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From Technological Literacy to the Philosophy of Technology and Technological Citizenship: A Progress Report

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I. Introduction

In the last paper I presented in this division of ASEE (Neeley, 2006), I complained that it was distressing to see a group with such an ambitious and worthwhile project saddled with a name that provided so little insight into its character and potential. The opening sections of *Technically Speaking: Why All Americans Need to Know More about Technology* (2002), a joint publication of the National Research Council and the National Academy of Engineering, make it clear that the initiative called "technological literacy" is concerned with a sophisticated and heterogeneous combination of "knowledge, ways of thinking, and capabilities" and focused on ambitious goals: "To take full advantage of the benefits and to recognize, address, and even avoid some of the pitfalls of technology. . . [to help citizens] become better stewards of technological change" (p. 2). Then, as now, "technological literacy" is the most widely recognized way of describing the project(s) in which this division is engaged. In my 2006 paper, I argued that we needed to rename the enterprise, mainly because "literacy" implied remediation rather than the aspiration to create something that had never existed before: a well-informed citizenry with the knowledge, motivation, and confidence to engage in purposeful deliberation about technology.

Looking back from a distance of over 10 years, I am pleased to say that the name "technological literacy" has not impeded progress in the enterprise the division was established to pursue. As the name expanded, first to "Technological and Engineering Literacy" (TEL) and then to "Technological and Engineering Literacy/Philosophy of Engineering" (TELPhE), the division has taken what I perceive as a very healthy "philosophical turn." Writing in the context of legal education, Chayes, *et al.* (2017) describe such a turn as "constructing. . . hypotheses about the larger principles and beliefs that basically motivate and shape [an enterprise and exhibiting] a marked and steady increase in the frequency of direct appeals. . . to philosophical literatures, in search of explanation or support of positions they take." For TELPhE, this has meant, among other things, focusing on the generalizable principles that distinguish engineering from related disciplines and that transcend particular technological milieus. The philosophical turn is in some ways a manifestation of a possibility that was glimpsed but not yet fully realized in 2006: the complementary goals of science, technology, and society (STS) scholars and the advocates of technological literacy.

In an effort to be specific about the forms progress has taken since 2006, this paper uses all of the papers (12 total) presented in the TELPhE Division at the 2016 ASEE Annual Conference as a representative body of work for the division. The papers, the essential details of which are summarized in the table below, exhibit a great deal of diversity in their topics, approaches, and the dimensions of TELPhE that they illuminate. These differences notwithstanding, four consistent themes emerge from the papers; all four of these themes illustrate how the philosophical turn has manifested itself in technological literacy. The first two were evident in the division's discourse in 2006:

1. The complementary goals of STS and technological literacy

2. The connections among TL, democratic deliberation, and communication about technology and engineering

The second two seem to have emerged more recently:

3. The relevance of research in TL to engineering education research more generally
4. The relevance of TL for engineers *as well as* non-engineers

Table 1. Titles, Authors, and Themes of the Papers Presented in TELPhE in 2016

Key to Abbreviations:

"Complementary goals" = 1. The complementary goals of STS and technological literacy
"Connections" = 2. The connections among TL, democratic deliberation, and communication
"Engineering education" = 3. The relevance of research in TL to engineering education research
"Engineers and non-engineers" = 4. The relevance of TL for engineers *as well as* non-engineers

Title of Paper	Author(s)	Theme(s)
"From Problem Solvers to Problem Seekers: The Necessary Role of Tension in Engineering Education"	Cheville and Heywood	Engineering education Engineers and non-engineers
"The Making of a Technology Literacy Course"	Dimitriu and Shadaram	Complementary goals Engineers and non-engineers
"Promoting Technical Standards Education in Engineering"	Gbur and Solomon	*No connection to any themes*
"Increasing Engineering Literacy Among Non-Engineering Students"	Grunert and Adams	Engineers and non-engineers Connections
"Why Technological Literacy and for Whom?"	Heywood	Complementary goals Connections
"Situating the Research to Practice Cycle for Increased Transformation in Engineering Education"	Karlin, Allendoerfer, Bates, Ewert, and Ulseth	Engineering education
"An Exercise to Promote and Assess Critical Thinking in Sociotechnical Context"	Krupczak and Mina (a)	Complementary goals Connections Engineering education Engineers and non-engineers
"Initial Results in Developing an Engineering Reasoning Assessment for General Education"	Krupczak and Mina (b)	Complementary goals Connections Engineering education Engineers and non-engineers

"Contextualizing 3D Printing's and Photosculpture's Contributions to Techno-Creative Literacies"	Malazita, Gelfuso, and Nieusma	Complementary goals Engineering education
"Furthering Continental Philosophers in the Engineering Domain"	Ricco	*No explicit connection to themes* *Illustrates how difficult it can be to make continental philosophy accessible to philosophers of technology and engineering educators*
"Judging for Themselves: How Students Practice Engineering Judgment"	Weedon	Complementary goals Connections Engineering education Engineers and non-engineers
"Engineering Practice as an Emerging Field of Inquiry"	Williams and Figueiredo	Complementary goals Connections Engineering education Engineers and non-engineers

The remainder of this paper describes and provides evidence of each of these trends. It also contemplates future directions of the TL enterprise, focusing on the unexploited resources provided by Philip J. Frankenfeld's conception of technological citizenship (1992). In most cases, Frankenfeld does not simply echo the themes from TL. Rather, he develops the philosophical and theoretical foundations for TELPhE, and, in many cases, illustrates what the content of TELPhD curricula might be.

II. The Complementary Goals of Science, Technology, and Society (STS) and Technological Literacy

In 2006, both TL and STS bore the imprint of the communities in which they originated (engineering and humanities and social sciences/STS, respectively). The papers presented at the 2016 conference provide evidence of significant integration and cross-pollination between STS and what has come to be known as TELPhE. In their historical overview of "Engineering Practice as an Emerging Field of Inquiry," Williams and Figueiredo provide a representative timeline depicting major contributions to research on engineering practice between 1911 and 2014. Many of the authors and works included on the timeline would qualify as canonical, or at least easily identifiable as, works in STS, for example, Latour's *Science in Action* (1987), Law's "Heterogeneous Engineering: The Case of Portuguese Expansion" (1987), Downey, *The Machine in Me: An Anthropologist Sits Among Computer Engineers* (1998), and Mukerji's *Impossible Engineering: Technology and Territoriality on the Canal du Midi* (2007). Krupczak and Mina (2016a), title their paper "critical thinking in *socio*technical context" [emphasis added] and argue that '"The status of being technologically literate cannot be bestowed upon engineering students without considering the inseparability" of knowledge and capabilities from critical thinking and decision making, the latter exemplified in the ABET outcome (h), "understanding the impact of engineering solutions in a global and societal context"'(p. 1).

Perhaps the most fully realized examples of the integration of STS and TELPhE are Weedon's "Judging for Themselves: How Students Practice Engineering Judgment" and Malazita, Gelfuso, and Nieusma's "Contextualizing 3D Printing's and Photosculpture's Contributions to Techno-Creative Literacies." Weedon's study of how student engineers learn "to attend to engineering problems like professional engineers" relies on "a method for studying philosophical and epistemological topics in science and technology studies (STS) developed by Michael Lynch" and published by Lynch in *Scientific Practice and Ordinary Action* (1993). Specifically, Weedon uses visual ethnography to capture and analyze the activity of a team of student engineers working on the design of a product. Drawing on painstaking analysis of the students' conversations, representations, and actions, Weedon concludes, "judgment in the engineering design context is less a mute ability of perception, and more an activity unto itself requiring recognition of issues, appeals to reason, and demonstrations for the benefit of others. In situations where no one person is completely invested with the power of arbitration (as in design), the need to argue for and demonstrate a judgment, strengthens judgment's force and promotes cooperation."

In "Contextualizing 3D Printing's and Photosculpture's Contributions to Techno-Creative Literacies," Malazita, Gelfuso, and Nieusma compare and contrast two "creative manufacturing technologies." The first is photosculpture, a promising but ultimately failed technology of the 19th century in which information captured by a camera was used to produce a clay sculpture that was a "photographically-exact representation of the subject." The second is the emerging technology of 3D printing (also called "additive manufacturing"). Their analysis demonstrates how essential a detailed understanding of underlying technology is for understanding, in turn, both the cultural contexts in which the respective technologies emerged and the factors that contribute to the success or rejection of a particular technology by consumers or by an industry.

Although they do not explicitly define what they mean by "techno-creative literacy," the term seems to denote the ability to use particular techniques and technologies in a creative enterprise, and, by extension, an understanding of the meanings that will be assigned to the products of that activity in a particular context. Their analysis shows (1) "how changing the conceptualization of the essence of creative work—shifting from mastery of (artistic) technique to (design) exploration—opens new spaces for introducing technological literacies to non-technical audiences" and (2) "that the hybridization of technical work and creative play around 3D printing offers a compelling supplement, if not alternative, to the mastery logic foundational within contemporary engineering education (and 19th century art)." They suggest that framing "techno-creative practice as an invitation for play and exploration [through which] engineering educators can both broaden the reach of their efforts to infuse technical skills training across liberal and informal education [and create] a more inviting and engaging environment for students of diverse backgrounds and interests." Of all the papers presented at the 2016 conference, this one has the most deep and explicit connection to cultural literacy as Hirsch defined it in the 1980s. It also represents a return to an often under-represented dimension of TL, hands-on skill.

III. The Connections Among Technological Literacy, Democratic Deliberation, and Communication

From its beginnings, TL was tightly linked to the demands of citizenship in a democratic, technology-oriented polity. As the editors of *Technically Speaking* express it, "From a philosophical point of view, democratic principles imply that decisions affecting many people or the entire society should be made with as much public involvement as possible. As people gain confidence in their ability to ask questions and think critically about technological developments, they are likely to participate more in making decisions" (p. 12).

In "Why Technological Literacy and for Whom?" Heywood raises "questions about the intent of technological literacy in society at the present time" and develops the philosophical foundations that establish the connections between TEL and democracy. Heywood argues that "Attempts to show how engineering and technology interact inevitably lead to models that conflate the two literacies and shows them to be embedded in the philosophy that derives them." That philosophy "shows no disconnect between the designer and the user (the engineer and the client), they are interdependent and carry a joint responsibility for [technology's] use."

He also specifically articulates the philosophical turn in technological literacy: going beyond "describing courses that enable the understanding of engineering principles" to an interdisciplinary approach in which "the notion of philosophy is extended to include the respondent perceived here as the 'public.'" As the discussion of Frankenfeld below demonstrates, this claim is virtually identical to both Frankenfeld's approach and Andrews' interpretation of that approach. Heywood continues, "There is no point in public discourse unless its intention is public responsibility." "Public discourse" in this context encompasses both democratic deliberation and communication between engineers and non-engineers.

In "Increasing Engineering Literacy among Non-Engineering Students," Grunert and Adams similarly argue for going beyond factual knowledge and understanding the complementary roles of engineers and non-engineers in engineering projects. In their qualitative study of student self-assessments of "engineering literacy as developed over the course of a semester-long class called *Citizen Engineering,"* Grunert and Adams sought to understand "how students identified the importance of engineering literacy in their lives." The students in the course were introduced to engineering "through practice, design thinking, analysis, and community engagement." Their findings confirmed earlier studies' conclusion that "Common understandings of engineers and engineering often begin with stereotypes." One interesting implication of this finding is that efforts to increase TEL should deal with stereotypes directly and use them as a point of departure for developing a more nuanced understanding of what engineering entails.

Grunert and Adams also found that the students recognized "that engineering encounters politics at every level." The students saw "the acquisition of knowledge" as the most clearly defined aspect of engineering literacy, but "In addition to the *what* of engineering literacy, students offered ideas as to *why* non-engineers needed to be engineering literate. The most prominent response relied on political engagement." Among other things, preparation for engagement entails having "the research skills to learn whatever you encounter," an ability that

Grunert and Adams interpret as combining "the ability to do research with the confidence to understand that information, to develop new knowledge. But all this begins with a knowledge of what questions to ask, who to look for. . . .By asking good questions, engineering literacy improves." Their analysis is particularly helpful because it provides a deep understanding of what effective "communication" between experts and non-experts entails and because it captures the rationale for developing life-long learning capability in engineering education and in university education more broadly. The mastery of specific technical information is important not because learners will *use* that specific information later, but rather, because that mastery builds the confidence and skills needed to learn about new technology as the need arises.

IV. The Relevance of Technological Literacy for Engineers *as well as* Non-Engineers

In 2006, TL was predominantly understood as the transfer of knowledge *from* engineering experts *to* non-experts. Over the last 10 years, the TELPhE community seems to have arrived at a new consensus: TEL is as relevant for engineers as for non-engineers. Grunert and Adams (2016) reflect this consensus when they assert that "engineering literacy develops citizens through their participation in a culture and society that depends on engineering projects. Engineering literate persons function fully within such a society, participating in engineering projects not only insofar as engineering training is required, but also in recognition of the broader social impact of those projects." Their paper highlights an interesting finding from their previous research: an "absence of meaningful difference between students in engineering courses of study and students in non-engineering programs."

Of course, this recognition goes at least as far back as "Improving Technological Literacy" (2002), in which Young, Cole, and Denton argued that "Even engineers, who have traditionally been considered experts in technology, may not have the training or experience necessary to think about the social, political, and ethical implications of their work and so may not be technologically literate" (p. 15). The papers presented at the 2016 conference (7 of the 12), echo this recognition. Krupczak and Mina's "An Exercise to Promote and Assess Critical Thinking in Sociotechnical Context" (2016a) is the most full and direct expression of engineering students as a primary audience for TEL education. Working from the premise that "less attention has been given to examining if individuals trained as engineers actually possess a broad understanding of technology and are able to engage in the type of critical thinking and decision making considered vital for a technologically literate citizenry," they conclude that "It is vital that the education of today's engineers expand[s] beyond mere technical competence to include the critical thinking abilities more broadly associated with technological leaders and technologically literate citizens."

In the design of their exercise, Krupczak and Mina assumed that the ability to predict possible impacts of an engineering solution is a good indicator of critical thinking and decision making. They presented first-year students with scenarios drawn from news articles and asked the students "to predict some possible impacts" of new technology, with impacts being "defined as changes in the existing social, economic, and cultural environment." Their paper describes a streamlined, reliable method for assessing this predictive ability. Their rubric for scoring the student responses makes distinctions that are potentially useful in both TEL education and in the philosophy of engineering. From lowest to highest level, those distinctions are:

- The student's response is not an impact.
- The student identifies an impact that is direct, obvious, readily apparent.
- The student identifies an insightful and less obvious direct impact.
- The student identifies a second-order impact, such as an impact that results from another impact, for example, the pervasive use of iPods leads to social isolation or loss of interpersonal skills.

The authors amply support their central claim that "Asking engineering students to predict the impacts of a newly introduced technology can serve as an efficient means of engaging first-year engineers in critical thinking on sociotechnical issues." One improvement on their approach would be to focus on the social and ethical *origins* of engineering solutions in addition to their impacts. This improvement is particularly warranted in view of their claim that engineers should be properly prepared to responsibly help shape "the sociotechnical future."

In "The Making of a Technology Literacy Course," Dimitriu and Shadaram describe a "Technology and Society" course designed for non-engineering students. During the two years reported in their paper, however, the enrollment of the course was nearly 75% students in technical majors. The topics covered in the course (for example, history of technology; ethics and technology; health and technology; war, politics, and technology; and technology and the future) would not likely have been included in those students' technical courses. Perhaps because it was designed for non-engineers, no specific technical background was required to take the course, though the students did need to "understand the basic terminologies associated with the different technologies" they encountered. This feature of the course design responds to an often-overlooked reality about engineering students, especially at lower levels of the curriculum: their specialized knowledge is not appreciably different than that of non-engineering students.

Dimitru and Shadaram's discussion of the course reveals some enduring problems in TEL: (1) an ongoing difficulty in defining TL and establishing its relationship to EL and (2) the tendency to think in terms of impact and technological determinism rather than mutual shaping of technology and society. Although the authors emphasize the importance of utilizing technology "for the benefit of humanity," they state that the idea uniting the topics of the course is "that technology is the engine driving the changes in our society." They also note that "The faculty teaching this class must have a broad knowledge and understanding of engineering, technology, and world problems, since the class debates may take unexpected turns, raise unanswered questions, uncover unknown situations, or bring to light things that are not usually covered in everyday conversations." This comment implies that many (perhaps most) faculty do not have this breadth of knowledge and understanding.

Given the disciplinary, specialized nature of higher education, such a situation would not be surprising. But it is ironic that university faculty might not have the breadth of knowledge and critical thinking skills that most advocates of TEL assume that all educated persons (and students who finish the courses they are teaching) should have. This observation highlights another relatively common theme in engineering education: the mismatch between what the students need to learn and what faculty are best-equipped to teach. It also provides evidence for one of the

claims I made in my 2006 paper: rather than recovering or reviving something that once existed but has been lost, we are attempting to create something that has never existed.

V. The Relevance of Research in Technological Literacy to Engineering Education Research More Generally

Another emerging trend in the papers is the relevance of research in TELPhE to engineering education research. More than half of the papers (7 of 12) addressed the ways in which research in TELPhE can inform and contribute to the improvement of engineering education. From this perspective, TELPhE constitutes, in at least some of its manifestations, a form of engineering education research. Several of the papers already discussed illustrate this trend. For example, Weedon's study of engineering judgment and Williams and Figueiredo's historical overview both focus on engineering practice and are motivated by a desire to improve engineering education. Several of the papers discussed earlier, specifically, the papers on 3D printing (Malazita, Gelfuso, and Nieusma), assessing sociotechnical thinking (Krupczak and Mina a), and developing an engineering reasoning assessment (Krupczak and Mina b), have significant implications for engineering education. In this section of the paper, I focus on two papers not yet explored in detail earlier: "Situating the Research to Practice Cycle for Increased Transformation in Engineering Education" (Karlin, Allendoerfer, Bates, Ewert, and Ulseth) and "From Problem Solvers to Problem Seekers: The Necessary Role of Tension in Engineering Education" (Cheville and Heywood).

Karlin, Allendoerfer, Bates, Ewert, and Ulseth focus on barriers to change in engineering education. As these authors define it, the "research to practice cycle" involves "elucidating new questions from [educational] practice and finding new answers through research, which is then applied in practice." The paper "situates the research to practice cycle in . . . organizational context to illustrate key barriers to transforming engineering education." They define organizational context as including "the tacit or explicit hierarchy of faculty, departments, colleges, accreditation bodies, and core systems such as the registrar and financial aid." The various groups possess and base their discourse on "their own founding axioms, or assumptions and ways of thinking." The differences in the axioms make it difficult for them to engage in productive dialogue. Although the authors do not express it in precisely these terms, one of the most significant implications of their research—the feature that connects it with TELPhE in my view—is a recognition of the mutual shaping of ideas about what engineering is and engineering education practices. In other words, the way we teach engineering will be decisively shaped by what we understand engineering to be. Because the philosophical turn in TEL focuses on transdisciplinary features shared across engineering disciplines, it is more likely to generate an understanding of engineering broadly conceived than the content of a particular engineering discipline would be.

Cheville and Heywood argue that "the current focus on problems in engineering education and technological literacy may be more constructively reframed by focusing on tensions." These tensions include those between (1) human beings as thinkers (*homo sapiens*) and human beings as makers (*homo faber),* (2) the utilitarian and humanistic aims of engineering education, (3) student- vs. instructor-centered learning, and, most significantly for our purposes

here, (4) engineers as problem solvers vs. engineers as problem seekers. They contend that, instead of viewing these tensions as problematic, we should view them as

> both necessary and generative [because] they are a natural part of human affairs and generative in that tensions highlight dialectics from which new truths or perspectives emerge. From this viewpoint, a key element of faculty development is formulating a defensible personal philosophy that both lets one navigate and learn from the inevitable tensions that will arise in practice as well as contribute to larger dialogs from which new systems and forms of education emerge.

By extension, TELPhE could be interpreted as an emerging form of education, or at least a helpful foundation for it.

Cheville and Heywood build on the work of Dias (2013), who argues that "engineering has an identity crisis." This crisis arises from three sets of tensions, which can be phrased as unanswered (and ultimately, unanswerable, questions): (1) is the influence of the engineering profession on society positive or negative? (2) are engineers primarily scientists or primarily managers? and (3) does theoretical or practical knowledge form the basis of engineering work? In Cheville and Heywood's view, "tensions themselves are not necessarily a source of problems, but . . . negative consequences are more likely to arise when tensions are unnoticed, misunderstood, unaddressed, or when systems under tension do not have the channels to foster meaningful dialog." One of the goals, then, of TELPhE is to recognize these tensions. The authors report on the tensions identified at a post-ASEE interdivisional workshop in 2015 in eight topic areas, each with dialectic poles:

1. Knowledge and epistemology (universal vs. contextual, theoretical vs. practical)
2. Assessment (formative vs. summative, process vs. product, objective vs. authentic)
3. Aims of education (industry needs vs. educating individuals, utilitarian vs. liberal)
4. Students and student experiences (sharing vs. security, actual impact vs. societal impact, engineers vs. all students, depth vs. breadth)
5. Identity (engineer first vs. intersectionality)
6. Teaching (pedagogical research vs. experience and practice, content vs. experiences)
7. Diversity and inclusiveness (inclusion vs. professionalism)
8. Practice of engineering (object-centered vs. human-centered)

If we take one of the central functions of TEL to be articulating assumptions that typically go unstated, the identification of tensions like these exemplifies the philosophical turn in TEL and the relevance of engineering education research to TEL.

VI. Using Frankenfeld's Conception of Technological Citizenship to Achieve the Larger Purposes of Technological and Engineering Literacy and the Philosophy of Engineering

The four trends delineated above reflect advancements in TELPhE and suggest the range of resources required to achieve its goals. The relevance and potential utility of Frankenfeld's conception of technological citizenship for achieving these goals are so striking that it is hard to imagine why the TELPhE and STS communities have not made more extensive use of his work.

After getting an undergraduate degree from Claremont College in government and a Ph.D. in political science at the University of Chicago, according to an article in the *Los Angeles Times* (1996), Frankenfeld spent seven years applying for college teaching positions. When he did not succeed in finding a college teaching position, he took a position with a Washington research firm where he was hired to "study the future of the automobile in American transportation." He apparently gave up on an academic career. Before he took the position with the research firm, he wrote two major articles: "Technological Citizenship: A Normative Framework for Risk Studies" (*Science, Technology, and Human Values,* 1992) and "Simple Gifts: Complex Environmental Hazards and the Responsibility to Leave a Controllable World" (*Futures*, 1993). Aside from an editorial by Clinton Andrews published in the *IEEE Technology and Society Magazine* in 2006 and discussed later in this section of the paper, Frankenfeld has received little attention and apparently has not published any more scholarly work.[1] His article on technological citizenship (TC) was published ten years before *Technically Speaking.*

As the biographies that accompany both of Frankenfeld's articles make clear, he brings a formidable intellectual background to bear on the task of defining the interdependent roles and responsibilities of experts and non-experts in managing complexity and risk. In describing his own work, Frankenfeld defines "technological citizenship as an ideal and emerging reality . . . . [that] covers environmental policy, technology assessment, risk ethics, democratic theory, informed consent, trust, technocracy, citizenship theory, intergenerational ethics, and risk communication" (1992, p. 484). This list indicates a rather intimidating range and variety of expertise and may explain why other scholars have not pursued TC in depth or detail. In "Simple Gifts," he exemplifies the philosophical turn by using "A scheme of Lockean common patrimony. . .to argue that forebears are morally obligated to leave future generations a world as controllable and as affordable as ours for experts and laypeople, despite potentially increasing complexity, ungovernability and cost of environmental hazards and an increasing pace of change" (p. 32). He fits the ethic and policy frame presented in "Simple Gifts" into "the larger context of a social contract of complexity and citizenship" (p. 32). "Simple Gifts" devotes relatively equal time to ethical foundations and to the policy implications that follow from them. "Technological Citizenship" places less emphasis on policy implications but illustrates the philosophical turn in both depth and detail.

In "Technological Citizenship," Frankenfeld develops a model that draws on the greatest traditions of philosophical ethics and political theory to envision a society in which technical

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[1] Andrews suggests that "a technological citizenship movement has sprung up," but does not give any specific examples beyond Frankenfeld's article. I have found no evidence of this movement beyond developments in TELPhE, which do not mention TC explicitly.

experts and non-expert citizens interact to share responsibility for creating a safe environment in which individuals can flourish and develop their fullest capacities. As Frankenfeld argues,

> The significance of the TC model for ethics—at least the particular version of TC presented here—is that it extends morality's domain from the responsibility to avoid concretely foreseeable or conceivable environmental hazards to an *a priori* responsibility to avoid the use of and research into any technology that is only suspected of being catastrophically hazardous because of its structural characteristics, even in the absence of envisioning *how* it is harmful (p. 460).

Much of Frankenfeld's analysis is directed toward reconciling differing values, potentials, and roles. For example, he insists that citizenship consists of "equal rights and obligations. . .[with the intent] to reconcile technology's unlimited potentials for human benefits and ennoblement with its unlimited potentials for human injury, tyrannization, and degradation. Such status, rights, and obligations are thus intended to reconcile democracy for lay subjects of technology's impacts with the right of innovators to innovate" (p. 462). As he puts it more colloquially later in the article, "with TC we seek not to kill the technology goose that lays the golden eggs but merely to housebreak it" (p. 463). He develops, systematically and in detail, (1) the jurisdictions of technological citizenship, (2) the rights of technological citizenship, and (3) the obligations of technological citizenship. Every level of his analysis reflects many of the enduring themes in TELPhE, for example, the importance and challenges of risk communication; the difficulties of accurately assessing risk; and the mutual responsibilities of experts and non-experts. The main difference is that in Frankenfeld's work, all of the themes are given philosophical foundations, and most of them are illustrated with examples of action that might follow from the insights Frankenfeld's framework generates.

"Technological Citizenship" could be read as an extended rationale for the Technological and Engineering Literacy/Philosophy of Engineering Division. Although Frankenfeld does not specifically discuss engineering education, his work has great significance for both engineering education and more general education for citizenship. In his interpretation of Frankenfeld's work, Andrews (2006) reflects Frankenfeld's recognition that expertise is domain-specific, so that even engineers are not likely to be technologically literate outside of their technical domain. Andrews makes the implications of TC for engineers explicit: "Those of us with technical backgrounds now have a special obligation to our fellow citizens to help them exercise good citizenship. If we stay quiet, we'll deserve what we get" (p. 4). He also acknowledges the potential dangers of citizen engagement:

> Citizens may approach. . .technological decisions with caution or exuberance, framed by "*laissez faire"* or interventionist politics, while pursuing incremental or comprehensive solutions. They will be as diverse in their technological citizenship roles as they are in other civic roles. The hope is that they are well-meaning individuals trying hard to make reasonable decisions in specific circumstances. The fears are that many of them are passive, and that they engage with technological change only on an economic level as consumers or producers, and not on a political level as citizens (p. 5).

As an opinion piece, Andrews' article is designed to motivate action rather than provide a detailed plan of attack. It is in many ways the antithesis of Frankenfeld's article, which is as challenging as it is rich.

VII. Conclusion and Unfinished Business

The papers presented in the TELPhE Division in 2016 provide ample evidence of the philosophical turn in TEL and of the ways in which that turn (1) reflects the original goals of TL, (2) highlights the interconnectedness of TELPhE with other domains of scholarship, and (3) amplifies the potential contribution of TELPhE to both engineering education and higher education generally. Frankenfeld's conception of technological citizenship constitutes a rich and untapped resource for the TELPhE community. It also illustrates the challenges of making the insights of philosophy and political theory accessible and relevant to engineering educators, policy makers, and citizens—not to mention the challenges of raising awareness in an environment where people are bombarded with claims on their attention.

Perhaps the most formidable challenges are challenges of political will and institutional innovation. As I noted in 2006, even if we manage to cultivate large numbers of technological citizens, it is not clear where the majority of people would exercise their abilities except in their limited roles as consumers or advocates for particular causes. At a minimum, however, technological citizenship gives us a name for the intersection of technical expertise, educational enterprises, and democratic ideals. And Frankenfeld's foundational work helps us envision the ways in which some of the most venerable traditions in philosophy and political theory can inform engineering practice and move us closer to the realization of something that never existed before: a well-informed citizenry with the knowledge, motivation, abilities, and confidence to engage in purposeful deliberation about technology.

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