The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #44541

Social Foundations of Education as a Model for Social Foundations of Engineering: Possibilities for Engaging the Philosophy of Engineering

Dr. Kathryn A. Neeley, University of Virginia

Kathryn Neeley is Associate Professor of Science, Technology, and Society in the Engineering & Society Department of the School of Engineering and Applied Science. She is a past chair of the Liberal Education/Engineering & Society Division of ASEE and is

William J Davis, University of Virginia

William J Davis, Ph.D. is an Assistant Professor in Science, Technology, and Society in the Department of Engineering and Society and the University of Virginia. William has degrees in literature and Science and Technology Studies, and has taught courses in English, philosophy, and sociology in universities in the USA and Mexico. His current research investigates the ethical and social implications of technology, including those related to artificial intelligence, automation, bioethics, machine ethics, and post and trans-humanism.

Dr. Bryn Elizabeth Seabrook, University of Virginia

Bryn Seabrook is an Assistant Professor in Science, Technology, and Society at the University of Virginia. She received her Bachelor of Arts in Humanities, Science and Environment with a minor in Vocal Performance in 2012, a Master of Science and Technolo

Joshua Earle, University of Virginia

Social Foundations of Education as a Model for Social Foundations of Engineering: Possibilities for Engaging the Philosophy of Engineering

Kathryn Neeley/William Davis/Bryn Seabrook/Joshua Earle
University of Virginia

Abstract

The field of social foundations of education emerged in the early 1930s with the aim of developing a comprehensive understanding of "the cultural phenomena—institutions, processes, practices, beliefs, values, and ways of knowing—that underlie any society's educational ideas and practices" [1]. By extension, social foundations of engineering—a field that does not yet exist, but should—would seek to understand the institutions, processes, practices, beliefs, values, and ways of knowing that underlie engineering education and practice. The fundamentals of these foundations have emerged in critiques of engineering grounded in several different perspectives including science, technology, and society (STS), engineering ethics, and engineering and social justice. Thus far, however, these perspectives have not coalesced into a coherent intellectual framework. In this paper, we draw parallels between engineering and social foundations of education as the field has evolved over time and argue that social foundations of education provides a promising model for social foundations of engineering. We draw on the literature in philosophy of engineering, STS, and engineering and social justice to identify intellectual traditions and frameworks that can be used to flesh out the conception of social foundations of engineering.

Keywords

Social Foundations
Philosophy of Engineering
Engineering Ethics

STS
Social Justice

Introduction

As Steven Tozer and Freeman Butts establish in "The Evolution of Social Foundations of Education," the field emerged in the early 1930s in response to growing awareness and increased understanding in several different domains, chief among them growing awareness that "teachers and school leaders need to study the social foundations of education if they are to understand the consequences of their actions as educators, and be able to make informed and ethical choices within their educational practice" [1]. Democratic ideals provided the primary ethical framework for the field, and efforts were directed toward educational change and reform motivated by the belief that the benefits of schooling provided to "persons most privileged in western, liberal, democracies ought to be benefits to all" [2]. From the beginning, the scope was comprehensive, including all of the "the cultural phenomena—institutions, processes, practices, beliefs, values, and ways of knowing—that underlie any society's educational ideas and practices" [1]. Thus, any discipline that engaged in "a basic and comprehensive study of the culture and of human behavior as these are related to the total educational enterprise" was in a position to contribute to the field [1]. Given the complexity of the educational system and its contexts, no single discipline can lay claim to it. It is best understood not as an intellectual territory or interdisciplinary field, but rather as a crossroads that connects academic expertise with public concerns about education.

As the field evolved over time from its original home at Teachers College, Columbia University, it became both a field of research in itself and a part of the professional preparation of teachers and administrators. Social foundations of education integrated the *what* (subject matter), the *how* (pedagogy), and the *who* (variety and individuality of people involved) of teaching and learning with the *why* (goals and motivations). It gained an institutional foothold beyond Teachers College and developed an organizational infrastructure that eventually coalesced around the Council for Social Foundations of Education (CSFE), a coalition of about 20 organizations that identify with the field. Since 1978, the CSFE has published standards that "establish an operational consensus in defining key terms in the field and how study in the foundations can best contribute to professional preparation of educators and researchers" [1]. As a mature field, it offers potential as a model for developing a corresponding field for engineering: the social foundations of engineering.

In this paper, we draw on studies of engineering education that are motivated by a concern very similar to that which motivated the founding of social foundations of education: the concern that engineering education will not prepare graduates for successful professional practice unless it addresses the various contexts in which engineering is practiced, the varied purposes it serves in those contexts, and the ways the actors and factors in those contexts both shape and are in turn shaped by engineered systems. This consensus and the abundance of proven approaches for doing so notwithstanding, practical understanding of these contexts still is not systematically integrated into the engineering curriculum. We believe that social foundations of engineering (SFEN) could facilitate integration. We argue that social foundations of education (SFED) serves as a useful model for SFEN, offering precepts to follow and illuminating the challenges we will face in developing the field.

In the remaining sections of this paper we (1) define the needs SFEN meets and the opportunities it offers, (2) outline the most salient characteristics of SFED as they align with engineering, (3) survey the intellectual resources available for developing SFEN, and (4) offer conclusions and discuss recommendations for future work that could contribute to both engineering education and the philosophy of engineering.

The Needs Social Foundations of Engineering Meets and the Opportunities It Offers

Bridging the Ideal-Actuality Gap

As is well-established in previous scholarship, there is a gap between the *actuality* of engineering's contribution to democratic ideals and its *potential* to contribute to human welfare [3]. Understanding the processes by which technical potential gets translated into social benefit (or not) is essential for bridging the gap, as is understanding the complex relationships between democracy and technology [4][5][6]. While there is a great deal of energetic scholarly activity directed toward understanding the dynamics of scientific and technological development, much of it with the aim of more fully realizing the contribution of science and technology to human welfare, the established paradigms for engineering practice and curricular design do not adequately accommodate the contextual factors that shape and are shaped by engineering—especially democratic ideals of inclusiveness and social justice. Relevant fields include:

1. science, technology, and society (STS)
2. technological literacy
3. history of science and technology
4. philosophy of science and technology
5. philosophy of engineering
6. history of engineering
7. engineering education
8. history of engineering education
9. engineering ethics
10. organizational behavior

Though the need for integrating expertise from these and related areas into engineering education was explicitly recognized when Engineering Criteria 2000 (EC2000) were introduced over 25 years ago [7], meaningful integration has yet to occur on a large scale. The philosophy of engineering, especially as it has been developed in the Technological and Literacy/Philosophy of Engineering Division of ASEE (TELPhE), points the way toward what Stephan Goldman (2004) described as "a contingency based philosophy of engineering [that] might enable more effective technological action" [8].

While courses on the foundations of engineering are plentiful, research suggests that no one is using social foundations of engineering as a coherent intellectual framework. We put SFEN forward here as a promising approach for establishing reasonable intellectual coherence among the contributing disciplines and offering possibilities for systematically preparing engineers to enable more effective technological action.

Bridging the Curriculum-Workplace Gap: Another Enduring Challenge

Establishing intellectual coherence among all relevant knowledge streams through a social foundations approach also has the potential to address one of the most perennial problems in engineering education: the disjunction between the capabilities engineering curricula systematically develop and those that students need to function effectively in practice settings, especially in the roles of innovators and managers. A series of studies of engineering beginning with the Mann Report (1918) have noted that the predominant context of engineering education is labs and classrooms in which students work individually to master content and analytical skills that are deliberately decontextualized, that is, abstracted from the specific contexts of engineering practice (e.g., business, government, or NGOs) and disconnected from the practical needs their expertise has the potential to address.

These circumstances are exacerbated by the fact that engineering faculty seldom have experience of the contexts or demands of engineering practice and, especially at R1 institutions, focus primarily on research (creation of new knowledge). Although the research is motivated by goals that at least in principle relate to social needs and commercial value, little to no attention is given to the details of implementation (the process of translating technical capability into fully realized benefits). The governing ideas and assumptions of educational contexts implicitly if not explicitly devalue other kinds of knowledge and capabilities. The non-technical capabilities that are valued in the context of practice (sometimes referred to as professional or contextual skills) have no obvious connection to disciplinary knowledge in the humanities and social sciences (HSS), a disconnect that may explain the persistence of the nomenclature of "soft skills" [9][10].

Workplace Readiness for Engineers: The Promise of Theoretically Informed Empirical Research

Theoretically informed empirical research on the behaviors needed in the workplace has generated actionable insights that can inform engineering pedagogy. Here we give two examples of large research projects that gathered rich ethnographic data, through interviewing and observing engineering practitioners in workplace settings, and used theoretical frameworks from the humanities and social sciences to describe those behaviors in terms that connect them to disciplinary knowledge and make it clearer how they can be developed in classrooms and courses.

In "Value Creation in the Engineering Enterprise: An Educational Perspective," Trevelyan and Williams (2018) report on research and analysis directed toward the questions of how engineers add value through their work and why firms employ engineers. In previous work [11-14], the authors had researched engineering practice extensively and discovered, among other things, that most work performed by engineers does not involve innovation or working on technically challenging problems. This finding is surprising given the emphasis on innovation, entrepreneurship, and technically challenging problems in engineering schools. They use the concepts of value creation drawn from literature in economics and business to analyze the factors investors consider when they decide to invest (or not) in a particular engineering enterprise, considering investors' goals, concerns, and decision-making processes as they analyze practitioners' reports of how they add value to their organizations. Their analysis reveals that "coordinating the work of other engineers, though not by using their considerable formal and organizational authority" [11] is a highly valued workplace activity and suggests that understanding value creation in business could help engineers communicate with executive decision-makers and prioritize the allocation of their time. They then offer suggestions for developing abilities that are relevant to these functions through a range of pedagogical strategies already in use.

In "Educating for Innovation and Management: The Engineering Educator's Dilemma," Carol Steiner takes a strong contextual approach by observing workplace behavior and using philosophy to understand commercial success in a technological innovation context. She describes how "what began as a study of communication in innovative firms and processes became a study of the specific traits, attitudes, and skills that successful innovator-managers possess" [15]. Drawing on concepts from Heidegger, she identifies "the practical inadequacies of orthodox science and engineering" [15] and argues that "individuality. . .defined as the courage to depart from one's professional paradigm, to exceed its bounds, to look beyond its borders both for problems and solutions" [15] is an important pedagogical goal. She usefully distinguishes between technical management (the management of technical projects) and "administrative leadership in diverse situations" [15].

She elaborates on the distinction to illuminate the ways in which the dominant paradigms in scientific and engineering education are conducive to the generation of new knowledge but are not useful for innovation and management. In her account, administrative leadership entails "the ability to work quickly on a variety of discontinuous activities that are brief in nature and require less reflective thought"; she contrasts this with the technical management paradigm of "working on a single project and finishing it at a high level of competence." Management and innovation, on the other hand, require people who are "nonconformist, commercially pragmatic, and flexibly cooperative" [15]. The key to improving engineering education, she argues, is not finding better ways to produce conventional engineers, but rather educating them to know when to abandon conventional approaches. While her work does not suggest particular pedagogical strategies, it does provide a deep explanation of why attention to context and a variety of perspectives—key features of a social foundations approach—are valuable.

Both sets of studies demonstrate the power of combining close observations of workplace behavior with theoretical frameworks drawn from philosophy to articulate specific capabilities and identify pedagogical strategies to develop them. The key to success in both cases is making a connection between analytical categories and theories developed in HSS disciplines and what engineers actually do in a variety of workplaces.

The Most Salient Characteristics of Social Foundations of Education and Their Alignment with Engineering

This section of the paper identifies the most salient characteristics of social foundations of education and interprets them in the context of engineering. The next section provides an overview of the intellectual foundations and bodies of scholarship that can be used to develop each of the characteristics for SFEN.

1. *Recognition of the fundamental embeddedness of the enterprise and the mutual shaping of the enterprise and its contexts.* In his landmark work *The Social Foundations of Education* (1934), George S. Counts articulated the initial definition of SFED cited earlier in this paper: "the cultural phenomena—institutions, processes, practices, beliefs, values, and ways of knowing—that underlie any set of educational practices" [1]. All of these factors are of interest and have been extensively studied for engineering education and practice.

2. *Expansiveness of scope.* According to Tozer and Butts, early proponents of SFED recognized that it required an expansive, almost all-inclusive approach:

"a basic and comprehensive study of the culture and of human behavior as these are related to the total educational enterprise. . .a fundamental understanding of the relationships of education to the deepest values, traditions, and conflicts in society and to the basic characteristics of human behavior" [1].

This same breadth of scope is apparent in the literature on humanistic education for engineers.

3. *The need for disciplined formal study not confined to a single discipline.*

   Understanding phenomena requires disciplined formal study that derives from traditional disciplines but is distinguished by its focus on a specific set of goal-oriented phenomena (education/engineering). Almost any HSS discipline is relevant, as are interdisciplinary fields and area studies. *Social foundations is not a discipline, but rather a set of intersections to be studied in relation to a specific set of phenomena.* Its goals cannot be achieved by scattered courses in the disciplines; its coherence comes from focusing on the activity in relation to its contexts.

4. *Use of academic expertise to address public concerns.*

   Engineering shares with other academic enterprises the tendency to value original individual contributions recognized by other experts in the field much more highly than practical significance. This tendency is at odds with the reality that matters of public concern (like education and the development and implementation of new technical capability) are inherently interdisciplinary. As one scholar of interdisciplinarity expresses it, interdisciplinarity arises when we try to connect academic expertise to public concerns [16].

5. *Practitioners as students of contemporary issues.*

   Tozer and Butts emphasize that the early proponents of social foundations of education "Came to believe that all teachers should become students of the issues of contemporary society and culture and of the relations of these issues to questions of educational aims, methods, and programs" [1]. The same conviction is pervasive in the literature on engineering education and particularly visible in the EC2000 accreditation criteria and the publications associated with them.

6. *An ability to view tensions as both creative and inevitable.*

   In his discussion of the "Original Foundational Disciplines" of SFED, Tozer states that "Since its beginnings in the Foundations Division at Teachers College Columbia (TCC) in the 1930s, the field has been marked by a productive tension between disciplines rooted in the social sciences and humanities—such as anthropology, sociology, history, and philosophy of education—and cross-disciplinary approaches that have integrated those disciplinary perspectives to analyze education in cultural contexts" [1]. This perspective is consistent with views and approaches in STS. The tensions listed in the table below are common to both SFED and SFEN.

Tensions in Social Foundations of Education and of Engineering	
Knowledge integration in courses devoted primarily or entirely to social foundations	Insights and approaches of social foundations permeating all aspects of the curriculum
Social foundations as a subject of academic research	Social foundations as an element in professional preparation
Rigorous, disciplined study and analysis	Desire to effect change in the world
Affirming the goals and contributions of the enterprise	Recognizing the ways outcomes fall short of ideals

7. *Differentiation and integration of multiple perspectives.*
   As mentioned earlier, SFED has fully articulated standards that define and justify the field, which is presented as combining three different perspectives: interpretive, normative, and critical. Both advantages and complications arise from intertwining interpretive, normative, and critical perspectives, each of which is explained in the table below. Although these perspectives have distinctive aims, they are typically intertwined in both research and professional preparation for practice.

a.

Perspective	Definition	Rationale/Outcome
Interpretive	Use concepts and theories developed within the humanities and social sciences to assist students in examining, understanding, and explaining education within different contexts.	Promote analysis of the intent, meaning, and effects of educational institutions, including schools. . .attend particularly to the diverse contexts within which educational phenomena occur, and how interpretation can vary with different historical, philosophical, and cultural perspectives.
Normative	Assist students in examining and explaining education in light of value orientations.	Promote understanding of normative and ethical behavior; recognize the inevitable presence of normative influences, in thought and practice; probe the nature of assumptions; examine the relation of policy analysis and values and the extent to which policymaking reflects values; encourage students to develop their own value positions on the basis of critical study and their own reflections.
Critical	Employ normative interpretations to assist students to develop inquiry skills, to question assumptions and arrangements, and identify contradictions and inconsistencies among social and educational values, policies, and practices.	Engage students in employing democratic values to assess educational beliefs, policies, and practices in light of their origins, influences, and consequences.

Although much of the language in these descriptions is transferable to engineering without modification, the specific questions raised from each perspective would take particular forms for engineering. The text below offers a brief definition of each perspective as it applies to engineering and provides examples of the kinds of questions that would be raised from each perspective. As with the perspectives themselves, many of the questions would yield answers that are relevant to other perspectives.

Interpretive refers to the ways that human beings conceptualize and experience engineering education and practice, with an emphasis on thick description of a diversity of perspectives, change over time, and the ways people have raised and answered questions such as these: What is engineering? What do engineers do? What constitutes engineering education? How have engineering education and practice been understood from various historical, philosophical, and cultural perspectives? How do the theories, terminology, and taxonomies of HSS disciplines and interdisciplinary fields help us more precisely describe the meanings people have attached to engineering practice, engineering education, and technological development more generally? How do organizations and ideas shape engineering?

The *normative* perspective emphasizes the role that values, goals, and priorities play in thought and practice in engineering and engineering education, with an emphasis on the extent to which customary behaviors conform to expressed values. Questions from this perspective would include: Why have various stakeholders valued engineers and engineering? Devalued or denigrated them? How well do managerial and business practices, regulation, and legislation align with the stated mission of meeting social needs and improving the quality of life for the common good? What is the relationship between personal and professional values?

The *critical* perspective is distinguished by the way it draws on normative and interpretive perspectives to question assumptions and assess outcomes of engineering education, engineering design, and technological development generally, with particular attention to contradictions and inconsistencies among social values and the values of the organizations and individuals engaged in engineering activity. The results of critique establish the positive value of engineering and provide insights about deliberate action that can be taken to improve outcomes. One particular area of interest concerns the relative weights of competing values where questions raised would include: How can we get out of binary oppositions between competing values (business advantage and engineering for the common good) and consider the means by which commercial, managerial, social welfare, and individual fulfillment values can be optimized in specific contexts rather than existing in a fixed hierarchy?

Intellectual Resources for Developing Social Foundations of Engineering as a Field

There are three domains of scholarship that demonstrate how the fundamental concepts of SFED are manifest in SFEN: philosophy of engineering, STS, and engineering and social justice.

Philosophy of Engineering

Engineering education scholarship has taken a “philosophical turn” since the mid 2000s, as evidenced by the works presented at the Technological and Engineering Literacy/Philosophy of Engineering Division of ASEE (TELPhE) [17]. Discussions in TELPhE increasingly attend to philosophical questions and analyses of general engineering enterprise, such as its competing utilitarian and humanitarian goals and values [18], the importance of tensions to understanding engineering practice [19], the practice and production of identity in engineering [20], and the cultivation of critical thinking skills as central to democratic deliberation regarding technologies [17]. We view this philosophical turn in engineering education as indicative of the diverse and nuanced perspectives required to address the epistemology, ethics, and ontology of engineering practice and artifacts. Social foundations of engineering incorporates themes and methods from the philosophy of engineering to provide engineers, and non-engineers, with the understanding and skills necessary to make sense of the world around them, and their place within that world. Philosophy, broadly, aims to show how disparate objects, ideas, and ephemera “hang together” [21], and social foundations of engineering provides perspectives on the sorts of relationships that need attention, elaboration, and dialogue if we hope to resolve current and future problems.

A challenge for the philosophy of engineering involves making that philosophy approachable, applicable, and actionable [22]. As Miller acknowledges, philosophy of engineering attends closely to “technical know-how, processes, and decision-making techniques, at the expense of considering its place in broader philosophical traditions” [23]. Given that many engineering educators wish philosophical content in engineering courses was more attuned to “the practical nature of the field” and emphasized “problem solving activities,” one initial tension to identify involves what the community of practicing engineers needs compared to what the community of engineering educators is equipped to offer students.

Interdisciplinary scholars, under various guises related to science, technology, and society (STS), possess the requisite education, mindset, and skills to make content in the philosophy of engineering relevant and applicable to engineering students. This is partly attributable to a philosophy of education [24] that is critical rather than accepting, questioning rather than concluding. The four ideologies Heywood describes draw the attention of engineering educators to analyze the topics we teach and how we deliver that content [24]. Importantly, attention to such ideologies also reveals the tensions and challenges at the heart of engineering: What do we see as issues that need attention (problem definition), how can those topics be addressed safely and effectively (material selection, siting, stakeholder identification), and who is accountable for these projects throughout their life cycle? No matter the specific topic or context, critical engagement with these questions increases the students' awareness of the competing interests and goals of various communities. In a social foundations of engineering course, students engage in discussion and constructive debate to understand what is at stake and for whom, thus building their analytic and communicative skills simultaneously.

As engineering educators [19] [22] [24] [25] have argued for decades, critical, reflective thinking on engineering design and practice is essential to the formation of engineers who aim to intervene in the world in some fashion. Engineering students need to learn how to investigate and evaluate the contexts of engineering projects so that they will appreciate and understand how to perform such critical assessments in their professional endeavors [22]. Importantly, time and space for critical assessments that involve questioning the purposes, ethicality, and social impacts of their work and projects should be included in engineering education. Drawing from work in social foundations of education [1][2], a philosophically informed social foundations of engineering course would meet these needs by balancing interpretive, normative, and critical perspectives and emphasizing how multiple philosophical perspectives permeate engineering education, engineering practice, and engineering mindsets of practitioners.

Social foundations of engineering, importantly, lays the foundation for applied ethics content by demonstrating through examples and cases, rich with content, the need for engineers and leaders that possess strong character. If we wish to claim that engineering practice aims to improve the world [24], then engineers need to understand the wants and needs of stakeholders, but they also need to think beyond present circumstances and imagine the future of their engineered products and systems. Engineers will face business, personal, and professional challenges in their lives and careers, and after defining and understanding the problems, and for whom they matter, engineers need the integrity to practice honestly and fairly.

Just as an ethics course does not aim to tell someone how to act in all situations, a social foundations of engineering course does not aim to teach students the only factors involved in a given scenario. Instead, social foundations of engineering would emphasize how problems can be defined and addressed based on competing perspectives for resolution, like seeing issues as problems or tensions [19]. If engineers think that issues are problems whose solutions can be mapped out theoretically, in advance, then they may imagine the problem will be resolved based on a set of prescribed actions. In a sense, the pieces of the puzzle exist, and they need to be placed correctly. If, on the other hand, engineers view issues as tensions within a system that is in dynamic equilibrium, then the tensions may not have or require resolution: The exploration of the tensions, the clarification and reframing of the issues, and the dialogue endemic to this process will be an end in itself. There are pieces, and there are puzzles, but many of the pieces will fit into more than one puzzle, and the pieces themselves may be malleable.

Social foundations of engineering demonstrates that a philosophical understanding of issues as problems or as tensions carries benefits and liabilities; rather than adjudicate these, a preferred approach involves exploring the consequences of each line of thinking. If design ideas do not prevail simply because they are efficient, elegant, or effective, then design ideas likely prevail because those communicating did so by attending to their audience's needs and wants. The philosophy of engineering provides educators and students with ways of viewing their practice, and the products of that practice. Though it does not support one normative moral theory as appropriate, or a specific ontological frame as accurate, the philosophy of engineering encourages discussion in each of these areas so that practitioners develop ideas and plans that meet the needs of diverse stakeholders. When added to a social foundations of engineering course, it supports the elaboration of goals and processes that are transparent and sustainable, granting that each of these terms also have varying degrees of interpretation.

Science, Technology, and Society (STS)

The academic field of science, technology, and society (alternatively science and technology studies, or STS) offers a suite of foundational projects which fit into the three perspectives at the core of social foundations of engineering. These projects include:

- artifacts as actors
- users and non-expert social groups as designers (or otherwise important to technoscientific production)
- the centrality of everyday objects
- the construction and maintenance of expertise
- critical perspectives on objectivity, normativity, classification, metrics, and measurement
- recognition that science and technology can be (and often is) done otherwise

In this section, we describe how these projects work within SFEN's interpretive, critical, and normative perspectives. Not all of these projects fit into each perspective, but many overlap and deal with more than one.

That artifacts—the things we design and build—act in the world is a central feature of the STS project. Langdon Winner [26] argues that artifacts have politics in two ways. First, artifacts can be used to solve disputes between social groups (i.e., through use). Second, they can have inherent politics by requiring larger social and political structures to exist. Michel Callon and Bruno Latour expanded on this idea by giving nonhuman artifacts agency in their foundational framework actor-network theory (ANT) [27-29]. This fact is central to a SFEN framework because there is often a gap between the everyday work of engineers and the result of a technology once it hits public use. Understanding how artifacts function as social actors—moving people, systems, and communities toward or away from certain paths—helps engineers and the public interpret the meaning of design, anticipate the effects of design choices, and inform how design should be done.

Another foundational argument in STS is that engineers are not the only ones participating in design and engineering. Trevor Pinch, Wiebe Bijker, and Thomas Hughes [30] built a framework called social construction of technology (SCOT), which argues that when technologies meet different social groups, those social groups interpret the technology in different ways. This leads to problems in the social groups being both solved and created (their example of bicycles, women riders, and the "dress problem" is perhaps the easiest to quickly mention here). Those social groups may then take up, reject, or want alterations to the technology. This interpretive flexibility relies on users' feedback until rhetorical and design closure can be reached (the bicycles in the original piece become the design we know today, but the closure of cellular phone design is a more contemporary example). Similarly, Tom Boellstorff [31] describes how users shape the experience within Second Life, an online virtual community with many thousands of users; Bess Williamson [32] describes how disabled people and their communities designed, built, and maintained various pieces of their lives including homes, cars, and other instruments in ways that affected federal law in the eventual passing of the Americans with Disabilities Act (ADA); and Steven Epstein [33] describes how AIDS activists changed the way clinical trials, experimental drugs, and the FDA all work through collective education and activism.

Expertise itself is also a core area of investigation in STS. Epstein [33] is relevant here as well. He describes how AIDS activists changed the process of drug testing by learning the science itself. By establishing their own expertise, and not just that they were the population most affected by the delay in getting HIV medications, they were able to build the trust necessary with scientists and policymakers that produced change and knowledge sharing. Bryan Wynne [34] similarly described how nuclear scientists and engineers dismissed the expertise of sheep farmers in Cumbria, England, delaying necessary technical and policy changes and mitigation strategies for radioactive isotopes in the local soil. The idea that "lay" experts (i.e., those outside of official certification structures like academia and engineering professional organizations) may have vital knowledge—and are often instrumental in engineering interventions to solve local problems—is a key critical perspective in STS.

Beyond the idea that technical objects (artifacts, systems, etc.) are worthwhile actors to follow, the concept that not all technologies we ought to discuss are cutting edge innovations, but can be everyday objects, is also important. Ruth Schwartz Cowan [35] described how the widespread adoption of household machines like dishwashers, laundry washers and driers, and gas and electric stoves led not to a relief of the work that women were expected to do every day, but instead to the expansion of that work's scope. Deb Chachra [36] describes the vast webs of infrastructure required to make everyday life possible in the U.S., from the power that lights our houses and workplaces to the roads on which we drive and the communications networks that allow us to speak to each other and access vital online resources. Lee Vinsel and Andrew Russel

[37] point out how we often get caught up in innovation narratives, but that once a technology is in use, most of our interaction with it will be in the form of maintenance. These perspectives help us interpret the meanings and effects of technologies on the public, and give us avenues of critique which can reveal ways we ought to guide our technical creation processes.

One area of STS—the deconstruction of objectivity, numbers, metrics, measurement, classification, and normativity—is particularly tricky to include in engineering education. Engineering is built on those very foundations, and destabilizing them may seem dangerous to the field of engineering. The deconstruction of normativity also clashes with the third perspective of SFEN, and often leads to STS avoiding normative findings. This is a shortcoming of STS and is one reason why we include the philosophy of engineering and social justice sections of this paper. Lorraine Daston and Peter Galison [38] describe how the concept of objectivity has shifted over time, explaining how it is socially constructed and thus not nearly as stable as we would like to believe. Geoffrey Bowker and Susan Leigh Starr [39] show how the very act of classifying is political and has massive consequences on our technologies (contemporary examples can be most easily seen in search algorithms; see Noble [40]). Theodore Porter [41] describes how even numbers are not as stable and uncomplicated as we are generally taught.

Finally, one of the most important arguments of STS is that things could/can be otherwise. No technology—whether artifact or system—is inevitable, and everything we build, we can change if we want. This is where more normative arguments come into play, and it is also where our discussion of social justice will pick up. For example, feminist STS—via standpoint epistemology [42] and situated knowledges [43]—gives us a new and likely better mechanism for describing how objectivity gets built, decentering the individual scientist/engineer as the all-knowing subject (see also our previous discussion of lay expertise). Indigenous ways of producing knowledge and engineering [44] also run counter to American hegemonic structures. The use of technologies by marginalized people in ways that run counter to standard orthodoxy (see: [45] [46]) gives us critical ways to open up possibilities to students and practicing engineers alike.

Engineering and Social Justice

The importance of technical competency is vital in engineering professional practice. However, the nature of practicing engineers extends beyond the bounds of technical proficiency. Engineering and social justice, including diversity, equity, and inclusion (DEI), illuminates the three perspectives of social foundations of education. These connections neatly align with the proposed social foundations of engineering framework. Riley examines different definitions of social justice, stating that these definitions illuminate how groups "struggle to end different kinds of oppression, to create economic equality, to uphold human rights or dignity, and to restore right relationships among all people and the environment" [47]. There are organizations where the connection between engineering and social justice is direct, such as Engineers for a Sustainable World, ESJP (Engineer, Social Justice, and Peace), and Engineers Against Poverty. Riley emphasizes that social justice and engineering are not two separate entities, but are rather inextricably linked at their core. A small sample of domains where these connections take place are water and energy, food production, globalization, underrepresentation, ableism, assistive technologies, and universal design. What professional engineers experience in terms of critical thinking skills and practice with social justice is not easily replicated in undergraduate curricula. A framework for social foundations of engineering includes these normative reflexive practices to prepare engineering students to connect social justice as an integral part of the profession.

Many scholars within ASEE have been mapping, testing, and implementing various foundations of social justice in different kinds of engineering classrooms. Leydens and Lucena outline six criteria that attend to engineering for social justice including listening, identifying structural conditions, acknowledging political agency and mobilizing power, increasing resources and opportunities, decreasing risks and harms, and enhancing human capabilities [48]. They specifically cite two courses where these criteria were tested: "Intercultural Communication" and "Engineering and Social Justice." What they discovered illuminates how undergraduate engineering students need more opportunities to reflect on the sociotechnical connections between social justice and engineering. The reflexive practices outlined by Leydens and Lucena show the need for an interpretive approach to social foundations of engineering. These criteria draw on different disciplines, including STS, to provide contextual literacy within engineering.

Undergraduate engineering departments across the country have been tasked with various DEI-DRIVE (diversity, equity, and inclusion-diversity, respect, inclusion, vision, and equity) initiatives. Armanios et al. describe the DEI principles and practices that were revised in the Department of Civil and Environmental Engineering at Carnegie Mellon University. They discuss how the DEI committee shares the responsibilities of contextualizing and correcting institutional biases. They highlight several ways to confront issues of DEI, including creating more opportunities for reflective discussions, building greater communication skills within team projects, distributing non-bias problem sets, and learning how to assess writing assignments beyond technical reports [49]. In many ways, they put into practice what Leydens and Lucena highlight in terms of sociotechnical understanding of engineering. By employing these critical skills, students and faculty alike better align and understand the professional skills of engineering at the heart of the social foundations of engineering framework.

One final example of engineering and social justice is the "hidden curriculum." Historically, engineering programs experience relatively high attrition rates, especially for underrepresented groups. The imagery is relatively consistent: You are a first-year engineering student attending a large lecture class only to be told by your professor to look to your left and right, as nearly half of your classmates will not make it to graduation from your rigorous degree program. This scenario is often referred to as the "weed out" model. What researchers, including Wallwey et al. [50], are noticing about the problematic nature of scenarios such as the one mentioned above is that establishing this imagery creates negative stereotypes about engineering education, engineers as individuals, and engineers as professionals. National Academies researchers note,

> "Research in hidden curriculum shows that processes like schooling and professionalization provide 'hidden' messages that propagate structurally and systemically through social networks and relationships, conveying important information about dominant norms, values, and beliefs of a field. In many ways, these pervasive messages may distort how students see themselves, experience their education, and navigate society as a result. But when hidden curriculum is addressed for positive outcomes, creating positive hidden curriculum, it results in higher persistence and retention in students" [51].

Instead of creating environments that perpetuate feelings of imposter syndrome and stereotype threat, debunking the hidden curriculum is necessary for social foundations of engineering. By adopting the key perspectives (interpretive, normative, and critical) as outlined in social foundations of education, the model for social foundations of engineering will be able to scale the positive outcomes and practices that engineering educators observe when they integrate themes of engineering and social justice, as well as DEI.

Conclusions and Future Work

The most important conclusion emerging from our analysis is that SFED is a very promising model for SFEN, especially in its attention to the importance of context, the requirement of knowledge integration that follows from the richness and variety of contexts, and its commitment to democratic ideals and changing things for the better. The tensions and challenges of SFED and SFEN are similar, which should be an advantage in the early stages of development of SFEN. Social foundations of education has not resolved these tensions, but it does provide a model for thinking about the tensions that are inherent in social foundations as a broad category.

One of the most significant shared tensions is the need to balance the hazards of engaging in critique from within engineering (what Tozer and Butts refer to as a rejection of unqualified optimism about future developments) with the opportunity for promoting meaningful change that brings us closer to the social and democratic ideals that motivate engineering enterprises. The concept of tempered radicalism as developed by Meyerson and Scully [52] provides practical and theoretical tools that can be used to understand and prepare both scholars and practitioners to deal with conflicts in values.

The most significant difference between education and engineering that emerged through our analysis is that most education takes place in not-for-profit organizations, while most engineering is undertaken by for-profit organizations. There is still a link to democratic ideals in education (or at least in the marketing of education), but it is somewhat tenuous in engineering. In any case, the opportunity for comparison and contrast between SFED and SFEN should help us articulate the characteristics and approaches of SFEN more precisely than if we were developing SFEN without such an obvious precedent.

There is still much work to do to develop the intellectual foundations of SFEN and the organizational infrastructure needed to coordinate the efforts of the many groups whose work is relevant to SFEN. We look forward to feedback from researchers and educators in those other groups as we develop a working consensus on how to establish the field and operationalize it in engineering curricula.

References

[1] Tozer, S. and Butts, R. F. (2010). The evolution of social foundations of education In: S. Tozer, B. Gallegos, A. Henry, M. Griner, and P. Price, eds. *Handbook of Research in the Social Foundations of Education*. Routledge.

[2] Stone, L. (2010). Philosophy of education In: S. Tozer, B. Gallegos, A. Henry, M. Griner, and P. Price, eds. *Handbook of Research in the Social Foundations of Education*. Routledge.

[3] Neeley, K., & Zajec, S., & Stup, M. (2020).“Aspirations vs. Reality in Engineering Education: An Analysis of Top-Rated Institutions and Degree Programs.” *2022 Proceedings of the American Society for Engineering Education.*

[4] Sclove, R. 1995). *Technology and Democracy.* New York: Guilford Press.

[5] Kleinman, D., ed. (2000). *Science, Technology, and Democracy.* Albany, NY: State University of New York Press.

[6] Neeley, K., ed. (2010). *Technology and Democracy: A Sociotechnical Systems Approach.* San Diego, CA:Cognella.

[7] Ollis, D., Neeley, K., & Luegenbiehl, H. (2002). *Liberal Education in Twenty-First Century Engineering: Responses to ABET/EC 2000.* New York: Peter Lang.

[8] Goldman, S. (2004)

[9] Graham, R. & Porterfield, T. (2018). Preparing today’s engineering graduate: An empirical study of professional skills required by employers. In 2018 Proceedings of the American Society for Engineering Education.

[10] Neeley, K. (2021) “A Provisional History of the Idea of ‘Soft’ vs. ‘Hard’ Skills in Engineering Education.” In 2021 ASEE Virtual Annual Conference Content Access Proceedings, 36604. Virtual Conference: ASEE Conferences, 2021. https://doi.org/10.18260/1-2--36604.

[11] Trevelyan and Williams (2018)

[12] Trevelyan and Williams (2007)

[13] Trevelyan and Williams (2010)

[14] Trevelyan and Williams (2012)

[15] Steiner (2000)

[16] LINE 229-230 – need a citation for the scholar in reference

[17] Neeley, K. (2017). From technological literacy to the philosophy of technology and technological citizenship: A progress report," *2017 Proceedings of the American Society for Engineering Education,* June 2017

[18] Miller, G. (2020). Western philosophical approaches and engineering, In D. Michelfelder and N. Doorn, Eds., *The Routledge Handbook of the Philosophy of Engineering*. Routledge

[19] Cheville, A., & Heywood, J. (2017). The philosophical foundations of technological and engineering literacy. *2017 Proceedings of the American Society for Engineering Education*.

[20] Dias (2013).

[21] Sellars, W. (1991). *Science, Perception, and Reality*. Atascadero, CA: Ridgeview Publishing Company. (Original work published 1963)

[22] Mina, M. (2014). How would philosophy of engineering help us conducting better classes in engineering disciplines? *2014 Proceedings of the American Society for Engineering Education*.

[23] Miller (2020).

[24] Heywood, J. (2017). Philosophy and engineering education: Should teachers have a philosophy of education? *2017 Proceedings of the American Society for Engineering Education*.

[25] Mitcham, C. (1994). *Thinking through Technology: The Path between Engineering and Philosophy*. Chicago, University of Chicago Press.

[26] Winner, L. (1980). Do artifacts have politics? *Daedalus*, 121–136.

[27] Callon, M. (1984). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *The Sociological Review, 32*(1_suppl), 196–233.

[28] Latour, B. (1996). *Aramis or the Love of Technology*. Harvard University Press.

[29] Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. OUP Oxford.

[30] Bijker, W. E., Hughes, T. P., Pinch, T. J., & Pinch, T. (1989). *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press.

[31] Boellstorff, T. (2008). *Coming of Age in Second Life: An Anthropologist Explores the Virtually Human*. Princeton University Press.

[32] Williamson, B. (2020). *Accessible America: A History of Disability and Design*. NYU Press.

[33] Epstein, S. (1995). The construction of lay expertise: AIDS activism and the forging of credibility in the reform of clinical trials. *Science, Technology, & Human Values*, *20*(4), 408–437.

[34] Wynne, B. (1989). Sheepfarming after Chernobyl: A case study in communicating scientific information. *Environment: Science and Policy for Sustainable Development*, *31*(2), 10–39.

[35] Cowan, R. S. (1983). *More work for mother: The ironies of household technology from the open hearth to the microwave* (Vol. 5131). Basic Books.

[36] Chachra, D. (2023). *How Infrastructure Works: Inside the Systems That Shape Our World*. Penguin Publishing Group.

[37] Vinsel, L., & Russell, A. L. (2020). *The Innovation Delusion: How Our Obsession with the New Has Disrupted the Work That Matters Most*. Crown.

[38] Daston, L., & Galison, P. (2007). *Objectivity*. Zone Books.

[39] Bowker, G. C., & Starr, S.L. (1999). *Sorting Things Out: Classification and Its Consequences*. MIT Press.

[40] Noble, S. U. (2018). *Algorithms of Oppression: How Search Engines Reinforce Racism*. NYU Press.

[41] Porter, T. M. (1996). *Trust in numbers: The pursuit of objectivity in science and public life*. Princeton University Press.

[42] Harding, S. G. (2004). *The Feminist Standpoint Theory Reader: Intellectual and Political Controversies*. Routledge.

[43] Haraway, D. J. (1991). *Simians, Cyborgs, and Women: The Reinvention of Nature*. Taylor & Francis.

[44] Kimmerer, R. (2013). *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Milkweed Editions.

[45] Nelson, A. (2016). *The social life of DNA: Race, reparations, and reconciliation after the genome*. Beacon Press.

[46] Brock, A. (2020). *Distributed Blackness: African American Cybercultures*. NYU Press.

[47] Riley, D. (2008). *Engineering and Social Justice*. San Rafael, California. Morgan & Claypool.

[48] Leydens JA, Lucena JC. Making the Invisible Visible: Integrating Engineering-for-Social-Justice Criteria in Humanities and Social Science Courses. In: *American Society for Engineering Education Annual Conference Proceedings 2016*. New Orleans, LA: ASEE; 2016.

[49] Armanios, D. E., Christian, S. J., Rooney, A. F., McElwee, M. L., Moore, J. D., Nock, D., Samaras, C., & Wang, G. J. Diversity, Equity, and Inclusion in Civil and Environmental Engineering Education: Social Justice in a Changing Climate. In: *American Society for Engineering Education Annual Conference Proceedings 2021.* Virtual Meeting: ASEE; 2021.

[50] Wallwey, C., Guanes, G., Grifski, J., & Milburn, T. Engineering and Exclusionary 'Weed-Out' Culture: A Framework for Exploring Literature for Meaning and Influence. In: *American Society for Engineering Education Annual Conference Proceedings 2022.* Minneapolis, Minnesota: ASEE; 2022.

[51] Alarcón, I. V. (2023). Hidden Curriculum: An Image Holder of Engineering. *NAE Perspectives*. [Online] https://www.nationalacademies.org/news/2023/02/hidden-curriculum-an-image-holder-of-engineering

[52] Myerson, D., &Scully, M. (1995) Tempered radicalism and the politics of ambivalence and change. *Organization Science, 6*(5), 585-600.