engineering is the creation of new technologies to improve human welfare.[3] The separate, but related goals, of engineering and science necessitate a differentiation between technological literacy, engineering literacy, and knowledge of science.

For a number of years groups seeking to define the content and curriculum of science and mathematics have included the human-built world, or technology, when developing content standards. Initially these efforts included technology as a peripheral aspect of science content.[5,6] In a recent K-12 effort, the International Technology and Engineering Educators (ITEEA, formerly the International Technology Education Association) developed Technology Literacy Standards[7] explicitly addressing technology. While these efforts are directed at K-12 students, the general topics and organization of the technical world provide useful information for efforts intended for the undergraduate level.

Project 2061: *Benchmarks for Science Literacy* (1993)

In 1993, the American Association for the Advancement of Science (AAAS) published, *Project 2061: Benchmarks for Science Literacy.*[5] The AAAS devoted one of the twelve chapters to the Designed World. The focus was on the products of engineering and their impact on daily life.

Eight topics were considered: Agriculture, Materials and Manufacturing, Energy Sources and Use, Communications, Information Processing, and Health Technologies. The benchmark recommendations emphasized that technology is a human activity that shapes our environment and lives.

The National Science Education Standards (1996)

In 1996 the National Academies produced the *National Science Education Standards.*[6] This document contained a section devoted to technology. A notable inclusion in these standards was a highlighting of the importance of the design process as a defining aspect of technological endeavors.

ITEEA *Standards for Technological Literacy* (2000)

In 2000 the then International Technology Education Association published *Standards for Technological Literacy: Content for the Study of Technology.*[7] The ITEEA standards project was a broadly based effort that included more than 150 reviewers from K-12 education, the sciences, and the engineering disciplines. An intent of this effort was to encourage educational curricula that would provide technological literacy to K-12 students.

The ITEEA 2000 Standards are comprehensive in scope. They are divided into five main categories that sub-divide into 20 specific standards. The five main categories used to define technological understanding include:

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

Important features of the scope of understanding technology are seen in the ITEEA standards. The standards consider the nature of technology or helping K-12 learners to be able to distinguish technology from other aspects of their environment. The standards also highlight the importance of specifically studying the complex interaction between technology and the society which creates it. The design process as the mechanism of technological development is a separate area of the standards. The standards then include specific abilities related to technology such as the ability to select technological products appropriate for a specific set of requirements, or to carry out basic problem-solving in the context of technological systems. The last main category attempts to identify certain broad areas of the human-built world such as communication, manufacturing, and energy technologies. The ITEEA standards represented a significant advance and elaboration of the parameters defining the technological world, and the recognition that, given the importance, all students should begin to develop an increasingly sophisticated understanding of technology starting at the earliest years of school.

National Academy of Engineering: *Technically Speaking* (2002)

During the same time period that ITEA was addressing technological understanding in the K-12 realm, the National Academy of Engineering began promoting the importance of public understanding of technology and engineering.[7] This lead to the publication of *Technically*

Speaking.[1] While the ITEA work was intended to influence the K-12 curriculum, *Technically Speaking* was intended to reach a broad audience and inform the general public.

Technically Speaking emphasized that technology consisted of the broad array of products and processes that are created by people to satisfy human needs and wants. This was an attempt to redirect the association of the word "technology" with personal computers and the internet to a broader definition encompassing all the technology of our human-built world. *Technically Speaking* also fostered the recognition that engineering and science are distinct but related activities. *Technically Speaking* advocated that knowledge in the technical realm might be categorized in a series of levels consisting of Knowledge, Capabilities, and Ways of Thinking and Acting.

The NAE makes an effort to distinguish technology and engineering from science.[1,3] Science is the development of an understanding of the natural world, while engineering is the creation of new technologies to improve human welfare.[3] The separate, but related goals, of engineering and science developed a differentiation between technological literacy and knowledge of science.

Engineering Literacy

While technological literacy has been well-defined, comparable standards or definitions of engineering literacy have not been developed. The various existing standards for technological literacy include elements that can be recognized as aspects of engineering. For example the design process is included in nearly all of the standards. This process is normally considered to be a hallmark of engineering activity. However the term engineering is not treated systematically by any of the technological literacy standards.

There is a need to distinguish between the terms engineering literacy and technological literacy. The two are interconnected and the potential for confusion is understandable. Never-the-less some effort should be made to clarify engineering literacy.

Distinctions Between Engineering Literacy and Technological Literacy

In this section some means to help distinguish engineering and technological literacy are described. This is considered to be an initial effort and the starting point for a discussion. Refinement of the engineering literacy concept is anticipated as was the case for technological literacy. Some area of distinction between engineering and technological literacy are listed in Table 1.

Table 1: Some Areas of Distinction between Engineering and Technological Literacy.

Engineering Literacy	Technological Literacy
Process	Product
Verb (Actions)	Noun (Objects)
Narrow focus	Broader focus

Process versus Product

One means to distinguish engineering from technology is by considering the difference between process and product. Engineering can be viewed as a process. The process of creating physical artifacts and procedures that meet human needs and wants. Technology on the other hand might be seen as the product of the process. Technology is the created device, system, or component that is brought into existence by humans engaging in a creative problem-solving process.

For example a person who is technologically literate might have a knowledge of the major systems of an automobile such as the engine, power train, and brakes along with the basic principles underlying the functioning of these systems. This is knowledge of the product. Engineering literacy would include knowledge or ability to design, analyze or otherwise create the constituent components of the automobile.

Verb versus Noun

A more general way to emphasize the distinction between engineering and technology is to introduce the idea that the difference between the two is related to the fundamental difference between a verb and a noun. In this discussion, engineering can be considered to be a verb. Engineering is an action. Something is happening which is identified as engineering. Engineering activity results in a transformation of materials, energy, or information. Something is different before and after engineering activity takes place.

Technology can then be classified as a noun. Technology can be viewed as the identifiable things that result from engineering or related work. Technological literacy would then include some knowledge of these components, systems, and processes.

As an example, consider an integrated circuit chip. An integrated circuit is a technological device. A person who is technologically literate might be able to recognize an integrated circuit, describe what it is, and explain the general uses and importance of integrated circuits. An engineering literate individual would be more familiar with how an integrated circuit can be used as a means of converting an abstract schematic design into a working physical object.

Narrow versus Broader Focus

Another area to help distinguish engineering from technological literacy would be to consider one as having a broader or more diverse focus than the other. If engineering literacy is viewed as having a focus directed more toward understanding the process of creating or designing

technological artifacts or systems, then technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society.

For example, while it is not necessarily the desired situation, it is true that individuals can engineer or create technological artifacts in a state of near isolation from other concerns or interests. The engineering design process can create its own isolated internal value system. A successful engineering effort can be defined as a design that works according to the specifications of those providing the resources to carry out the project. Incarcerated individuals might be compelled to create a particular technological device with no knowledge of the intended use of that device. If the device functioned as intended and met all specified design requirements it would be difficult to argue that the creators were not engineering literate. However without knowledge about why the particular design requirements were chosen, and what use the device served, it could be said that the prisoner-engineers did not fully understand the technology and were therefore not technologically literate.

Evolution or Change Over Time

It may be helpful to consider how the understanding of engineering or technology may evolve or change over time. It can be seen that both engineering and technology have both a time-independent or permanent nature and also a constantly evolving or changing aspects. The engineering processes can be viewed as independent of the specific nature of technology which changes over time as technology evolves. The specific artifacts, processes, and systems that define any technological era are transient. The hardware aspects of technological literacy will be an ever-changing subject. The interactions and relationships of society to technology are viewed as constant and little-changed as different artifacts and systems move into and out of importance to daily life.

Role of Analysis

Since engineering literacy appears to be directed more toward the process creating or improving technological objects it may be that computation and analysis appear differently in engineering literacy than technological literacy. It may be that an individual who is technologically literate might acquire an ability to use technological tools and mathematical methods in a problem-solving context. It would seem that in engineering the purposes of analysis are more narrowly focused toward creating and improving technological products.

For example, a person who is technologically literate may sample a drop of water from a pond and then count the number of single-celled organisms in one drop of pond water by correct use of an appropriate microscope. This person may then be able to use information obtained from maps and other published data to determine the volume of the pond. They may then be able to use a spreadsheet to determine an estimate of the total number of single-celled organisms in the pond. This process has involved technological systems and quantitative analysis but it would not appear that this activity would be classified as an engineering project.

Degree of Overlap and Open Questions

Once a distinction is made between engineering literacy and technological literacy, the question of the degree of overlap between the two concepts becomes an interesting potential area of discussion. What is the overlap or commonality between engineering literacy and technological literacy? Is one completely contained within the other? Is engineering literacy a subset of technological literacy or is the opposite the case?

One way to help frame the question of the relationship between engineering literacy and technological literacy is to ask: are engineers technological literate? If not why not? Is this because of a deficiency in current engineering education or is it due to a fundamental difference between the scope of engineering and technological literacy? Alternatively, in considering general education, what are the appropriate elements of engineering and technological literacy to be included?

Summary and Conclusions

An initial effort to distinguish between engineering and technological literacy has been made. A clear well-defined understanding of each of these areas is an essential part of developing these literacies. Engineering literacy is directed more toward the process of creating or designing technological artifacts or systems. Technological literacy includes a wider ranging scope including the products or results of the engineering process as well as the relation between technology and society. The extent to which engineering and technological literacy form a subset of each other remains a topic for future discussion and investigation.

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