# Future Directions for Technological and Engineering Literacy and the Philosophy of Engineering

**A White Paper of the**
**Technological and Engineering Literacy / Philosophy of Engineering (TELPhE) Division**
**American Society for Engineering Education**

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## I. Introduction: The Origins and Purpose of the White Paper

The purpose of this white paper is to suggest possible future directions for the Technological and Engineering Literacy and the Philosophy of Engineering (TELPhE) Division. The white paper project emerged from discussions at TELPhE annual business meetings in 2018 and 2019. The general issue of what should be future directions of the division raised fundamental issues about the nature and interpretation of technological and engineering literacy and the philosophy of engineering.

In concert with these discussions, past TELPhE Division Chair Carl Hilgarth pointed out that the question "Why should anyone be technologically literate?" has received little attention [1] and an answer to this question is essential to move the discussion of technological literacy / philosophy of engineering into the public arena. In addition, Hilgarth pointed out that extending the impact of the division beyond traditional academic audiences may require transforming the definition of technological and engineering literacy [2].

At the 2019 Division Business meeting, member Alan Cheville introduced the perspective that technological literacy should be seen as a social justice issue.

In light of the major issues being raised, Professor Emeritus John Heywood offered to create a white paper. The white paper would review the issues raised and bring recommendations to the division. In the interim, other TELPhE members joined the white paper effort.

## II. Historical Context

Suggestions about future directions for TELPhE necessitates a brief review of the historical background of the division.

In 2002 the National Academy of Engineering Committee on Technological Literacy published Technically Speaking: Why All Americans Need to Know More About Technology [3]. The major recommendations of the NAE committee were as follows:

- Strengthen the presence of technology in formal and informal education including K-12 and the undergraduate education of non-STEM students.
- Develop the research base to support efforts to improve technological literacy in the United States.

- Enhance informed decision making on technological issues.
- Reward teaching excellence and educational innovation.

In 2005 a workshop was held at the National Academies on The Technological Literacy of Undergraduates: Identifying the Research Issues. This was organized by John Krupczak and David Ollis [4].

At this workshop the need for an organization to serve as a focal point for technological literacy efforts was discussed. The participants felt that the ASEE would be an appropriate home and a new ASEE Technological Literacy Constituent Committee (TLCC) was formed in June 2005. The TLCC became the Technological Literacy Division in 2008. Since its founding, the Technological Literacy Division has sponsored sessions, panels discussions, and workshops every year at the ASEE annual conference. The division grew to approximately 600 members. Throughout this time the work within the division was largely directed at the second of the four NAE recommendations, specifically developing the research base to support efforts to improve technological literacy in the United States.

It bears noting that during this time a significant amount of work to address the NAE's interest in promoting technological literacy in K-12 has been taken up by the K-12 Engineering efforts. The ASEE Pre-College Engineering Education Division (PCEE) has addressed this need. Most of the K-12 engineering standards and curricula focus on career opportunity awareness, the engineering design process, and engineering applications of science and mathematics.

As the K-12 engineering efforts grew, the term "engineering literacy" began to be used in various places as distinct from "science literacy." This complicated the work of the division since the term "technological literacy" was also used to refer to similar concepts. In 2011-2012 a group within the division made an effort to clarify the difference between technological literacy and engineering literacy [5]. This work intended to resolve the confusion by suggesting that engineering literacy could be viewed as having a focus directed more toward the process (verb - action) of creating or designing technological artifacts or systems. Technological literacy includes a broader view of the products (noun – object) or the various results of the engineering process as well as the relation between technology and society. In light of later work, these definitions, while helpful, are now recognized as being incomplete [2].

The widespread use of the term "engineering literacy" as synonymous with "technological literacy" in both popular media and academic publishing resulted in discussions within the division of the possibility of amending the name from the Technological Literacy Division. A concern was that some both within and outside of ASEE would not associate technological literacy with engineering literacy. Thus, potential collaborators or adopters interested in "engineering literacy" would overlook the work of the division.

During this time period efforts began within ASEE and elsewhere to draw attention to the need for a focused effort to broaden understanding of the philosophy of engineering education. Well-attended workshops were held at the 2007 Frontiers in Engineering Education Conference in Milwaukee, Wisconsin, the 2008 FIE Conference in Saratoga Springs, New York and at the 2009 FIE Conference in San Antonio, Texas. At FIE 2010 in Arlington, Virginia discussions were held regarding the view that engineering educators would benefit from examining the philosophy of engineering education. In 2011 a day-long symposium on the topic was held prior to the FIE Conference in Rapid City, South Dakota. At the 2013 ASEE Conference the Technological Literacy Division sponsored a panel discussion entitled "Philosophy of Engineering, Its Importance and Role in Shaping the Future of Engineering Education". The panel drew an engaged standing-room-only audience.

Recognition emerged that the philosophy of engineering education and technological and engineering literacy share common ground in addressing fundamental questions about the essential characteristics of human-created technological systems and the nature of knowledge and competence in this domain.

A name change of the division to the Technological and Engineering Literacy / Philosophy of Engineering Division (TELPhE) was approved by the ASEE at the 2014 Annual Conference.

To address broader issues and to help reach a wider audience, the division has produced a series of publications entitled "Philosophical and Educational Perspectives in Engineering and Technological Literacy" [6-9]. One goal of this format was to stimulate dialogs and record them in ways that are both readable and archival. Included in these volumes was a series of responses to John Heywood's "Why Technological Literacy and for Whom?" which was presented at the 2016 ASEE Annual Conference and Exhibition in New Orleans, Louisiana. Responses from division members gave a variety of views on the nature of technological literacy. John Heywood then gave a paper replying to these comments [10].

In 2018 the division instituted awards. An annual Meritorious Award and a Best Paper Award recognize significant accomplishments. Such awards are consistent with the practices of many active ASEE divisions. The creation of these divisional awards helps to respond to the NAE's recommendation to "reward teaching excellence and educational innovation."

This historical background demonstrates that TELPhE has embraced the goal of helping all Americans to have a better understanding of technology as originally envisioned by the National Academy of Engineering. Additionally, starting from the original Constituent Committee, the group has evolved to address new challenges and opportunities.

## Overview of Areas of TELPhE Effort

Since the establishment of the division, numerous members have contributed to the development of the research base and pedagogical approaches to improve the broad understanding of technology in the United States.

Prior to the creation of the ASEE Technological Literacy Constituent Committee (TLCC) in 2005, some educators addressed the promotion of the broad understanding of technology. Works by Heywood [11,12] and Byars [12] are illustrative of these efforts. In that period terminology was varied and contributions reflect a crossover between engineering/technological literacy and science literacy.

Division members have developed multiple dimensions of technological and engineering literacy. The ASEE Conference Proceedings now contain a significant body of work in this area. An overview of the topics addressed includes the following:

Personal Empowerment with Respect to Hardware

Some faculty and researchers have made efforts in helping non-engineers develop a more empowered relationship with modern technological hardware. These efforts focus on a "how things work" understanding of technology. This might also be considered as qualitative or conceptual engineering. The goal is that non-engineers should be more informed users of technology and this information can be gained by people who are not necessarily STEM professionals. Division members have developed a considerable amount of research around this approach.

Responsible Citizenship

Some work emerging from TELPhE has advocated for technological literacy as a component of responsible citizenship. A key theme in this group is the idea that given the pervasive nature of technology as part of everyday life, technological and engineering literacy should include an ability to understand the social, political, economic, and ethical implications of technological developments.

Engineering Literacy for Engineers

Another perspective that has been advocated from within the TELPhE division is engineers themselves are not engineering literate. The argument here is mainstream engineering education is too narrowly focused on engineering sciences. Engineers would benefit from the broader range of topics encompassed through technological literacy.

Engineering as a Missing Element of General Education

Work within the division has advanced the belief that engineering represents a unique way of thinking and knowing and should therefore be included as an element of general education for all students. Some aspects of engineering seen as essential to general education include the design process, engineering thinking, systems thinking, and quantitative reasoning.

Engineering Minor

A group of educators lead by Mani Mina at Iowa State University developed the approach of an engineering minor to provide a means for non-engineering undergraduates to develop technological and engineering literacy. These degrees do not focus on teaching specific engineering technical content but on teaching students how to develop the broad understanding and practical technological competence outlined by the National Academy of Engineering.

Course Development

TELPhE members have reported on courses developed and taught for undergraduates to further engineering and technological literacy. Several broad categories can be discerned.

*Survey Courses*

Some division members have created what might be termed Technology Survey Courses. These courses address a range of technologies. In some cases course content may include social and historical dimensions of engineering and technology. Approaches are varied including lectures, demonstrations, and laboratories. Scientific principles involved in technological applications is often a major component of these courses.

*Technology Focus Courses*
These courses tend to address a single technological topic or issue. Subject matter is intentionally focused rather than intentionally broad. In some cases, the courses have a substantial technical or quantitative component. The classes frequently include laboratories or projects. In some courses the social and historical aspects of the topic are introduced. Examples include the hydrogen economy, energy, materials, and bridges and civil infrastructure.

*Engineering Design for Everyone*
These courses focus on the engineering design process. In some implementations the courses include engineering majors along with non-engineering majors. Not uncommon in this group are introduction to engineering courses that are open to students not majoring in engineering.

*Technological Impacts, Assessment, and History Courses*
These courses emphasize the relation between technology and culture, society, history. There is considerable overlap between courses offered by TELPhE members (primarily taught by engineers) and similar courses offered in Science, Technology and Society Departments.

Taken together this body of work by TELPhE members attests to the types of accomplishments that can be achieved and provides confidence that further successes are possible.

**III. Opportunity: Circumstances Requiring Action**
Numerous aspects of current events, ranging from individual to global, reinforce the reality that the role of technology is ever more pervasive, invasive, inescapable and essential in everyday life. At the same time, despite some progress, engineering and STEM education have fallen short of the 2002 vision of the National Academy of Engineering outlined in Technically Speaking. The "broad understanding of technology" remains a challenge.

Looking back to the NAE's 2002 recommendations it appears that the goal to "enhance informed decision making on technological issues" has been under-addressed. The work of division members has developed the research base to support efforts to improve literacy but advancing informed decision making at all levels has not yet received significant attention. The public good suffers when individual and collective decision making on technological issues is trapped between a tyranny of the experts and a largely scientifically and technologically challenged media. A need exists to clarify models of technological decision making. Enhancing decision making requires a good understanding of how this process occurs.

Directing more effort to enhancing informed decision making on technological issues helps to answer the question of "Why is technological and engineering literacy necessary?" It is now more apparent than ever that informed decision making on technological issues is vital at all levels ranging from individual to global.

Enhancing informed decisions furthers social justice and the common good. The social justice perspective can be seen as a clear imperative that all individuals should be empowered to be able to make informed decisions about technological issues that impact them on a personal and societal level.

Decision making can be interpreted broadly and in doing so the education of engineers is included within technological literacy. Engineering design is a decision-making process. The factors involved in that process are multiple and including engineering design as one type of technological decision making raises fundamental issues about the underlying philosophy of engineering and engineering education.

**IV. Findings**

Progress on the circumstances requiring action should be informed by the following findings of the white paper group.

The terminology of technological and engineering literacy remains problematic. Other vocabulary considered by the white paper group were "technological competence" or "empowerment". Also suggested was "critical thinking" in a technological context. However critical thinking is also overused as is literacy. A possibility is a phrase like "technological and engineering navigation". The term "navigation" appears awkward because it implies employing a vast knowledge base of science and mathematics to carry out the navigation effort.
This is an area where philosophy can play an important role. The types of literacy and descriptors used are going to depend on an individual's values and how they interact with technology. Possible options include "technological literacies" or "technological affordances". In this case affordances is considered as defined by Gibson [14], that is "affordances of the environment are what it offers the animal, what it provides or furnishes."

The approaches to technological and engineering literacy should provide a framework of what does the average person need to know to be able to control technology. In other words, *"how do I control the technology that's trying to control me?"* Technological literacy is a framework of decision making. This competency encompasses technological and engineering decision making at some level. Technological competence is the skill that provides a technological way of viewing the world that enables individuals and groups to respond to and control the technological contingencies encountered in everyday life. The idea of technological judgement has also been suggested [15] and this can be linked to technological competency. [17]

The concepts of technological and engineering literacy are not a specific course or even a series of courses. There is no coherent subject that should be called technological literacy because it itself relies on knowledge from a wide range of areas. Technological literacy requires bringing that knowledge together. Technological literacy can be thought of as a competency in dealing with technological problems at various levels. Solutions to technological problems are necessarily contingent. Technological literacy is a competency in dealing with contingency.

A central issue concerning technological literacy is the distinction between the necessary and the contingent. This distinction should be made clear. Engineering involves contingency and the ability to make contingent decisions, while science is reductionist and truth seeking, concerned primarily with identifying what is necessarily true. An educational structure that is organized around reductionism and identification of what is true by necessity is not well aligned with developing abilities to make contingent decisions. Developing an ability to conduct contingent decision making is not well supported by the traditional western system of education. Some aspects of contingent decision making involving a technological component only minimally involve engineering but are essentially the management of technology and the scale of technology systems. The original idea of necessity and contingency come from a very widely discussed philosophy of engineering paper by Goldman [16].

The ability to assess and control the technological contingencies encountered in everyday life involves the ability to frame questions that determine the parameters of an inquiry (first order questions), and to discern questions that consumers and citizens needs to be able to ask and also to determine the veracity of the answers given (second order questions). Contingent decision making could enable civic navigation of new forms of democracy that are not based on an endless frontier.

The distinction between the necessary and the contingent presents new opportunities in higher education. This is the time for engineering to come out of its silo. Engineering should be leading this effort and contributing to the university. Coming out of a silo means partnering, and that might be one theme of conversations.

Technological literacy and shifting from necessity to contingency draws attention to the role of engineering in the university. This is a longstanding tension in engineering education and shifting from necessity to contingency could frame the situation in a manner that encourages other engineering educators to engage this issue.

Case studies similar to John Heywood's work on the Boeing 737 Max Accidents and the Grenfell Fire Incident [17,18] could be developed to promote the development of informed decision making. These analyses indicate that the solution to technological problems, in particular those of wide-ranging importance to citizens, involves "knowledges" other than those that are technical. While case studies are useful examples to develop informed technological decision-making, case studies should not be confined to analysis of disasters and accidents.

The question "What does technological literacy mean?" is in some ways a policy issue. It is notable that TELPhE originated from policy decisions of the National Academy of Engineering. Consequently, policy and the informing of policies could be an appropriate direction for TELPhE's future work.

The current structure and activities of TELPhE as they have evolved may not be optimal in terms of achieving the broader goals of the division. In particular, the habit of publishing primarily in the ASEE proceedings is not necessarily reaching the national and international constituency that might be interested in the work of the division. Along these lines, some mechanisms may already be in place that are underutilized. For example, the division's by-laws currently include the provision that: "The division shall produce and distribute such publications as the Executive Committee deems appropriate to promote the objectives of the division."

**V. Conclusions and Recommendations to the TELPhE Division**
To meet the present challenges, the division should consider the following actions:

**1. Emphasize informed decision making on technological issues.**
Direct future efforts of the division toward enhancing informed decision making on technological issues which also advances social justice. Technological literacy could be framed as informed decision making and a social justice issue. Implications of informed decision making on technological issues for the philosophy of engineering and engineering education should be pursued.

**2. Address "technological literacy" label misunderstandings.**
Solve the "technological literacy" label problem. The term "technological literacy" remains open to wide interpretations obscuring efforts to develop a broad understanding of technology by all citizens. Targeted conference sessions or panel discussions may be appropriate actions to consider.

**3. Advance understanding of necessary versus contingent.**
Promote clarification and broader understanding of the distinction between the necessary and the contingent. It is difficult to have the necessary conversations around necessity versus contingency approaches even in the literature. Work could be done in developing a language around discussing these issues.

**4. Create case studies.**
Consider what pedagogical approaches may be effective to achieve the envisioned competencies and informed decision making. Case studies may be a productive direction in which to begin. It could be useful to examine what case studies might be suitable for teaching in this area and should include cases with negative outcomes and those with positive outcomes.

**5. Develop new dissemination approaches.**
Developing literature accessible to both the public and educators should be a priority. There is a need for more widespread promotion of the division's work. Materials that empower individuals to make more informed decisions on technological issues should be disseminated widely. The division should consider a working group to examine options for a "TELPhE Press" or similar publications effort of the division. Existing provisions in the by-laws could be activated.

**6. Study models of technological decision making.**
Clarify models of technological decision making. To enhance technological decision making a good understanding of how it does (and doesn't) occur is needed. A TELPhE call for papers could be made to initiate this work.

**7. Develop collaborations and partnerships.**
TELPhE should seek partners and collaborators in these efforts outlined above. These could be both within ASEE and outside of the organization.

**8. Monitor progress annually.**

Each year the Divisional Business meeting at the ASEE annual conference should include discussion of the question: What is TELPhE doing that is central to our mission? This practice might assist the division in maintaining consistently impactful work.

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