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"Should we consider transforming the definition of technological and engineering literacy..."

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"Should we consider transforming the definition of technological and engineering literacy…"

Abstract

During the 2019 ASEE Annual Conference and Exposition, several session papers, panels, and special presentations put forward that there are other components to technological and engineering literacy / philosophy of engineering. These suggest a broader understanding (and perhaps definition) of this literacy and philosophy than previously thought; that perhaps historical industrial, cultural, educational, and political perspectives have constrained our thinking, perspective, and philosophy. Thus, should we consider transforming the definition of technological literacy and engineering to place value and importance on ethno-technologies and cultures, scaffolding, social justice, language and dialects, design, and the internet of things; will this foster a more inclusive approach to understanding technological and engineering literacy / philosophy of engineering such that the importance of these can be extended beyond traditional (academic) audiences?

Introduction

In broad terms, technological and engineering literacy has been the expressed need to create, among others, a knowledgeable and informed student, parent, public, policy maker, politician, investor, elected official, and corporate leader. This concept was driven by the importance of facing daily technological and engineering literacy problems and decisions in areas such as [1]:

- Product and process risks.
- Communication technology.
- Government regulation and policy.
- Availability of resources.
- De-monopolization of technical know-how.
- The now extra-national nature of innovation

On a national level, the need for technological literacy and engineering literacy became manifest through publication of:

- International Technology Education Association. Standards for technological literacy: content for the study of technology [2].
- "*Technically speaking: Why all Americans need to know more about technology"* [3].
- "*Tech Tally: Approaches to Assessing Technological Literacy"* [4].

These led the discussion into the American Society for Engineering Education (ASEE) and the formation within ASEE of a technological literacy constituent committee, and ultimately, the Technological and Engineering Literacy / Philosophy of Engineering (TELPhE) division.

In a sense, this was acknowledgement that as a society became more specialized, a narrow focus of technological and engineering literacy precluded an understanding, a flexibility, and an adaptable knowledge in this area that is essential for a society to function. The general approach to achieve this objective was to develop technology components for K-12 education and to incorporate technological and engineering literacy components in higher education general education program course offerings. The success of these initiatives was supported by statistics and data reported in studies conducted by academia, government agencies, and professional societies [5]. However, during the 2019 ASEE Annual Conference and Exposition, several sessions, panels, and special presentations put forward that there are other components to technological and engineering literacy, suggesting a broader understanding (and perhaps definition) of this literacy and philosophy than previously thought; that perhaps historical industrial, cultural, educational, and political perspectives have constrained thinking, perspective, and philosophy, with respect to what is technological and engineering literacy, and as a consequence the definitions that have been associated with it.

Developing a literacy

The task of a literacy is to be able to develop a knowledge which then can be recalled and applied to a particular situation, or if the knowledge is not completely congruent with what the situation calls for, that the literacy enables an extraction of knowledge related to, or an extrapolation of knowns into the region where an understanding of a particular aspect of technology or engineering is at issue. The matter at hand at hand may be individual or societal. In general, this type of literacy has generally required the use and understanding of language, calculations, and process [6].

Krupczak, et al. [7] separated technological literacy and engineering literacy. The former is distinguished as, *"... all of the many products of the engineering disciplines ... in a broad sense [that] is any modification of the natural world made to fulfil 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*." [7]. The authors noted that while technological literacy was well defined, such was not true for engineering literacy, stating that while the various existing standards for technological literacy include elements that can be recognized as aspects of engineering, it is the design process that is "*normally considered to be a hallmark of engineering activity,"* but that the *"term engineering is not treated systematically by any of the technological literacy standards.*" [7].

The authors proposed as the means to distinguish technology literacy from engineering literacy was by considering the difference between process and product, that technology might be seen as the product of the engineering process creating devices, systems, or components that are brought into existence by humans engaging in a creative problem solving process (engineering), and that engineering is "*the process of creating physical artifacts and procedures that meet human needs and wants*." [7]. Thus their definition for each literacy [7]:

- Technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society [7].
- Engineering literacy is viewed as having a focus directed more toward the process of creating or designing technological artifacts or systems [7].

Another way to help distinguish technological from engineering literacy would be to consider technological literacy as having a broader or more diverse focus than engineering literacy. Thus, technological literacy includes a broader view of the application of products or results of the engineering process as well as the relation between technology and society, while engineering literacy is considered as having a focus directed more towards understanding the process of creating or designing technological artifacts or systems [7].

TECHNOLOGICAL LITERACY: PRODUCT → OBJECT (NOUN) → BROAD FOCUS [7]

ENGINEERING LITERACY: PROCESS → VERB (ACTION) → NARROW FOCUS [7]

Evolution or change over time

It's helpful to consider how the understanding of engineering or technology may evolve or change overtime. While both engineering and technology each have a time-independent or permanent nature and a constantly evolving or changing aspect, the engineering process can be viewed as independent of the specific nature of technology, which is evolutionary. Thus, while the artifacts, processes, and systems that are associated with any technology or technological era are transient, and the tangible aspects of technological literacy will change, the interactions and relationships of society to technology can be viewed as constant and little-changed even though different artifacts and systems move into and out of importance to daily life. Thus, the understanding of technology evolves and changes, and the hardware aspects of technological literacy are an ever-changing subject as a function of the interactions and relationships of society to technology as different artifacts and systems move into and out of importance to daily life. In contrast, the engineering process, even though its tools (technology) may change (slide rule vs. computer, equations vs. parametric studies), remains constant [7].

Representative of this is an episode related by Henry Petroski, in *To Engineer is Human: The Role of Failure in Successful Design* [8]. In his opening chapter, Petroski relates a conversation with a neighbor after the Kansas City Hyatt Regency skywalk collapse. The neighbor wondered why engineering did not know enough to build so simple a structure as an elevated walkway. He then went on to cite the Tacoma Narrows Bridge collapse, the American Airlines DC-10 crash in Chicago, and some other famous failures and hypothetical nuclear power plant accident scenarios he was sure would exceed the Three Mile Island radiation release. The neighbor's point to Petroski was that engineering did not quite have the world of their making under control. Petroski responded that predicting the strength and behavior of engineering structures is not always so simple and well-defined an undertaking as it seems, which did nothing to address the neighbor's technological and engineering literacy. Concluding, Petroski observed that "*Engineering has as its principle object not the given world but the world that engineers themselves create*." This would immediately suggest the need to extend the understanding of technological and engineering literacy beyond being congruent with design, process, and product situations, or enabling the extraction or extrapolation of knowledge into areas outside the known envelope, as these may not necessarily be present in the level of technological and/or engineering literacy either in the individual or the immediate society that is involved with the particular issue or understanding. Thus while there is a core belief that everyone should know more about technology and engineering, and progress has been made in defining objectives, developing curriculum materials, and instructional programs, methods of assessment of the level of technological and engineering literacy, there still needs to be continuing movement to move these literacies into contexts and areas in a manner where they will do the most good, and to have some assessment mechanism to ascertain the progress towards achieving this objective [9].

From this starting point, the definition of technological literacy and engineering literacy began to change, and they began to meld. The need to distinguish between levels of literacy, as well as to where these levels should be introduced [6], and how they should be instructed became a matter of national and academic focus. This led to STEM education, technological literacy courses and government-sponsored studies and initiatives that sought to bring technical and engineering knowledge to individuals and groups who weren't naturally inclined to this area, either by choice or lack of access to appropriate knowledge. Once this understanding was established, it suggested the definition of technological and engineering literacy is consideration of the product it produced, the process by which the product was produced, and the technological judgement associated with the value of the end product and the determination of its utility [6]. Thus, technological and engineering literacy began to be conducted in a traditional academic context and administered much in the manner of a general education course; that is to have broad appeal, to be non-threatening to students (especially with respect to grade point average outcome), and be both a function of the faculty's area of expertise and a function of the audience to whom the course or program is directed.

The next dimension of technological and engineering literacy was to add entrepreneurship and move it into an economic dimension, a more practical business / commercial framework from it being an abstract research initiative [6]. And then the discussion (Keilson) took the STEM concept, expanding it to STEAM to move technological and engineering literacy into being also a knowledge for citizenship, for living skills and competencies, and for employment competencies [6], and lastly, that any particular society is dependent on a given level of technological and engineering literacy for survival (Cheville) [6].

The Technology and Engineering Literacy Framework for the 2018 National Assessment of Educational Progress [10]

Within this framework aimed at assessing technology and engineering literacy at the 4th, 8th, and 12th grade levels, is a discussion that notes that an understanding of technology and engineering literacy begins with a clear understanding of exactly what technology and engineering literacy means. The framework defines technology as *"... any modification of the natural world done to fulfill human needs or desires.*" [10] noting that historically the term "*technology*" has a much broader and deeper meaning than just today's context of being associated with computers and related electronic devices by elaborating that technology "… *encompasses the entire human-made world, from the simplest artifacts ... to the most complex ... as well as including the entire infrastructure needed to design, manufacture, operate, and repair technological artifacts…"*

[10] and postulates that while engineers *"may not actually construct artifacts … they are the ones who develop the plans and directions for how artifacts are to be constructed… .*" [10]. The framework defined engineering as *"… a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants*." [10]. These definitions closely reflect Krupczak, et al. [7].

Then, the framework combined these definitions resulting in technology ***and*** engineering literacy being *"…the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals.*" [10]. In establishing this definition, the framework noted that technology and engineering literacy comprises attributes in three importantly interconnected areas:

- Information and communication technology: Familiarity and facility with this technology is essential in virtually every profession in modern society [10].
- Technology and society: Knowledge of the effects that technology has on society and the natural world and the sorts of ethical questions that arise from those effects is crucial for understanding the issues surrounding the development and use of various technologies and for participating in decisions regarding their use [10].
- Design and systems: An understanding design and systems is a broadly applicable skill particularly valuable in assessing technologies that can also be applied in areas outside technology [10].

In establishing the latter definition, the framework leads to a recognition that the understanding of the aspects of the nature, processes, uses, and effects of technology and engineering literacy are particularly important to participate intelligently and thoughtfully in the economic, civic, and social spheres of modern society. In so doing, the framework effectively moved the conversation of technology literacy and engineering literacy at the 4^{th}, 8^{th}, and 12^{th} grade level from one of simple (if not traditional) technical know-how or skills into the concept of it being an amalgam comprising, in addition to technical know-how, attributes that once were considered independent (or irrelevant) variables outside the traditional technology and engineering thought and educational process.

The 2019 TELPhE discussion

During the 2019 ASEE Annual Conference and Exposition, TELPhE-sponsored panel [11], paper [12], [13], and distinguished lecture [14] sessions put forward that there are other components to technological and engineering literacy. These sessions added several here-to-fore unconsidered (and seemingly unrelated) dimensions to the discussion suggesting a necessity for a broader understanding of this topic than previously thought, and that perhaps historical industrial, cultural, educational, and political perspectives have constrained our thinking, definitions, and philosophies of technological and engineering literacy.

Beginning with a review of the "*founding*" documents for technological and engineering literacy [2], [3], [4], and then noting that post 2008, the conversation regarding technological and engineering literacy started to change from how-to-do-it academically to associating the development of these literacies with non-formal learning experiences, thus raising the question of how do the literacy definitions and standards apply in these contexts, and leading to the observation that literacy, in the end, even with definition, can mean a "*million things*." From this arose the concept of terminology and communication, i.e. the effect on conveying information in dialects, slang, and insider jargon, as well as the discontinuities involved in how we communicate technological and engineering literacy in and through any given language, noting that translations from one language to another, from one culture to another can be affected by changes in word meanings and idea constructs and contexts (Remember the 1990's VW commercial that featured "*Fahrvergnügen*." How did we translate this into English?). Today, with the proliferation of maker spaces, tinkering also entered the discussion with the observation that anyone who wanted to, can acquire a 3-D printer, computer design software, a laser cutter, electro-mechanical components and other readily available bench-top technology and engage in a process of design, manufacture, and application for personal or recreational applications, or as an entrepreneur, or to acquire skills needed for employment, or other career objectives, or be more at home and competent in the Internet of Things than a technical professional.

The ability to engage in critical thinking was among the salient points included in the discussion of technological and engineering literacy, but it was noted in the discussions that a lot of contemporary technical and engineering education is based on the "*kit*" concept which eliminates critical thinking, and also doesn't lead to an understanding of failure, and of how to fix it, and of understanding what happened to avoid a repetition, and the lack of which, in the end, attenuates technological and engineering literacy, and as a result, knowledge.

From this, the questions added to the issue of technological and engineering literacy included:

- What is the purpose of technological and engineering literacy?
- What do we want from it educationally?
- Where does the political spectrum enter into it?
- Do the teachers of technological and engineering literacy need a philosophy of technological and engineering literacy not just for personal technology, i.e. social media and digital-age communications, but more importantly, to be able to effectively include essential knowledge for the recipient to effectively function in a career and as a citizen, or in a society? Some examples would be:
    - Grenfell Tower [15] where public policy and engineering design superseded the safety concerns of residents.
    - Understanding climate change [16] – local implications vs. global implications – and how this matters to the life of a community (Locally, it may not be felt or apparent, but elsewhere it's disastrous in the life of a community such as the Sahara Desert spreading southward into sub-Saharan Africa.).
    - Addressing issues, research problems, developing and communicating possible solutions, and achieve goals related to technology and society such as energy generation [17], [18]; flood control for large urban areas along major waterways [19].
    - Developing resources safely so as not experience another Deepwater Horizon environmental disaster [20].

Thus the view of what comprises technological and engineering literacy and how to define it may well be dynamic when it comes to context of its understanding and application.

Have we reached the end of being able to define technological and engineering literacy as a function of traditions, history, and pedagogy? Should we move into a new context that, while it includes the salient points that we traditionally ascribe to technological and engineering literacy and recognize them in new contexts, for varietal audiences using familiar language and examples that can be related to, i.e.: going back to Petroski's story, such that we, as technical and engineering professionals become better at answering and explaining rather than trying to create individuals and societies that have the attributes (literacies) we want them have?

A context for redefinition

In promoting technological and engineering literacy, the level of competency that is necessary for the literacies to function needs to be established, and that in promoting these literacies, we need to scaffold to include under-prepared and underserved populations (equity), be inclusive and welcome diversity (social justice); we need to understand that cultures have technological and engineering literacy built in, but that it's easy to dismiss these literacies as "*folk stories*" passed from generation to generation; that perhaps our construct of technological and engineering literacy is Anglo-European centric as a function of scientific principles developed through research versus rules of thumb ("*There aren't no calculations, no drawings. We built it the way we've always done it, and the building didn't fall down.*"), and that technological and engineering literacy is really a construct of where you culturally and geographically come from, of what your ethno-technologies are (Do we accept and value ethno-diverse technology and engineering as well as we value ethno-centric technology and engineering?), and that someone may be well-versed in a technology that has been lost or technologically superseded in one culture or society but is still extant from where they came from (Example: food preservation versus the refrigerator. There are still places where there are no refrigerators, and in these places food is being preserved by people using technology that most other people don't even know still exists. Do these folk have technological literacy; do they have engineering literacy?

Thus the transformed definitions should be carefully constructed using common language and terms, have room to validate ethno-technological and engineering literacy and practices as well as language differences, provide suitable entry points for under-prepared and underserved constituencies who, never-the-less have technical and engineering know-how, that places the definitions of technological and engineering literacy at the appropriate level for those who need to understand and use them, that promotes equity in K12 pathways, and maintains a 30,000-ft perspective on practices, processes, and systems to avoid the myopicism that can come from drilling too far down into areas of expertise.

The public discussion and definitions of technological and literacy and engineering literacy continues in pedagogical terms, being found largely in periodic national reports and academic research and papers. In light of the fact that we are living in an increasingly created world, we should begin to see these literacies as social processes in the sense that they are pushing society forward through unknown waters to arrive at some destination, hence the need to transform these literacies beyond a pedagogy to a broader understanding within the technical community and within a technologically oriented society.

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